CASE STUDY

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EVALUATION OF NEUROTHERAPY FOR A PATIENT WITH CHRONIC IMPAIRED SELF-AWARENESS AND SECONDARY ADHD AFTER SEVERE TBI AND LONG TERM COMA USING EVENT-RELATED POTENTIALS

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SUMMARY

Background: We examined the effectiveness of neurotherapy for chronic, impaired self-awareness and secondary ADHD (SADHD) diagnosed in the patient after severe TBI. We hypothesized a good response to relative beta training.

Case report: Patient A.A., age 30, after severe TBI and long-term coma, suffered from chronic, impaired self-awareness and SADHD, manifesting two years post trauma. Only slight progress was made after behavioral training. The patient took part in a neurotherapy program consisting of 40 sessions of relative beta training. We used standardized neuropsychological testing, as well as ERPs before and after the completion of neurotherapy.

Results: At baseline, A.A. showed an excess of relative mu-rhythm, possibly associated with ADHD (alpha subtype); decreased beta generated centrally, indicating hyperactivation of the central medial cortical area and possibly associated with anxiety; and a decreased visual-related component, an indicator of TBI. There was no significant improvement of the P300 NOGO component after the conclusion of the neurotherapy program. However, as hypothesized, she showed improvements in cognitive parameters, especially attention, memory and executive function, including remission of the impaired self-awareness and SADHD. The patient finished her studies and has now started working.

Conclusions: A neurofeedback program using relative beta-theta training produced slight physiological changes in our TBI patient, but major cognitive and behavioral changes, including reduced impaired self-awareness and SADHD. ERPs can be used to assess SADHD and functional brain changes induced by neurotherapy, but has limited application for interpreting the brain mechanism of chronic, impaired self-awareness after severe TBI and long term coma.

Key words: executive dysfunction, behavioral changes, SADHD, relative beta training

INTRODUCTION

Impaired self-awareness and secondary ADHD constitute in theory two completely distinct syndromes of neuropsychiatric disturbances occurring after severe TBI and long-term coma (Prigatano et al. 1986; 2010; Mauritz et al. 2008).

Self-awareness, commonly referred to as "insight," is a term used in the rehabilitation context to describe a patient's acknowledgement of his or her strengths and limitations, in particular the ability to understand the nature of impairment and appreciate its implications. Self-awareness is a cognitive process requiring integration of information from both external reality and inner experience. This is reflected in the definition of self-awareness as "the capacity to perceive the self in relatively objective terms whilst maintaining a sense of subjectivity" (Prigatano & Schacter 1991:13). Therefore, self-awareness involves an interaction between thoughts and feelings. It is this subjective or affective component that distinguishes self-awareness from self-knowledge (Prigatano, 1999). In addition to an appreciation of one's present state (and how it differs from the pre-morbid state), self-awareness involves the ability to determine one's future state, or set realistic goals for the future (Pachalska, 2007; Fleming, 2012; Herzyk 2012).

Self-awareness may also be called “metacognition,” which refers to a person’s ability to be aware of his or her own cognitive functions, or “knowing about knowing.” Metacognitive functions include the ability to self-monitor and self-correct behavior, and are among the highest cognitive functions. Self-awareness is a broader construct, however, since it relates not only to awareness of cognitive abilities, but physical, social, and communicative functions as well (Fleming 2012).

Clinical manifestations of impaired self-awareness can vary considerably from patient to patient (Prigatano, 1999), and can vary as time passes from the brain injury (Pachalska, 2008). Several studies have pointed out how lack of awareness can seriously interfere with functional recovery and rehabilitation training (Gialanella et al., 2005).

The term “secondary ADHD” (SADHD) is used for an Attention-deficit/hyperactivity disorder (ADHD) presenting with a non-developmental etiology; it was first used to describe attention deficits following pediatric traumatic brain injury (TBI; see Gerring et al., 1998). SADHD does frequently appear following TBI in children, but it also occurs in adults (Herskovits et al., 1999; Levin et al. 2007; Max 2004). It includes impulsivity, excessive verbalization, difficulty sustaining attention, and distractibility. Because SADHD is an important disorder resulting in behavioral impairment and associated cognitive and adaptive function deficits, it is critical to elucidate both the phenomenology and the psychosocial and biological risk factors of SADHD. Little is known about the phenomenology of SADHD in terms of subtype (e.g., inattentive, hyperactive/impulsive, combined, and not otherwise specified, “NOS”). In a sample of consecutively hospitalized children with TBI, all subtypes occurred at the 6-month follow-up interval, with the most common being the inattentive subtype, followed by NOS (Max et al., 2005).

There can be little doubt as to the diagnosis when the symptoms occur in pure form, but in clinical practice this happens rather rarely. As a rule we deal in individual cases with complex, overlapping dysfunctions, which means that the presenting symptoms, especially at the beginning of the diagnostic process, could equally well result from various defects that may be of completely distinct etiology.

