Title Algorithm and software development for analysis and classification of EEG measurements during administration of neuropsychological tests for AD/HD

Titre: Développement de nouveaux algorithmes pour l'analyse et la classification des données EEG lors de l'administration de tests neuropsychologiques dans le TDA/H

EPI Equipe Defi, Inria-Saclay

Financement CORDIS INRIA Saclay

Expertise souhaitée

The candidate should have a Master's degree in Computer Science or Applied Mathematics, be able to program in Matlab or Python, and have done classwork in statistics. Past experience in Brain-Computer Interface is helpful.

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Lieu de la thèse

CMAP, Ecole Polytechnique. Le Centre de Thérapie Interpersonnelle, pôle psychiatrique du 7ème, rattaché au C.H. Sainte-Anne.

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Ecole Doctorale

Encadrement Co-directed by Jing-Rebecca Li (INRIA-Saclay, Equipe DEFI) and Dr. Hassan Rahioui

Hassan Rahioui est psychiatre et docteur en psychologie. Chef du pôle psychiatrique du 7e arrondissement de Paris rattaché au centre hospitalier Sainte-Anne, il est également enseignant chercheur en psychopathologie à l'université Paris Diderot et président de l'Association française de thérapie interpersonnelle.

Jing-Rebecca Li est chercheuse au sein de l'équipe Defi travaillant en modélisation mathématiques et neuro-imagerie.

Thématique Mathématique et Science de la Vie

Description détaillée

Context and objectives

1. Background on AD/HD

Attention Deficit Disorder with or without Hyperactivity (AD/HD) in adults is gaining attention only recently in the scientific community because it had been considered, wrongly, that this pathology disappeared after adolescence. It is a neurobiological disorder that can be very disabling in the personal and professional life of the person who has it. Though it can be aggravated by psycho-social factors, AD/HD is essentially genetic (and therefore often hereditary). AD/HD affects approximately 5% of the general population, leading to attention deficit with possible hyperactivity and impulsivity problems. Hypersensitivity problems, frequent and short fluctuations in energy, emotions and mood, as well as organizational difficulties often resulting in procrastination, are also common.

Attention deficit is the main symptom of AD/HD and it is presented in 3 types that differ greatly in the behavioral aspect:

- Inattentive Type

It is more an inconsistency of attention than a deficit of attention. Those who only have this component are dreamers and move from one idea to another, often without putting them into action and thus starting few actions.

- Hyperactive type

Hyperactive adults become with age less physically agitated but relentlessly move from one action to another without finishing most, preventing them from reaching their goals (which are too many or incompatible with their disorder).

- Impulsive type

Here the patients act or speak before thinking, take risks, have an explosive temperament or give up on everything regularly.

At present, there is no single diagnostic test for AD / HD. An appropriate diagnostic assessment for AD / HD (and all other childhood psychiatric disorders) generally involves a process of collecting data on the history, course and duration of symptoms, both at home, school, and at work using clinical interviews and behavioral scales. Because inattention is pathognomonic to almost all childhood psychiatric disorders, and it is often difficult to make differential diagnoses between AD / HD and other disorders that may have a similar presentation, including Autism spectrum disorders, mood and anxiety disorders, and learning disabilities. Given that the diagnosis of AD/HD is not obvious and complementary evaluation tools are lacking, the practitioner is looking to investigate tools that may facilitate his or her evaluation.

2. Neuropsychological tests

Neuropsychological tests are important tools to quantify the attentional and/or cognitive deficits of patients compared to controls. The tests are usually administered by trained psychologists and can

complement a clinical diagnosis. In particular, tests of attention, working memory, short term memory, selective attention, inhibitory control are useful to study AD/HD populations. ADHD is associated with impaired performance on measures of response inhibition, working memory, and other aspects of executive functions, yet data also suggest significant neuropsychological variability within and across ADHD samples.

In recent years, many neuropsychological tests are administered and scored on a computer, by presenting the patient with visual or audio stimuli and recording his or her responses. The accuracy of the responses, the types of errors, as well as reaction times average and variability all contribute to the neuro-cognitive profile of the patient.

Even though many of the neuropsychological testing suites are commercial and expensive, we mention an exception, in particular:

PEBL: The Psychology Experiment Building Language. (http://pebl.sourceforge.net/)

PEBL is a programming language and execution environment whose premise is the following:

Free psychology software for creating experiments

Allows the design of custom experiments or the use of ready-made ones

Allows the exchange of experiments freely without license or charge

3. Electroencephalography (EEG)

After a long period of decline, the use of EEG has become attractive for research and clinical purposes in AD/HD. Recent work has seen the use of EEG with high densities (256 electrodes) for more precise spatio-temporal information on the dynamic aspects of cortical activation and intracortical communication. These new recording capacities are gradually entering the field of psychiatry. In situations that are closer to the clinical, a vertex-measured theta-to-beta power ratio under open-eyes or closed-eyes conditions was proposed to capture the relative contributions of two relevant frequency bands to diagnose and monitor ADHD; however, the true functional significance of this measure remains unknown. An increase in theta band was found throughout the life span of adolescents and adults with AD / HD compared to non-AD / HD populations. This increase, however, may be a non-specific marker for cortical dysfunction common to other disorders, such as epilepsy, bipolar disorder, and polysubstance abuse. There is a long history of EEG research documenting EEG abnormalities in AD/HD, especially the increase in fronto-central thetatic power, decreased beta activity and increased theta / beta. Attempts to correct these EEG abnormalities, coupled with a lower positive response to stimulant drugs, are the reason for neurofeedback (NF).

