香 港 大 學
THE UNIVERSITY OF HONG KONG

Laidlaw Scholars Programme 2020-21

Research Proposal

Guidelines on how to prepare a research proposal:

- Identify a project of your choice and discuss the topic with your academic supervisor at HKU.
- Prepare a research proposal including the following details:

1. Title of research project:

Instantaneously Monitoring Cognitive Load with Electroencephalography (EEG)

2. Research question:

What is the accuracy of monitoring cognitive load with EEG? And how to improve it?

3. Summary of the work to be undertaken by the applicant (e.g., background information, location, history, context, limitation, methodology, and timeline)

Research Gap

Although brain-computer interface has been developed for many decades, the feasibility of using non-invasive technology to measure neural signals and assess mental states have been questionable. The major obstacle lies in the low signal-to-ratio of non-invasively measured EEG data. Moreover, most of the previous research relied on simple features (e.g. narrow band power) to assess cognitive states that are usually complex. We proposed that the accuracy can be improved by exploiting multi-dimensional features from the EEG data.

Importance and Impact

In recent years, the research on neural oscillations has been picking up speed. Progress has been made on both theoretical and technological/methodological grounds, these breakthroughs have further implications on different practical fields, such as education and human-computer interaction.

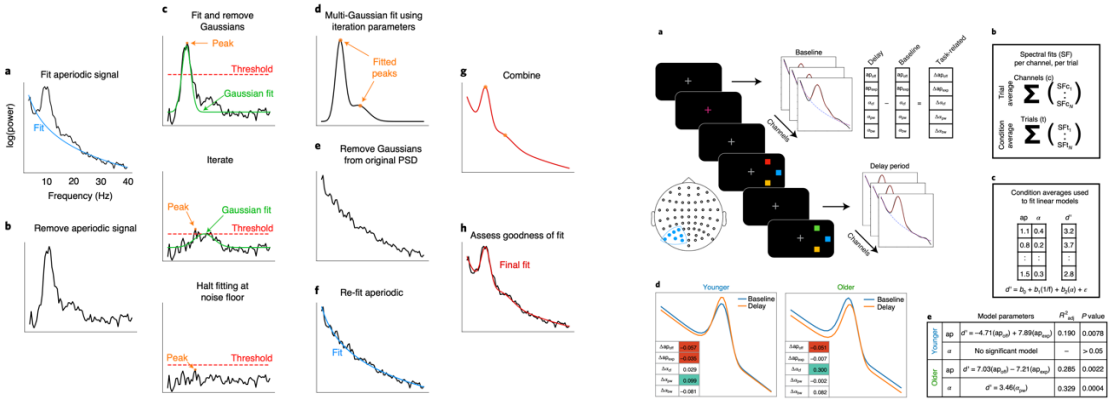
The research on cognitive load theory (CLT) concerns cognitive load's effects on one's learning efficacy. CLT research attracts both neuroscientists and educational researchers as it could help educators to devise effective and efficient teaching and learning strategies. Traditionally, the evaluation of instructional design (ID) primarily based on formative assessment, which is arguably a less accurate, time-consuming measurement of learning effectiveness. The measurement of cognitive load, on the other hand, provides a more reliable and sensitive parameter of understanding learners' perceived mental effort. In turn, CLT research would greatly improve the quality of ID that could inform education policy.

Machines have become crucial in daily human activities, CLT studies could potentially contribute to the research of human-computer interaction, i.e. ergonomics, user experience and user interface design. For example, the development of neurophysiological measurements can help analyse

drivers/pilots' attention and distraction levels by exploring the limitations of human working memory.

Feasibility

With the advancement in neuroimaging technology, measuring cognitive load — through measuring neural oscillations — became possible. Studies have explored the correlation between neural oscillations, e.g. event-related desynchronisation/synchronisation (ERD/ERS) of alpha and theta bands, and different levels of task difficulty. Furthermore, new algorithms also enable the extraction of both periodic and the 1/f-like aperiodic neural components, which are previously ignored. With better parameterisation, it is expected that more nuanced cognitive phenomena could be examined through electrophysiological data, such as cognitive load.