The question arises as to how either impaired self-awareness or SADHD symptoms are related to EEG spectra and ERPs, or whether ERPs can be used to assess functional brain changes induced by neurotherapeutic programs. This is a case study in which we address these questions. EEG spectra and ERPs in a patient with chronic, impaired self-awareness and SADHD were compared with the normative data (HBIdatabase) in order to assess the main neurophysiological deficits found in this patient.

The deviations from the norms are discussed in terms of well known pathophysiological patterns in the ADHD population, such as increased theta:beta ratio (Monastra et al., 1999), decreased P3b component (Masson et al., 2001), and decreased P3 NOGO potential (Ducrocq et al., 2006).

CASE STUDY

Patient A.A. (initials altered to protect patient privacy) is a 30-year-old, right-handed, Polish female. She was a student in her last year of special education at a university. As a child she suffered a minor skull fracture, but without any long-lasting effects, except for mild attention problems.

In October 2002, on her way home from work, she was involved in a single-car, single-passenger accident, the circumstances of which have never been fully explained (the car struck a roadside tree). She was admitted to the emergency room in critical condition (Glasgow Coma Scale 3) with a major closed-head injury, and remained in coma for over a month. Despite her poor condition, the crisis passed without surgical intervention. In addition to the head trauma (with coma, followed by post-traumatic epilepsy as the primary neurological symptoms), A.A. also suffered other bodily injuries, including a hematoma in the knee and L5-S1 spondylolisthesis (a 5 mm posterior shift of the affected vertebrae), with lateral curvature of the lumbar spine and rotation of the vertebral bodies.

In early November, immediately after she regained consciousness, she showed considerable confusion. Her speech was initially echolalic, then palilallic (especially emotive language, in which she expressed her love for her family over and over again); other spontaneous utterances began to appear somewhat later. For three months she spoke of herself exclusively in the third person singular using a childish nickname that had not been used of her by the family for 15 years. For several weeks she did not recognize herself in pictures or in a mirror, and later identified herself, again, in the third person: that is, she did not say, “That’s me!”, but rather, “That’s A!” using the childish nickname. She frequently asked what had happened to her that she was in the hospital; when told that she had been in an accident, she acknowledged the information with “uh-hum,” and then a moment later put the same question again.

In neuropsychological testing performed in December 2002 she showed post-traumatic amnesia. She does not remember the accident or anything that happened after she left home that day. Memory loss has been among the most persistent complaints; in December 2002 she was unable to remember her therapist from one day to the next. She was disoriented in time and place, with numerous memory gaps that she filled with florid confabulations. Her episodic and autobiographical memory was weak and very fluid; she was markedly uncritical, verbose, distinctly childish, labile, short-tempered, and uninhibited, and she had difficulty making plans and organizing daily activities.

During her stay in the rehabilitation clinic she made some progress in both motor and cognitive functions. At the time of discharge, however, she was still inclined to florid confabulation. There were also disquieting incidents of confusion in sexual identity that occurred after her return home; for example, on several occasions she crawled into her mother’s bed at night and asked to be caressed and stroked in intimate places, at the same time attempting to do the same for her mother. She was quite distraught when her advances were refused, but the next morning she did not remember the incidents. Although she had some opportunities for social contacts with men, she was not promiscuous or even especially flirtatious, nor did she seek contact with her fiancé (see below).

Impaired self-awareness and SADHD were found in standard neuropsychological testing by the consulting neuropsychiatrist and neuropsychologists.

Three years later, A.A., despite several hospitalizations that included standard rehabilitation for TBI cases (Pachalska et al. 2002; Pachalska 2008), still displayed impaired self-awareness, serious identity and memory problems with florid confabulations, and executive dysfunction. Additionally, she was diagnosed with SADHD, the symptoms of which are similar to the DSM-IV TR criteria for ADHD (APA, 2000; see also Max et al., 2005).

An EEG showed delta, theta, and sharp waves of moderate degree, visible in the frontal and temporal leads, with a tendency to seizure activity, though induced hyperventilation had no effect. The patient is under medication with Tegretol and still has very occasional petit mal seizures.

MRI STUDIES

The study was performed in the sequences FSE T1, FSE T2 fr, PD and FLAIR, with cross, sagittal and transverse views, in layers with a thickness of 5 mm. The corpus callosum was found to be attenuated. The white matter in both the frontal and parietal lobes and in the genu and posterior portion of the trunk of the corpus callosum showed hyperintense area, visible in T2-weighted images, corresponding to glia scars. In both frontal lobes, especially in the right, gliosis had occurred back to subcortical white matter, accompanied by atrophy of the adjacent cortex. In relation to an earlier study in March of 2005, there had been a slight progression of glia in the right frontal lobe, and discrete cortical atrophy of both frontal lobes. Otherwise, the signals in both gray matter and white matter were normal. The ventricles were somewhat expanded, consistent with moderate subcortical brain atrophy (Figs. 1 and 2).

The patient has not been under treatment since 2008, despite the persistence of the neurocognitive symptoms mentioned above, because she believes that she is healthy and does not wish to participate either in research or any therapeutic program.

