# Form 101 Content

## **A1. Title of Project**

A framework for hybrid machine and human computation for the accurate and scalable analysis of human clinical EEG recordings

## **A2a. Principal and Co-Investigator(s)**

Principal Investigator

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Co-Investigator

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## **A3. Faculty Supervisor(s)**

None

## **A4. Student Investigator(s)**

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## **A5. Level of Project**

Faculty Research

Research Project/Course Status: New Project/Course

## **A6. Funding Status**

Funded, NSERC-CIHR Collaborative Health Research Project (CHRP) Grant, title “A framework for hybrid machine and human computation for the accurate and scalable analysis of human clinical EEG recordings”, period of funding April 1, 2015 - April 1, 2018.

## **A7. Does this research involve another institution or site?**

University of Toronto, University of Ottawa, Sunnybrook Health Sciences Center

## **A8. Has this proposal, or a version of it, been submitted to any other Research Ethics Boards/Institutional Review Board?**

University of Ottawa: Approved 7/7/2014 (PI Dr. Jigme Dorji Wanchuk). Toronto Academic Health Sciences Network: Approved 9/23/2012 (PI Dr. Andrew Lim)

## **A9. For Undergraduate and Graduate Thesis Research**

Not a Departmental Requirement

## **A10. Expected project commencement date / expected project completion date**

08/1/2015-08/1/2019

## **A11. Conflict of Interest**

None

## **B1. Purpose and Rationale for Proposed Research**

### B1.A. Describe the purpose (objectives) and rationale of the proposed project and include any hypothesis(es)/research questions to be investigated. This description must make every important point clear without the need to refer to other documents. For a non-clinical study summarize the proposed research using the headings: Purpose, Aim or Hypothesis, and Justification for the Study. For a clinical trial/medical device testing, summarize the research proposal using the following headings: purpose, hypothesis, justification, and objectives;

**Purpose:**

Electroencephalography (EEG) is a key tool in the diagnosis of epilepsy and sleep disorders. In current practice, EEG recordings are visually analyzed by specialist technicians and physicians. However, this is a slow process and dependent on the availability of these expert annotators. This limits EEG as a diagnostic medical tool in smaller communities. Even in larger centers, the time consuming nature of human EEG analysis can lead to backlogs and significant delays in diagnosis and treatment. Thus, there is a need for rapid, scalable, cost-efficient, accurate EEG interpretation that is not heavily dependent on the time of highly trained specialists. These limitations have motivated efforts to develop fully automated algorithms for the interpretation of human EEG signals. Unfortunately, to date, these approaches have had limited success, in part because many aspects of EEG interpretation are fundamentally image classification problems that while straightforward for trained humans, are difficult to fully automate.

The purpose of this research is to design a framework for hybrid machine and human computation to achieve accurate and scalable analysis of human clinical EEG recordings in both resource-rich and resource-poor health settings.

**Hypotheses:**

Our hypotheses are:

* Our hybrid approach, combining non-expert, expert and machine contributions, can produce comparative quality annotations but at a much lower cost.
* The crowd-generated annotations would help EEG specialists make more informed decisions about their classification
* Interfaces can be constructed in such a way that non-experts can feel a sense of engagement while performing EEG analysis tasks.

**Justification for the study**:

Approximately 250,000 Canadians, suffer from epilepsy [18]. Meanwhile, the prevalence of sleep apnea, the most common sleep disorder, has been estimated at 2-4% in adults [20]. EEG is key to the diagnosis of epilepsy, sleep disorders, and other neurological diseases. A large center such as the Toronto Western Hospital can perform over 12,500 EEGs annually. EEG and other tests for epilepsy are estimated to account for >21% of the direct costs of caring for epilepsy patients [18]. Visual interpretation of EEG by trained specialists has the drawbacks of being slow, expensive, and inefficient. Furthermore, these drawbacks make it difficult to provide EEG-based diagnostics in smaller communities in Canada and internationally.

