NEUROINFORMATICS: APPLICATION OF Q-EEG IN PEDIATRIC RESEARCH AND PRACTICE

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ABSTRACT

The discipline called 'Neuroinformatics' stands upon three pillars: data management and sharing, development of computational models of the nervous system and neuronal processes, which simultaneously may lead to development of new methods for information technology.

Research activities in the Division of Bioinformatics at the Macedonian Academy of Sciences and Arts include the first category associated with integration and interpretation of neuroscience data trough the help of quantitative or computerized EEG (Q-EEG). The course of work using this technique includes following steps: recording of multichannel EEG with the administration of standardized tests, signal processing and extraction of features from investigated EEG signal, analysis of EEG features and comparison of subject's data with a normative database corrected for time-of-day variations.

In pediatric practice certain Q-EEG techniques are established as an additional tool for diagnosis of epilepsy, cerebrovascular diseases, postconcussion syndrome, learning disability disorders, attention disorders, schizophrenia and depression.

Q-EEG is also used as a base for neurofeedback treatment which is specific operant-conditioning paradigm where an individual learns to influence the electrical activity (frequency, amplitude or synchronization) of his brain. It involves teaching skills through the rewarding experience of inducing EEG changes reflected in a perceivable signal (light or sound). It has been shown that neurofeedback is particularly useful for pathologies characterized by dysfunctional regulation of cortical arousal, such as epilepsy and attention deficit hyperactivity disorder (ADHD). In Macedonian medical practice we provide treatment for following problems: psychosomatic, behavioral, elimination, phobic, eating and sleeping disorders, as well as ticks, stuttering, ADHD, and children who suffer from some chronic diseases.

In summary, Q-EEG is proven as a very useful tool in pediatric research and practice that can further evolve by constant cooperation between informatics and neuroscience. Areas where computer science can be of particular help are associated with developing technologies to improve and facilitate processing of large amounts of EEG data and application of new electronic and software technologies for better arrangement, organization and management of databases.

I. INTRODUCTION

The fields of neuroscience and informatics are deeply interconnected into vast and intricate network of shared principles and interests. Connections resulting from their common conceptual orientation lead in both directions e.g toward neuroscience and informatics at the same time. Indeed, the transformation of information into quality idea is a major concern of both, cognitive neuroscience and informatics as well. This is best described by William Pollard's saying: "Information is a source of learning. But unless it is organized, processed, and available to the right people in a format for decision making, it is a burden, not a benefit". On the other hand, connections that result from the practical cooperation of these disciplines begin mainly in the needs of modern neuroscience and end with the solutions of informatics. They arose with the production of vast amounts of neuroscience data which could be compared, cross-referenced, integrated and interpreted trough the help of informatics.

Connections described above, are but a few that inevitably led to creation of new scientific discipline called 'Neuroinformatics'. The idea for this discipline was born nearly 20 years ago by Dr. Stephen H. Koslow, director of the Division for Neuroscience at the National Institute for Mental Health. He conducted the first analysis of the need for such discipline, initiated the first project in this field, introduced it to the political community in USA and EU and popularized it with the several books he wrote on this topic. Nowadays it is already accepted as an autonomous scientific area defined as "combination of neuroscience and informatics research in order to develop and apply the advanced tool and approaches that are essential for major advances in understanding the structure and function of the brain" [1].

II. Q-EEG: IMPORTANT NEUROINFORMATIC TOOL

Neuroinformatics is special field within the range of bioinformatics comprised of three elements:

- Data management and sharing. This segment is also known as "Neuroscientific Science Library", because it is associated with electronic acquisition, storage, querying, retrieval, visualization, integration, modelling, simulation, analysis, synthesis and sharing of data. More precisely, it deals with neuroscience information from molecular to brain systems levels, including issues of implementation, standardization, management, quality control, copyright, confidentiality and acceptance.
- Computational models of the nervous system and neuronal processes. Namely, although many relevant techniques have already been developed in other fields, the neuroscience community must collectively design and develop special-purpose analytical tools and algorithms that are optimal for their needs. [2] This segment is also known as "Computational Neuroscience".

- Development of new methods and concepts for information technology.

Research activities in the Division of Bioinformatics at Macedonian Academy of Sciences and Arts include the first category associated with neuroscience data integration and interpretation. Most important technique performed in the research practice is quantitative or computerized EEG (Q-EEG) roughly defined as a comparison of EEG data from investigated subject with normative EEG database using statistical analysis.

A. Principle of Work

The method of Q-EEG work rests upon the following elements:

- Recording of multichannel EEG with the administration of standardized tests: eyes open, eyes closed, visual continuous performance, auditory continuous performance, reading test and math test.
- Signal processing and extraction of features from investigated EEG signal. In typical practice, EEG signal is digitized, edited or adjusted to remove cerebral artifact, and subjected to spectral analysis using the Fast Fourier Transformation.
- Analysis of features such as: Frequency distribution, Voltage, Locus of the eventual phenomena, Waveform, Inter-hemispheric symmetries etc.
- Comparison of subject's data with a normative database corrected for time-of-day variations. Data is also evaluated for percentage change across states and compared with a normative database for state modulation. Finally, topographic maps show covariance between all sites at relevant frequencies compared with a normative database to obtain functional cortical interactions [3].

III. Q-EEG in Pediatric Research and Practice

The pediatric practice relays upon Q-EEG for the process of diagnosing and treating several pathologies.