In 2011, the patient was severely beaten and raped by two men. The perpetrators were brought to trial, but acquitted, largely because on the witness stand, the patient, testifying as the purported victim, stated that she was healthy, nothing was wrong with her, and nothing hurt her; she claimed that she had never had any accident, and that rough sex was very pleasurable for her. This induced the patient's family to convince her to seek a psychiatric consultation, and then further rehabilitation.

Only slight progress was made after 40 sessions of behavioral training (the procedure and results are described in more detail in Pachalska, 2008). No changes were found after two months of rehabilitation designed especially for her needs, using the methods recommended by Prigatano & Morrone-Strupinksy (2010).

In early 2012, ten years after the accident, A.A. struck her younger sister, breaking her jaw. With the other hand, she tried to stroke her sister's hand. Specialist consultants (a neuropsychiatrist and a neuropsychologist) found that her neurocognitive symptoms had worsened, particularly both quantitative and qualitative disturbances of consciousness.

These and other problems motivated A.A.'s parents to ask for help, and she was enrolled in a program of neurotherapy.

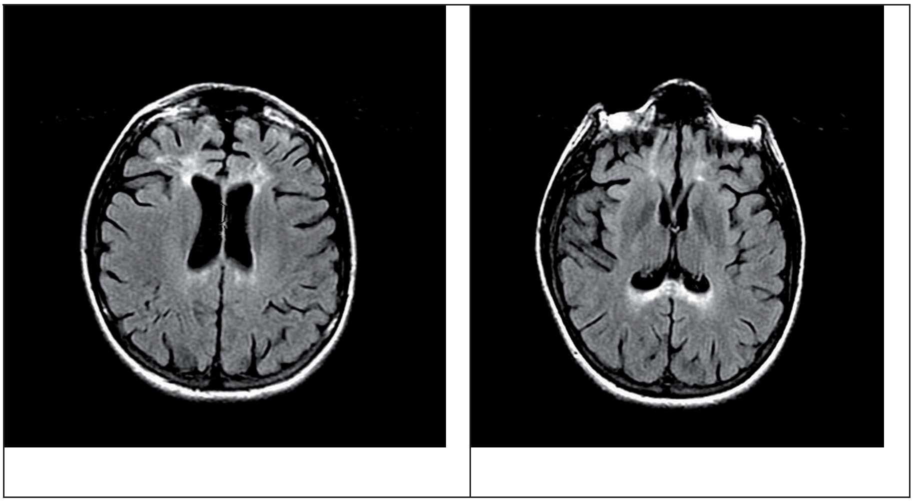

Fig. 1. Brain MRI. 2005. FLAIR and frFSET2 sequences, axial plane. Gliotic posttraumatic changes in frontal lobes (largest in the right hemisphere)

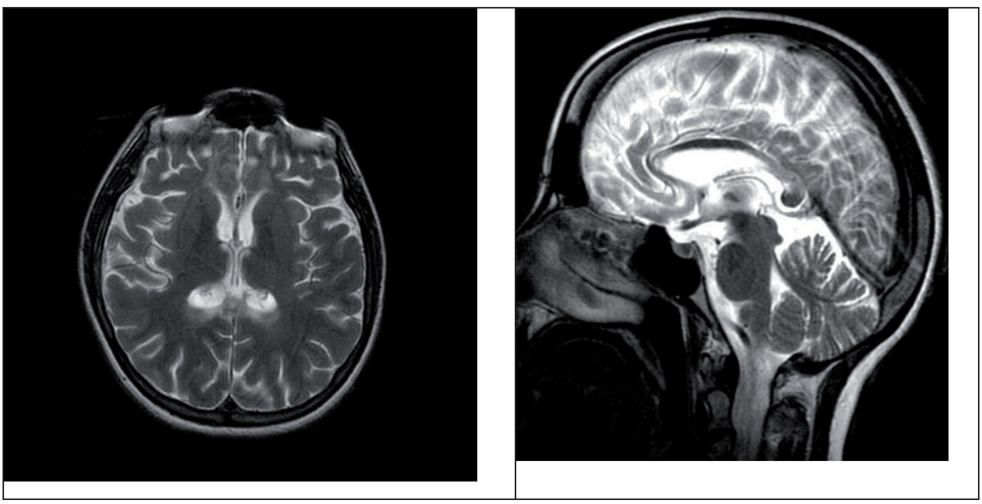

Fig. 2. Brain MRI. 2008. FrFSET2 and FLAIR sequences, axial plane. Gliotic posttraumatic changes in the frontal lobes, especially in the right hemisphere, more prominent than in 2005, with atrophy of brain parenchyma (external porencephaly)

THE PROGRAM OF NEUROTHERAPY

The patient was admitted to a day clinic for rehabilitation in March of 2012. Neurofeedback protocols are usually constructed by comparing EEG spectra in Eyes open and Eyes closed conditions with normative data (see: Thornton and Carmody 2009). However, in this particular patient no deviations from the norms in the EEG spectra were found. The only abnormality associated with ADHD was observed in Event Related Potentials (ERPs). The component generated in the supplementary motor cortex was of significantly lower amplitude in this patient in comparison to norms. This observation indicates hypo-functioning of the executive system. This pattern of ERP has been found in a group of ADHD patients (Kropotov & Mueller, 2009). On the basis of this indirect observation, conventional beta training for ADHD was prescribed for the patient.