Algorithm schematic on real data. (Left)

Event-related spectral parameterization of working memory in aging. (Right)

The development of mobile EEG further aids the CLT research in an educational context, as data collection could be done in actual learning scenarios instead of laboratory settings. This makes the neurophysiological findings more translatable to educational applications.

Timeline

March-April: Training on EEG data collection, further background research and literature review
May-June: Task programming and participant recruitment
July: Data collection
August: Data analysis and writing

Budget/Expenses

Laboratory related expenses:

- Compensations for experiment participants
- EEG consumables
    - EEG gel
    - Syringe
    - Towels

References

Antonenko, P., Paas, F., Grabner, R., & Van Gog, T. (2010). Using electroencephalography to measure cognitive load. *Educational Psychology Review*, *22*(4), 425-438.

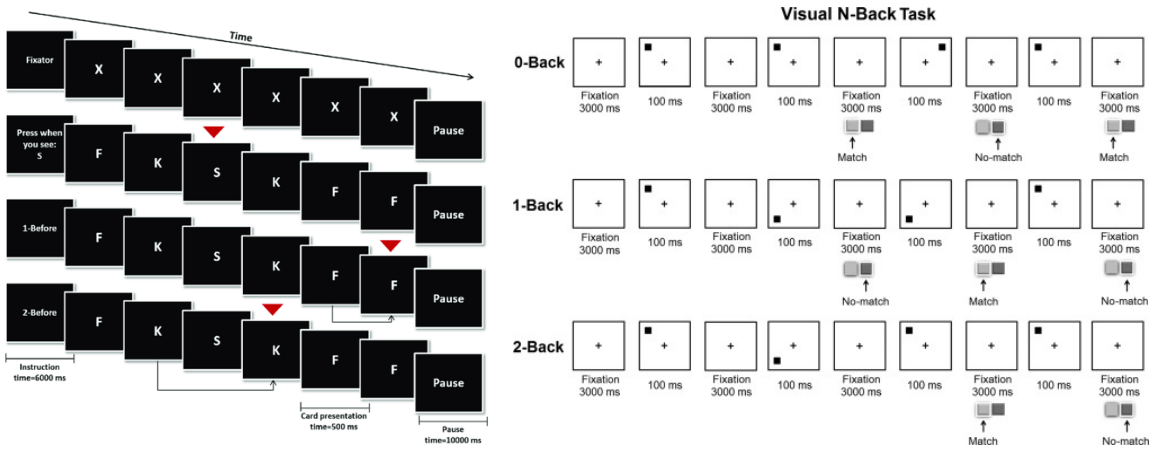
Donoghue, T., Haller, M., Peterson, E. J., Varma, P., Sebastian, P., Gao, R., ... & Voytek, B. (2020). Parameterizing neural power spectra into periodic and aperiodic components. *Nature neuroscience*, *23*(12), 1655-1665.

4. Details of supervision arrangements (e.g., how are you going to conduct your research? Will focused group/survey be conducted? How often will you meet your supervisor? Is laboratory work required? Etc.)

Notes:
If you wish to pursue a research opportunity at University of Leeds or University of St. Andrews, please name three professors with whom you would like to conduct your research. Once you are shortlisted for the award, the Horizons Office will match your proposal to a potential host supervisor according to your preferences.

Experiment Design

This experimental, quantitative research is to be done with electroencephalography (EEG). Original data will be collected, with experiment participants to be recruited on a convenience and voluntary response sampling basis. The experiment design includes two major tasks (coded with and administered through PsychoPy): a working memory task (n-back task) and an arithmetic task (counting task). Participants are expected to complete all the aforementioned tasks while wearing an EEG cap, which records the participant's electrical brain activities. EEG data will be collected in both laboratory and non-laboratory (with a mobile EEG setup) settings. Further spectrum analysis will be carried out to examine neurophysiological measurements of cognitive load.



N-back task.

Resources

Experiment resources, training and particulars (e.g. EEG equipment, ethics approvals) are supported, courtesy of Dr. Ouyang Guang and his team (Reading and Learning Laboratory, Faculty of Education). Dr. Ouyang and I will have weekly meet-ups to guide my research.

Name of applicant: _____ Nicholas Tsz Lok WONG _____

Signature of applicant: _____ Date: _____13/2/2021_____