4. Objectives of this PhD thesis

A. Create software interface coupling the administration of neuropsychological tests to concurrent collection of EEG data.
B. Collect longitudinal EEG data in clinical (AD/HD) population and controls.
C. Develop, implement and evaluate the performance of several classification approaches to distinguish between AD/HD and controls as well as AD/HD subtypes.

Methodology

This PhD project concerns the incorporation of EEG data in the diagnosis and evaluation of AD/HD in a clinical setting. The EEG data will be acquired using commercially available wireless EEG headsets. Four headsets have been purchased for this project: 2 EMOTIV Epoc+ systems (14 EEG channels plus 2 reference channels) and 2 EMOTIV Insight systems (5 channels).

AD/HD patients will be recruited by Dr. Hassan Rahioui (psychiatre et docteur en psychologie, Chef du pôle psychiatrique du 7e arrondissement de Paris rattaché au centre hospitalier Sainte-Anne). A group of non-clinical controls will also be recruited. The AD/HD patients at the centre médico-psychologique (CMP) are currently offered one or several of the following options: 1) medication (Méthylphenidate); 2) talk therapy (in group setting); 3) meditation class (in group setting); 4) individual therapy (psychomotricité ou ergothérapie); In the future, it is possible that cognitive remediation therapy (CRT) (la remédiation cognitive) may be offered.

The patient volunteers and controls will be asked to take common neuropsychological tests most relevant to AD/HD (working memory, attention, inhibition). In particular, we will start with the Conners Continuous Performance Task (14 min) and the Test of Variables of Attention (TOVA) (22 min) from the PEBL (The Psychology Experiment Building Language) website. EEG data will be acquired concurrently during the administration of the tests.

We will create a computer interface that 1) administers the tests; 2) records the patient responses/significant events; 3) record EEG data and mark the EEG recording with the significant event markers associated to the tests. The patients and the controls will be asked to take the same tests several times during the course of the typical length of therapy (once a month, for example).

We will process and analyze the obtained EEG data in the resting state and around marked events during the neuropsychological tests, computing event-related potential, power spectrum, spatial correlations and perform independent component analysis (ICA) of the EEG time series from the 14 or 5 channels headsets. In particular, we will search for metrics that are robust and stable longitudinally in the control population and that have the potential to differentiate between controls and the AD/HD population. We will vary experimental parameters in the neuropsychological tests (task type, level of difficulty, etc) in the search of these robust metrics. We will utilize and compare various classification approaches (for EEG discrimination of AD/HD) in order to differentiate the controls and the clinical population. This will be an iterative process where the neuropsychological testing parameters may be modified to facilitate the classification procedure.

By looking for a set of robust and longitudinally stable metrics that can differentiate between the controls and the AD/HD population (as well as possibly within the AD/HD population), we expect to contribute to understanding what type of changes (due to therapy, for example) in the AD/HD group may be expected to be detectable by EEG along with neuropsychological tests.

Finally we plan to examine the correlation between several measures of patient response during the course of therapy/medication: 1) self-reported outcome by the patient; 2) evaluation by the therapist; 3) results of the neuropsychological tests (response accuracy, reaction time/variability); 4) EEG features.

Expected outcome

The scientific contributions of this PhD will be in the following areas.

Predictive (robust and stable) EEG features.

The integration of EEG collection concurrent to the administration of neuro-psychlogical tests is still in its infancy. If the tests are taken by the same person multiple times within a short period of time, the EEG signals may not be, a priori, stable in the obtained event related potentials and in the power spectrum across the multiple channels. We will look for biologically relevant features that are robust and remain stable over multiple administrations of the tests. This requires sophisticated statistical analysis of time series data across multiple channels. We will check the features in terms of interpretations that are coherent with known information about the relevant brain networks and associated wave frequency bands.

Development of new algorithms for the classification of EEG features

Given candidate EEG features and the labels relating to events during the neuro-psychlogical tests (commission errors, omission errors, etc.), we will develop new algorithms for classification. We will consider linear combinations of the candidate features that best predict the labels with different constraints on weights and regularization for objective function. In particular, a challenge to overcome in this problem is the fact that there may be significant noise or signal drop-out in some EEG sensors during administration of the tests due to factors that are difficult to control in a clinical setting (some sensors may not have good contact with scalp, patients may touch the head during the tests, etc.). Thus, the classification algorithm development in this thesis will need to be robust with respect to noise and missing data.

Towards the diagnosis AD/HD and the differentiation of AD/HD subtypes.

EEG based measurements can be a potential tool to tackle this task. The precise anomalies EEG can reveal during neuro-psychological tests are not well-understood and there is a lot noise. This motivates the development of outlier-robust techniques and finding the underlying biologically relevant features of the classes. For example, sparse/structured-sparse coding techniques are known to be outlier-robust. Union of Subspace methods are typically faster, with slightly worse theoretical guarantees when applied to vectors. They are typically applied for vectors and extension to time-series is a nice challenge. In short, we will investigate the classification problem while taking into account noise and variability in the control and patient populations.

In this thesis we will work on the validation of the use of consumer quality wireless EEG headsets in a clinical setting. We plan to process, analyze and display the results of the neuropsychological tests and the acquired EEG data in a format that is the most useful and informative for clinicians and patients. This will be the start of a collaborative effort between the Defi team at Inria-Saclay and the mental health professionals at the centre hospitalier Sainte-Anne and l'université Paris Diderot to use EEG in the aid of therapy (guidance of therapy, evaluation of therapy outcome).

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