The patient took part in 40 sessions of relative beta training, whose goal was to activate the frontal cortex by enhancing beta activity recorded over the frontal electrodes. In more detail the procedure was as follows: electrodes were placed at Fz and Cz (bipolar recording). The procedure was to increase the ratio of beta EEG power to EEG power in the theta and alpha frequency bands. The beta frequency band was from 13 to 21 Hz. The combined theta and alpha frequency bands were from 4 to 12 Hz. Each session included approximately 20 min. of neurofeedback training.

NEUROPSYCHOLOGICAL TESTING

Neuropsychological testing was conducted using clinical interview and standard neuropsychological batteries. At baseline, i.e. before neurotherapy, the results showed multiple deficits, constituting both quantitative and qualitative disturbances of consciousness, cognitive deficits (see Table 1), and behavioral problems.

In the Patient Competency Rating Scale – revised (PCRS-R) (Prigatano et al., 2005; adapted for Polish, Pachalska, 2007), we found impaired self-awareness and disturbances of identity, with episodic confabulations and delusions concerning herself and/or persons close to her.

In order to evaluate the qualitative disturbances occurring in A.A.'s behavior, we used the Frontal Behavioral Inventory (Kertesz et al., 1997, 2000, adapted for Polish, Pachalska et al., 2002). We found signs of „alien hand" and other features of frontal syndrome), such as irritability, restlessness, active and passive aggression, anxiety, hypersensitivity, hypersexuality and unreasonable behavior, but the number of points (24/72) did not quite meet diagnostic criteria for frontal syndrome (26/72 pts).

Cognitive deficits (see: Table 1, baseline) included low IQ (WAIS-R); impaired attention, especially spatial span; and memory problems (WMS-III), especially deficits in logical and verbal memory, especially after a filled delay. We also found impaired executive functions.

Patient A.A. participated in an assessment of attention, including a computerized performance measure (Conners' Continuous Performance Test-II, CPT-II), parental and self-reporting measures (Conners 3), and a structured diagnostic interview for ADHD and other psychological disorders (Diagnostic Interview for Children and Adolescents-IV, DICA-IV). On the basis of results, as well as the whole clinical picture, two independent consulting neuropsychologists agreed that the profile of her cognitive and behavioral disturbances were consistent with SADHD.

After the neurotherapy program, A.A.'s verbal and non-verbal IQ increased significantly (cf. Table 1). Most of her cognitive dysfunctions also resolved, including immediate and delayed logical and visual recall on the WMS-III (cf. Table 1). Her results for maintaining attention on the WMS-III improved (34/40 points). In other

Table 1. Neuropsychological testing of patient A.A., baseline and follow-up

Measure	baseline	follow-up
WAIS-R		
IQ – Full	64.0/100	96.5/100
IQ – Verbal	69.0/100	99.0/100
IQ – Nonverbal	61.0/100	89.0/100
Attention		
WMS-III Spatial Span	3 (1st %ile)	12 (75th %ile)
Visuospatial Ability		
WAIS-III Block Design	3 (1st %ile)	8 (25th %ile)
Logical Memory		
WMS-III Immediate logical memory	7/24	20/24
WMS-III Delayed logical memory	4/24	18/24
WMS-III Immediate visual recall	12/41	37/41
WMS-III Delayed visual recall	6/41	26/41
Verbal memory		
CVLT Short Delay Free Recall	0/9(<1st %ile)	2/9 (<1st %ile)
CVLT Long Free Recall	0/9(<1st %ile)	2/9 (<1st %ile)
CVLT Long Delay Cue Recall	0/9(<1st %ile)	2/9 (<1st %ile)
Executive Functions		
TMT– Number Sequencing	Discontinued	54s. (10th %ile)
TMT– Number Letter Sequencing	Discontinued	150s. (<1st %ile)

Table 1(cont.). Neuropsychological testing of patient A.A., baseline and follow-up

Stroop		
Color	90 s. (<1st %ile)	41 s. (16th %ile)
Word	29 s. (25th %ile)	42 s. (63rd %ile)
Interferences	Discontinued	128 s. (<1th %ile)
WCST		
Categories	0 (2-5th %ile)	2 (>16th %ile)
Perseverative Errors	46 (<1th %ile)	19 (37th percentile)
Conceptual Level Responses	63 (<19th %ile)	48 (45th%ile)
Failure to Maintain Sets	Discontinued	4 (2-5th %ile)

TMT = TrialMaking Test
Level of performance corresponding to the percentiles
98-99 %ile = Very Superior
91-97 %ile = Superior
75-90 %ile = High Average
25-74 %ile = Average
9-24 %ile = Low Average
3-8 %ile = Borderline
2nd %ile and below = Impaired

cognitive functions, A.A.'s results also improved in the follow-up examination.

On the auditory learning task, she had forgotten all the words after a 15-minute filled delay at baseline, and got 5 words in recognition; however, in the follow-up examination she remembered 2 words after the delay, and got all the words at recognition. This general pattern was repeated in nearly all neuropsychological testing.