There will be several benefits associated with building a low cost EEG analysis system:

1) Timeliness. The use of automated algorithms to prune EEG records will reduce the human input needed to review each record. Meanwhile, careful task decomposition may allow much of the required human input to be provided by available non-EEG trained health care workers. Specialists may be called upon to provide input only on ambiguous cases, thus allowing a large proportion of records to be screened in near real-time without specialist input.

2) Accuracy. By decreasing the hours of recording requiring human review, and allowing for parallel review of ambiguous features by multiple experts, the proposed system will minimize errors due to lapses in vigilance, and improve accuracy especially in ambiguous cases.

3) Cost Efficiency. Specialist labour is the main cost associated with EEGs. By decreasing the need for this, our system should decrease EEG costs.

4) Capacity. By decreasing the amount of specialist labour needed to interpret each EEG, a single specialist will be able to review a much larger number of EEGs. For smaller Canadian communities the overriding benefit with be the capacity to obtain EEG recordings locally without transferring patients or relying on outside experts, reducing costs, and allowing more rapid diagnosis and treatment.

**Objectives**:

The objectives of this research are:

1. Develop a general set of algorithms to decompose EEG analysis into micro-tasks, and integrate the responses of non-expert and expert human processors with automated algorithms to solve EEG-related clinical problems.

2. Develop a general framework to compare these algorithms against fully automated approaches and specialist analyses, and an iterative approach to improve these algorithms.

3. Apply the algorithms to the interpretation of clinical EEGs from Canadian hospitals.

4. Integrate these algorithms with EEG smartphone-based recording device developed by the Bhutan Epilepsy Project to allow recording and interpretation of EEGs in remote settings.

5. New understanding about the medical EEG analysis tasks themselves

The outcomes of this work will include two prototype systems freely available for general use by health care organizations – one for analyzing conventional EEG data from large Canadian hospitals, and one integrated with the smartphone EEG recording system developed by the Bhutan Epilepsy Project for use in rural and remote settings by health care professionals (e.g., nurses) without EEG training. For Canadian hospitals, the benefits will include improved robustness, speed, and efficiency of EEG interpretation, resulting in more timely and accurate diagnosis of epilepsy, sleep disorders and other neurological conditions, as well as more efficient utilization of scarce specialist resources. For more remote regions in Canada and internationally, the integrated smartphone-based version will provide access to accurate, scalable, cost- and time-efficient local EEG diagnosis, with minimal need for outside EEG specialists.

### B1.B. In LAY LANGUAGE, provide a one paragraph (approximately 100 words) summary of the project including purpose, the anticipated potential benefits, and basic procedures used.

Electroencephalography (EEG – the measurement of human brain activity using electrodes on the scalp) is a key tool in the diagnosis of epilepsy. It is also a key step in the diagnosis of sleep disorders. Right now, interpretation of EEGs is dependent on specialized neurologists. This limits access to EEG services in smaller communities. Even in large communities, the laborious nature of EEG interpretation and the heavy reliance on specialists imposes substantial costs on the health care system, and can delay diagnosis and treatment. In this research, we will design a series of experiments that involves understand how non-experts and experts classify EEG data, when their capabilities are augmented by automated algorithms and novel interfaces. Benefits will include improved timeliness and accuracy of epilepsy and sleep disorder diagnosis, accompanied by reduced costs. For more remote regions in Canada and elsewhere, our smartphone-integrated device will provide local access to accurate and cost-efficient EEG diagnosis avoiding the need to travel to larger centers.

## **C1. Methodology/Procedures**

### C1.A. Indicate all of the procedures that will be used. Append to the form 101 a copy of all materials to be used in this study.

Computer-administered task(s) or survey(s) Are they standardized? Some

Interviews (in person)

Interviews (by telephone)

Audio-recording

Video-recording

Secondary uses of information:

Experiment 0:

The expert video and audio recordings will be reviewed by researchers in professor Edith Law’s lab to help improve training procedures for non-expert sleep spindle annotators.