A. Q-EEG as a Diagnostic Tool

Q-EEG technique is well-established additional tool in diagnosis of:

- Epilepsy screening for possible epileptic spikes or seizures in long-term EEG monitoring or ambulatory recording to facilitate subsequent expert visual EEG interpretation;
- Cerebrovascular Diseases;
- Postconcussion syndrome;
- Learning disability;
- Attention disorders (Fig.1);
- Schizophrenia;
- Depression. [4]

Routine EEG has long been an established test used in evaluations of dementia and encephalopathy when the diagnosis remains unresolved after initial clinical evaluation.

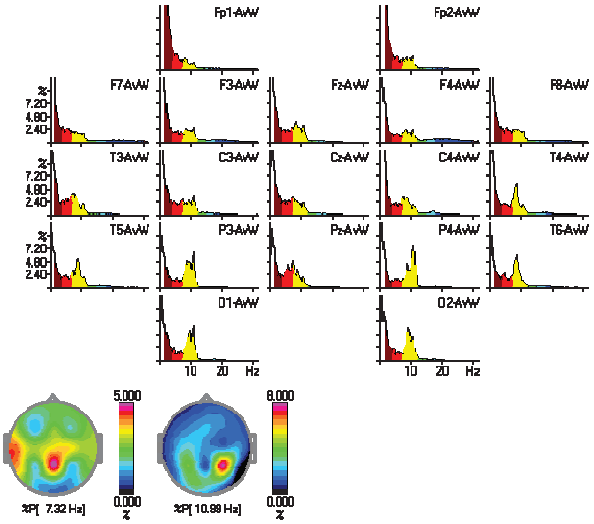

Figure 1: Q-EEG of ADHD Patient.

B. Q-EEG as a Therapeutic Tool

Quantitative EEG is also utilized as a base for Neurofeedback (NF) treatment. NF refers to a specific operant-conditioning paradigm where an individual learns to influence the electrical activity (frequency, amplitude or synchronization) of his brain. It involves teaching skills through the rewarding experience of inducing EEG changes reflected in a perceivable signal (light or sound) (Fig. 2). It has been shown that neurofeedback is particularly useful for pathologies characterized by dysfunctional regulation of cortical arousal, such as epilepsy and attention deficit hyperactivity disorder (ADHD) [5-10]. Other clinical applications of NF include slow wave alpha/theta feedback training as a complementary therapeutic tool in the treatment of substance abuse [11], brain-computer interface in paralyzed patients' [12] or in schizophrenia [13].

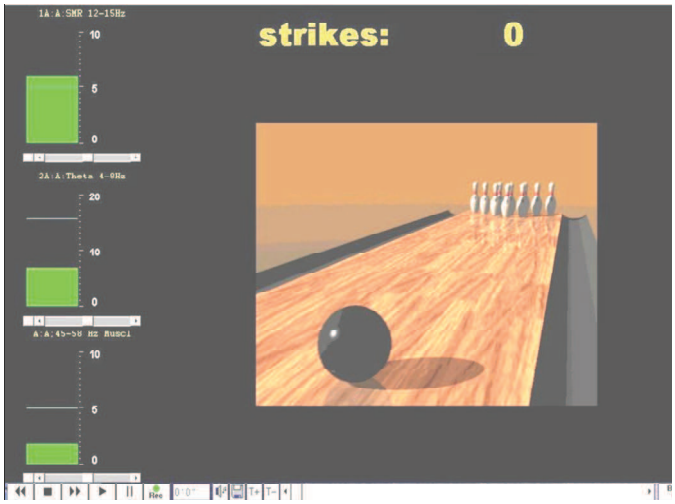

Figure 2: Computer Animation for NF Treatment.

In Macedonian medical practice we provide treatment for following problems:
- Psychosomatic disorders;
- Behavioral problems;
- Elimination disorders (enuresis nocturna and encompresis);
- Anxiety and phobic disorders;
- Ticks;
- Eating disorders (anorexia, bulimia, obesity);
- Sleeping disorders;
- ADHD/ADD;
- Posttraumatic Stress Disorder (PTSD);
- Obsessive-compulsive Disorder (OCD);
- Speech problems (stuttering).

In addition, neurofeedback treatment proved useful as additional option in patients suffering from chronic disease. At the Pediatric Clinic in Skopje 20 % from all admitted patients are children with some form of chronic diseases such as: cystic fibrosis [14], bronchial asthma, oncology diseases, diabetes mellitus and rheumatologic diseases, some kinds of immune deficit, epilepsy, brain injuries and kidney failure.

In some of the mentioned conditions neurofeedback protocol is created according to individual EEG indices. What's more, by comparing the neurofeedback results at the beginning and the end of a treatment, the neurofeedback is actually used for evaluation of the dynamics (e.g. progression/regression) of the treated illness.

IV. Concluding Remarks

Q-EEG is proven to be very useful tool in pediatric research and practice that can further evolve by constant cooperation between informatics and neuroscience. Areas where computer science can be of particular help are associated with developing technologies to improve and facilitate processing of large amounts of EEG data and application of new electronic and software technologies for better arrangement, organization and management of databases. In that way our understanding of this scientific matter will involve development of models that are not just descriptive, but predictive and explanatory as well, and the final result be enhanced and improved knowledge of brain's structure and function.

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