After neurotherapy, all disorders of consciousness resolved, including the impaired self-awareness. The patients knows and acknowledges that she had an accident, and that she has a variety of neurocognitive dysfunctions as a result. She knows that the scar on her throat is from a tracheotomy, and that the scar on her knee is from surgery. She knows that she still has difficulty with memory; however, she is trying to use electronic aids that record the facts she needs to remember, and things that need to be done. She reads and writes a great deal (among other things, she sends e-mails to her friends and therapists). She is even considering whether to make an appeal on the rape case (which is not impossible in Polish law, in the absence of a "double jeopardy" rule). The disturbances in attention have also decreased, and do not at the moment form a clinical picture of SADHD.

She has worked hard and conscientiously, and her progress has been very gratifying. After 20 sessions of neurofeedback, she independently prepared for and passed her final exam for her master's degree in May of 2012. After 40 sessions of neurofeedback, during summer vacation, she completed her MA thesis, which she had begun even before the accident, and successfully defended it in early September, 2012. In September, as of this writing, she began work, and seems to be doing well.

EVENT RELATED POTENTIALS (ERPS)

Event related potentials (ERPs) were used to assess functional changes in the patient induced by the rehabilitation programs. We used this approach for the following reasons:

- First, ERPs have a superior temporal resolution (on the order of milliseconds) as compared to other imaging methods, such as fMRI and PET (which have a time resolution of 6 seconds and more; Kropotov, 2009).
- Secondly, ERPs have been proven to be a powerful tool for detecting changes induced by neurofeedback training in ADHD children (Kropotov et al. 2005; Kropotov & Muller, 2009).
- And finally, in contrast to spontaneous EEG oscillations, ERPs reflect stages of information flow within the brain (Kropotov, 2009; Kropotov et al., 2005).

The diagnostic power of ERPs has been enhanced by the recent emergence of new methods of analysis, such as Independent Component Analysis (ICA) and Low Resolution Electromagnetic Tomography (LORETA; Kropotov, 2009).

A modification of the visual two-stimulus GO/NO GO paradigm was used (Fig. 3). Three categories of visual stimuli were selected:

- 20 different images of animals, referred to hereinafter as “A”;
- 20 different images of plants, referred to as “P”;
- 20 different images of people of different professions, presented along with an artificial “novel” sound, referred to as “H+Sound”.

All visual stimuli were selected to have a similar size and luminosity. The randomly varying novel sounds consisted of five 20-ms fragments filled with tones of different frequencies (500, 1000, 1500, 2000, and 2500 Hz). Each time a new combination of tones was used, while the novel sounds appeared unexpectedly (the probability of appearance at any given moment was 12.5%).

The trials consisted of presentations of paired stimuli with inter-stimulus intervals of 1 s. The duration of stimuli was 100 ms. Four categories of trials were used (see Fig. 3): A-A, A-P, P-P, and P-(H+Sound). The trials were grouped into four blocks with one hundred trials each. In each block a unique set of five A, five P, and five H stimuli were selected. Participants practiced the task before the recording started.

The patient sat upright in an easy chair looking at a computer screen. The task was to press a button with the right hand in response to all A-A pairs as fast as possible, and to withhold button pressing in response to other pairs: A-P, P-P, P-(H+Sound) (Fig.3). According to the task design, two preparatory sets were distinguished: a “Continue set,” in which A is presented as the first stimulus and the subject is presumed to prepare to respond; and a “Discontinue set,” in which

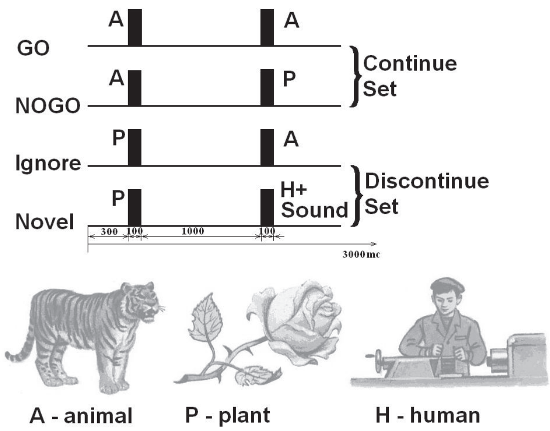

Fig. 3. Schematic representation of the two stimulus GO/NOGO task. From top to bottom: time dynamics of stimuli in four categories of trials. Abbreviations: A, P, H stimuli are “Animals”, “Plants” and “Humans” respectively. GO trials occur when A-A stimuli require the subject to press a button. NOGO trials are A-P stimuli, which require suppression of a prepared action. GO and NOGO trials represent “Continue set” in which subjects have to prepare for action after the first stimulus presentation (A). Ignore trials are stimuli pairs beginning with a P, which require no preparation for action. Novel trials are pairs requiring no action, with presentation of a novel sound as the second stimuli. Ignore and Novel trials represent “Discontinue set”, in which subjects do not need to prepare for action after the first stimulus presentation. Time intervals are depicted at the bottom.