Experiment 1:

The anonymized spindle annotations will be shared with our partner institutions to aid in the development of

### C1.B. Provide a detailed, sequential description of the procedures to be used in this study. For studies involving multiple procedures or sessions, use of a flow chart is expected. Where applicable, this section also should give the research design (e.g., cross-over design, repeated measures design).

### Experiment 0: Expert Identification of Sleep Spindles in Adult EEG

### Experts in EEG analysis will be presented with anonymized EEG samples from the Sunnybrook health science center's neurology lab. The experts will be video taped while they attempt to identify sleep spindles in the EEG traces. Throughout this process, the experts will be encouraged to describe the thought process that they use to analyze EEG recordings in detail. We will ask the experts clarifying questions throughout the process as required. We will pay the experts fifty dollars per hour in remuneration, and the task will last one to two hours depending on scheduling and availability. The consent form, data release forms and task template are attached to this application.

### Experiment 1: Non-Expert Identification of Sleep Spindles

### Online participants will identify sleep spindles through an online tutorial, based on the instruction sheet created by Warby et al (2014). Next, the participants will be asked to identify sleep spindles in twenty short sections of EEG recordings from the DREAMS sleep spindle database. Each section will contain at least one sleep spindle. The participant will identify the spindles by clicking on them, and then pressing submit. After the participant submits each section, the answers will be presented complete with explanatory notes to help them improve throughout the task. Additionally, participants may choose to review the instructions at any time without penalty. The participant will be paid a base rate of two dollars for completion of the task, plus a bonus of up to five dollars based on how many spindles they managed to correctly identify. The bonus payment is intended to encourage the online participants to spend more time on the tutorial, and to be careful throughout the task. The tutorial, consent form and design mock-ups of the interface are attached to this application. The data collection system used in this task was built by student investigator Josh Bradshaw specifically for this study and is hosted on Canadian webservers. The data collection system has redundant systems in place to ensure participant anonymity.

### C1.C Will this study involve the administration/use of any drug, medical device, biologic, or natural health product?

### No

### C1.D Will you be using or processing any biological materials such as human blood, tissue, cells or bodily fluids in the proposed research?

### No

### C1.E Will you be using or processing any biological materials such as human blood, tissue, cells or bodily fluids in the proposed research?

### No

## C2. Participants Involved in the Study

### C2.A. Indicate who will be recruited as potential participants in this study.

Non UW Participants: Adults

Participants will be recruited from Amazon’s online service Mechanical Turk.

### C2.B. Describe the potential participants in this study including group affiliation, gender, age range and any other special characteristics. Describe distinct or common characteristics of the potential participants or a group (e.g., a group with a particular health condition) that are relevant to recruitment and/or procedures. Provide justification for exclusion based on culture, language, gender, race, ethnicity, age or disability. For example, if a gender or sub-group (i.e., pregnant and/or breastfeeding women) is to be excluded, provide a justification for the exclusion.

### Experiment 0: Experts in EEG analysis will be recruited from the Neurology labs of Sunnybrook health science center. If more experts are required, they will be recruited from other neurology labs affiliated with the University of Toronto.

### Experiment 1: Participants will be recruited and participate via Amazon's Mechanical Turk online marketplace. In order to participate in the marketplace (and thus in the study), the employees must be adults ages eighteen years or older capable of providing banking information for Amazon deposits. In addition, it can be assumed that all participants have at least rudimentary familiarity with computers and web tools. Finally, to ensure that the participants possess the relatively high level of literacy and implicit cultural understanding required to read and understand the instructions, the study will be limited to American participants. All American participants will be allowed to participate, regardless of their rating on Mechanical Turk.

### C2.C. How many participants are expected to be involved in this study?

Experiment 0: 1-5 expert participants.