P is presented as the first stimulus, and the subject does not need to prepare to respond. In the “Continue set,” A-A pairs will be referred to as “GO trials,” A-P pairs as “NO GO trials.” Averages for response latency and response variance across trials were calculated. Omission errors (failure to respond in GO trials) and commission errors (failure to suppress a response to NO GO trials) were also computed.

EEGs were recorded from 19 scalp sites. The electrodes were applied according to the International 10-20 system. The EEG was recorded referentially to linked ears, allowing computational re-referencing of the data (remontaging).

RESULTS

Behavioral parameters in GO/NOGO task

Table 2 shows the parameters of the patient’s behavior in the GO/NOGO task. The patient was slow before treatment (as manifested in slower than normal reaction time) and inconsistent in response (as manifested in larger than normal error in the variance of response). After treatment, the subject remained slow, but was more consistent in response.

Table 2. Behavioral parameters in GO/NOGO task

	Omission	Commission	Reaction time (RT)	Error of variance of RT
Post	1%	0%	567*	5.8
Pre	2%	0%	555*	11.7*
Pre vs Norms	P=0.91	P=0.71	P=0.1	P=0.08
Norms	1.8%	0.5%	414	8.6

EEG spectra

No statistically significant deviations from the normative data were found in either Pre or Post conditions (Fig. 4). However there was a significant decrease of posterior alpha activity in resting and task conditions after neurotherapy sessions. This may indicate that the posterior cortex of the subject became more active after treatment.

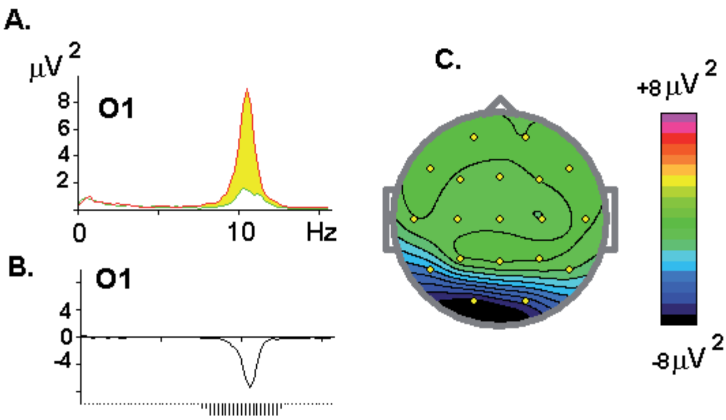

Fig. 4. EEG Spectra changes after neurotherapy. EEG spectra at O1 electrode in the eyes closed condition before (red) and after (green) neurotherapy. EEG spectra changes induced by the neurotherapy. Large vertical bars below the curve indicatedp-values of statistical significance of the difference (p<0.01). Topograpy of EEG spectra difference at 11 Hz

ERPs

It should be stressed here that very large deviations from normative data are found in the independent component generated in the supplementary motor cortex and associated with action suppression operation (Fig. 5). As our previous study has shown (Kropotov & Mueller, 2009) this ERP pattern is seen in the adult ADHD population group. However, this ERP component did not change significantly after the neurotherapy sessions.

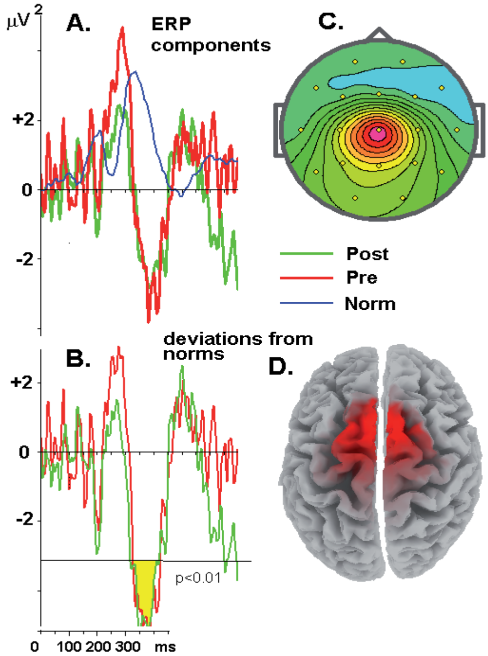

Fig. 5. ERP independent component changes after neurotherapy. Action suppression independent component before (red line) and after (green line) neurotherapy in comparison with the grand average component computed for a group of healthy subjects. ERP component differences (patient-norms) before (red line) and after (green line) neurotherapy. The horizontal line indicate p-values of deviations from the reference smaller than 0.01. Topography of the action suppression independent component, sLORETA image of cortical generators, the action suppression component

DISCUSSION

This case study confirms the observations of other authors that among the problems most detrimental to the process of recovery and the level of functioning after discharge from the hospital for TBI patients are neuropsychiatric disorders, with particular emphasis on diverse, full and partial syndromes of self-awareness (Prigatano, 2012, Della Sala et al., 2009).

Traditional therapies for functional brain recovery after severe traumatic brain injury and long term coma are still not satisfactory (Mauritz et al., 2008; Choi et al. 2008; Pąchalska et al., 2010; Benedictus et al. 2010; Marvasti 2011).

To date the best approach has been deemed to be intensive physical and cognitive therapy (Pąchalska, 2008) however, the results are limited and functional gains are often minimal (Pąchalska et al., 2012). Therefore, adjunct interventions that can augment the response of the brain to the behavioral and cognitive training might be useful to enhance therapy-induced recovery in TBI patients. In this context, neurofeedback self-regulation and noninvasive brain stimulation appear to be options as additional interventions to standard physical therapies (Schoenberger et al., 2001; Pachalska et al., 2012).

In the case of neurofeedback in TBI patients, quantitative electro-encephalography (qEEG) patterns are assessed and then compared to a normative database. Deviations in qEEG patterns from the normative group usually form the basis for the intervention plan (Kropotov, 2009). In the patient described here, however, no deviations from the reference database were found in the spontaneous waking state EEG. The only clinically relevant deviation from the norms was found in the ERP component generated in the supplementary motor cortex. Functionally this component is associated with action inhibition. In our study with adult ADHD patients (Kropotov & Mueller, 2009) this component was found to be decreased in the ADHD population. This indirect observation enabled us to suggest a conventional neurofeedback protocol (relative beta training) intended to activate the frontal lobe.

The comparison of EEG spectra and ERPs in this patient before and after neurofeedback sessions did not show any significant changes. The only clinically positive changes were found in behavior. They were associated with a decrease in the variance of reaction time.

It should be stressed here that elevated variance of reaction time is associated with excessive fluctuation of attention. This behavioral pattern is often found in the ADHD population (Kropotov, Mueller, 2009). We can conclude, then, that behaviorally the patient improved.

Unfortunately, no statistically significant changes in the ERP action inhibition component were observed in this patient. This is in contrast to our previous studies on the effect of relative beta training on ERPs in a group of ADHD children (Kropotov et al., 2005). In this study, the inhibition NOGO wave was shown to increase after 20 sessions of relative neurofeedback training. There are two possible explanations of this discrepancy: 1) the positive effect on ERPs was shown in children with primary ADHD, while our patient is an adult with secondary ADHD, induced by brain damage; 2) the ERP waves are quite stable characteristics of the human brain functioning with high test-retest reliability, and 40 sessions of self-regulation in an adult brain are not sufficient to induce statistically reliable changes.

So how do we explain the patient's success after neurotraining?

Could it be that the neurotraining directly or indirectly improved her psychiatric status, which therefore improved her judgment? Could she be more focused in her attention and therefore perform better on tests? Could she be less anxious and therefore perform better on tests?

We can assume that the answer to these questions is, yes. She had a decreased visual-related component, an indicator of TBI, and also decreased beta generated centrally, indicating hyperactivation of the central medial cortical area, associated with anxiety. We can assume, then, that on the one hand, she improved her abilities to perceive stimuli from the outside world, and on the other, there was a reduction of anxiety. Therefore, emotional factors also play a particularly important role in her recovery. This observation confirms the findings from other studies; we have seen patients after traumatic brain injury who have elevated anxiety and depression that do poorly on tests, but later show good performance if their overall emotional state has improved (Prigatano 1999; Pachalska 2007).

Still, there may be other factors going on in her life that could also result in an improved performance on psychometric tests. We should point out that our patient had severe traumatic brain injury and has very poor judgment. Thus she does not have specific areas in which she displays a lack of awareness. Her comments in court further underscore the global impairment in judgment, and there could well be comorbid psychiatric difficulties that account for her behavior. For example, the presence of episodic confabulations and delusions again emphasize how psychiatric factors may influence her judgment and how she responds to the questions on the Patient Competency Rating Scale.

In our opinion, the chronic neuropsychiatric disorders that had persisted for ten years, with particular emphasis on impaired self-awareness, played the most important role in the poor progress the patient was making in rehabilitation. As stated by other authors, chronic impaired self-awareness can negatively influence a person's phenomenological state, which interferes with their ability to engage in rehabilitation (Prigatano & Altman, 1990) and/or to adhere to a necessary course of treatment (Amador & David, 2004).

Therefore, impaired self-awareness can be a major problem preventing patients from engaging themselves in brain injury rehabilitation. A patient with low levels of self-awareness is likely to be unmotivated or uncooperative in therapy, set unrealistic goals, display poor judgement, and fail to see the need for compensatory strategies, let alone apply them in everyday life. Rehabilitation can be a frustrating exercise for both the patient and the rehabilitation team as a result. Individuals with higher levels of self-awareness are more likely to actively participate in rehabilitation, experience stronger therapeutic alliances, and achieve better rehabilitation outcomes in terms of the level of community integration (Fleming 2012).

Our patient began to be aware of her own problems. She claimed to take pleasure in rehabilitation, and she began to train, read and write. As a result, she shows improved memory and executive functions. Special attention should be given to the significant reduction of the symptoms of SADHD.

The long-term study presented here supports the arguments of Prigatano (2010), that disturbances of subjective experience (such as impaired self-awareness) have not been well understood, although some progress has been made. It is therefore necessary to continue the search for the brain mechanisms underlying these disorders.