Experiment 1: Up to 100 online participants.

## C3. Recruitment Process and Study Location

### C3.A. From what source(s) will the potential participants be recruited?

Online worker marketplaces; specifically Mechanical Turk

### C3.B. Identify who will recruit potential participants and describe the recruitment process.

### Experiment 0: Experts will be recruited by collaborator Dr. Andrew Lim from the Sunnybrook Health Sciences Center neurology lab.

### Experiment 1: Potential participants will be recruited via the Amazon Mechanical Turk marketplace. Tasks within each condition of the survey are exposed through a search interface on the marketplace. A task is shown with a title and description. Users of Mechanical Turk can sort tasks by posting date, remuneration amount, time allotted, keyword search, and otherwise. Only American users will be able to complete the tasks for this study. A sample of a task posting as it would be seen by a potential user is attached. Remuneration and study time are exposed in a separate field of the task posting.

### C3.C. Where will the study take place? If procedures involve direct contact with participants or occur in an off-campus setting, please ensure question D2 is completed.

## Experiment 0 will take place at Sunnybrook Health Sciences Center

## C4.Remuneration for Participants

### Will participants receive remuneration (financial, in-kind, or otherwise) for participation?

Experiment 0: Experts will be paid fifty dollars per hour in remuneration. This is less than or equivalent to their normal professional hourly rate.

Experiment 1: Participants will be paid a base rate of two dollars for annotating twenty windows of EEG recording. All participants will be paid equally regardless of performance.

## C5. Feedback to Participants

### Describe the plans for provision of study feedback and attach a copy of the feedback letter to be used.

## Experiment 0: The participants will be given the opportunity to provide study feedback verbally at the end of the task, and they will be provided with a form containing the contact information of all of the researchers involved so that they can contact us regarding results or any other concerns.

## Experiment 1: Feedback will collected using the last page of the web task. The feedback page is attached to this application.

## D. POTENTIAL BENEFITS FROM THE STUDY

### D1. Identify and describe any known or anticipated direct benefits to the participants from their involvement in the project. Often there are no direct benefits to participants. Experiencing an interview, for example, is not a benefit. Remuneration is not a benefit.

### There are no anticipated or known benefits to participants as a result of this study.

### D2. Identify and describe any known or anticipated benefits to the scientific community/society from the conduct of this study.

## Experiment 0: This task will contribute to building an anonymized dataset of gold standard sleep spindle annotations. This dataset will be extremely invaluable to researchers attempting to build automatic classifiers for sleep spindles.

## Experiment 1: This study will contribute to a better understanding of human-computer interaction, specifically improving our understanding of incentive mechanisms for motivating participation on crowdsourcing platforms. Additionally, it will contribute to a better understanding of how effective non-experts can be at EEG analysis when provided with only basic instructions.

## E. POTENTIAL RISKS TO PARTICIPANTS FROM PARTICIPATION IN THE STUDY

### E1. Identification of Known and Anticipated Risks to Participants

### For each procedure used in this study, provide a description of any known or anticipated risks/stressors to the participants. Consider physiological, psychological, emotional, social, economic risks/stressors.

### Experiment 0: No known or anticipated risks. Neurologists spend a great deal of their time analyzing EEG, as well as comparing and explaining their results with colleagues, so this task poses no risks or stressors.

### Experiment 1: No known or anticipated risks. We anticipate no risks to participants. Participants will be accessing the study via the same location and interface they use to access Mechanical Turk regularly, making it very unlikely that any risk greater than everyday life will be experienced. Tasks in the study are impersonal and require no difficult physical or emotional contribution.

### E2. Procedures/Safeguards for Protection of Participants

### Describe the procedures or safeguards in place to protect the physical and psychological health of the participants in light of the risks/stressors identified in E1.

Not applicable.

## F-Consent Process

### F1. What process will be used to inform the potential participants about the study details and to obtain their consent for participation?