In our opinion, it is extremely important in this study to adopt the microgenetic model of consciousness as a basis for diagnosis and therapy (Pąchalska et al., 2012; this issue). Consciousness is often equated with wakefulness (Prigatano, 1999). However, as we know, such a definition is not precise enough for neuropsychologists (Pąchalska, 2007). For this reason, many researchers recognize that conscious experience involves both knowledge (Heilman 1971; Herzyk

2011), as well as the individual's relationship to the surrounding reality (Brown 1977, 2002, 2012). Emotional factors play a particularly important role here (Brown, 2012).

This means that consciousness involves not only knowledge, which is a factor activating and regulating how intentional human action is planned and carried out, but also, as stated in other works (Pąchalska 2007, 2008; Pąchalska & Kaczmarek, 2012) other mental processes, such as:

- self-regulation of physiological functions (e.g. the sleep-wake cycle);
- automatization of actions (e.g., the formation of complex learned series of actions, from learning to walk to virtuoso piano playing);
- modeling activities (e.g., attitude, emotional and motivational states, which are not always fully accessible to conscious awareness, but guide life activity);
- conscious action (including the relationship with the world around).

The complexity of the relationship between conscious and unconscious states at all levels of operation - from the biological to the psychological and cultural - should be emphasized here. These relationships are formed also on the border of self and world, both consciously and unconsciously.

With this approach it is possible to better understand the existing, unreal internal mental model of the patient and the world that is characteristic for persons with a variety of disorders of consciousness (Fig. 6).

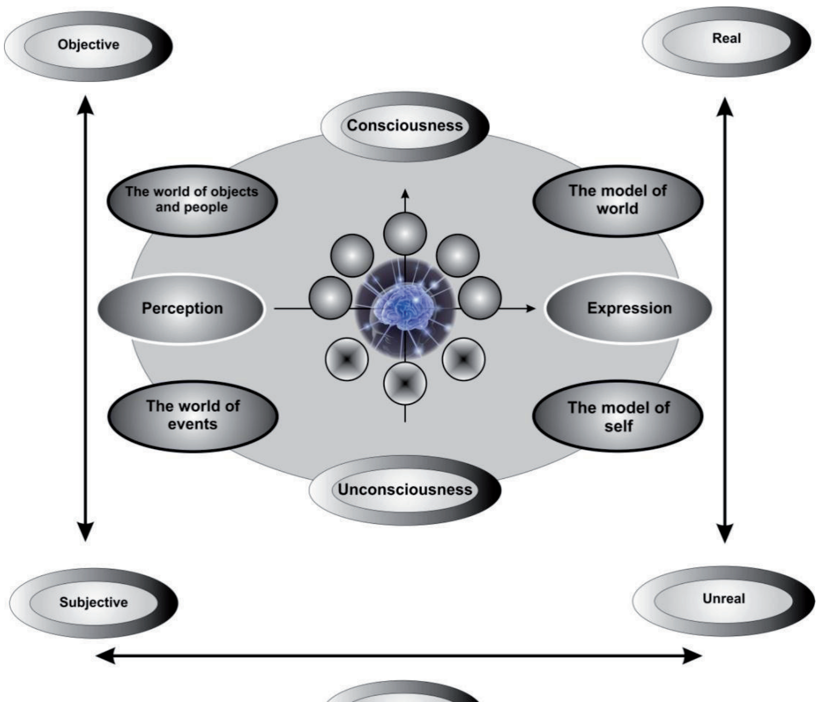

Fig. 6. Model of disorders of consciousness. The structure of Self in relation to the brain, mind and world [a detailed description of this model in Pąchalska and Kaczmarek, 2013]

A better understanding of the patient's problems, along with the selection of appropriate and interesting games for use in neurofeedback, made it possible to modify an existing, disturbed mental model of self and world in favor of a different, real, and more objective model, specific to those without disorders of consciousness. It seems that for this reason it was possible for the patient to complete the studies interrupted by the accident. She passed her final examination; she finished her master's thesis, which she had started before the accident, over the summer holiday, and defended the thesis in September of 2012.

To sum up, it should be stressed that the „mental model of the world," understood as an individual's mental image of the real world, which is the basis of conscious experience, is connected not only with intellectual evaluation of phenomena, but also involves emotions and the moral evaluation of one's own behavior and that of others . Associated with this model, „our personal, subjective experience allows us to develop beliefs regarding to our capabilities and how we function in the real world" (see also Prigatano, this issue).

These views are confirmed by the life situation of the patient. She has begun working in a nursing home, and the first reports from her family indicate that she is doing well.

CONCLUSIONS

A neurofeedback program using relative beta-theta training produced only slight physiological changes, but large cognitive and behavioral changes, which led to the reduction of chronic, impaired self-awareness and SADHD in this patient, who had suffered a TBI and long term coma .

ERPs can be used to assess SADHD as well as functional brain changes induced by neurotherapy, but it shows limited capability for the interpretation of the brain mechanisms of chronic, impaired self-awareness after severe TBI and long term coma.

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