## Experiment 0

## Information letter with written consent form

Experiment 1

Online participants will give their consent using an online form

### F2. If written consent cannot be obtained from the potential participants, provide a justification for this.

Not applicable

### F3. Does this study involve persons who cannot give their own consent (e.g. minors)?

No

## G-Anonymity

### G1. Provide a detailed explanation of the procedures to be used to ensure anonymity of participants and confidentiality of data both during the research and in the release of the findings.

### Experiment 0: The video recordings will only be reviewed by members of the CrowdEEG research team. The annotations produced by the experts will be completely anonymized using the CrowdEEG annotation interface, which will store no personal identifying information about the expert who completed the annotations.

### Experiment 1: In effect, worker tasks will take the form of an anonymous survey. Because we are using a third-party worker marketplace to recruit participants, we are given limited information regarding each participant, and will retain only an Amazon-generated ID number. This ID number will be further obfuscated via a one-way cryptographic encoding, which ensures that we can verify two separate tasks are completed by the same user but cannot reconstruct that user's Amazon ID number from the ID we store. This choice has been made in light of the recent discovery that Amazon ID numbers can be used in combination with other Amazon records to discover participant names and addresses. Other data we collect is exclusively related to study tasks and does not provide any information about the participant.

### G2. Describe the procedures for securing written records, questionnaires, video/audio tapes and electronic data, etc.

### Experiment 0: All data collected will be electronic. The video recordings of the experts will be stored in an encrypted format in a locked lab in the David R. Cheriton School of Computer science.

### Experiment 1: The data will be stored with only password protected computers. All data collected will be electronic. The data will not be linked with any other data set. While the data will not leave the institution, participant responses are first sent through Amazon's Mechanical Turk service and servers before it will be received by researchers, and Amazon has access to de-identified information about each participant recruited through its service.

### However, it is stated in the Mechanical Turk terms of service (section 3b) that all intellectual property rights regarding the participants' responses are ceded to the requester (in this case UW researchers). Thus, while Amazon has access to the information and can link it to participants, it is outside of their legal rights to do so without permission from the researchers.

### Anonymized EEG and annotation data will be stored using Dropbox Pro, a service which provides both password-protection to access data as well as data encryption. According to the Dropbox terms-of-service, the data hosted on Dropbox is owned by the user. Dropbox's encryption model makes it impossible for them to access the data.

### Some of the anonymized EEG and annotation data will be shared with our collaborating institutions. For each institution a data release agreement will be established. The relevant data release agreements for the University of Ottawa and Toronto Academic Health Sciences Network are attached.

### G3. Indicate how long the data will be securely stored, the storage location, and the method to be used for final disposition of the data?

Electronic Data

Erasing of electronic data after 8 year(s).

Location: Encrypted file storage on a secure PC in a university laboratory with restricted physical access.

### G3.A. Audio/Video Recordings and Electronic Data

All: [Data will be retained indefinitely in a secure location.]

### G3.B Specify storage location

HCI Lab, DC3591 and/or office of Edith Law in DC3138

### G4. Are there conditions under which anonymity of participants or confidentiality of data cannot be guaranteed.

Yes. All data must go through Amazon's services and will be stored on their servers in addition to our own store indefinitely. As stated in section G2, all ownership of the generated data is property of the researchers through Amazon's terms of service. However, we do not have complete control over how the records will be stored and used and can thus provide no complete guarantees.

## H-Partial Disclosure and Deception

### H1. Will this study involve the use of partial disclosure or deception? Partial disclosure involves withholding or omitting information about the specific purpose or objectives of the research study or other aspects of the research. Deception occurs when an investigator gives false information or intentionally misleads participants about one or more aspects of the research study.

No

## APPENDICES

Attached:

Experiment 0:

Information Letter and Consent Forms

Information/Cover Letters

Materials

Feedback letter