AFRL-AFOSR-UK-TR-2019-0036

NeuroFalcon - Neurotechnology for Fast Assessment of Loss-of-CONsciousness

Oren Shriki
BEN GURION UNIVERSITY OF THE NEGEV
1 BEN-GURION BLVD.
BEER SHEVA, 84105
IL

07/25/2019
Final Report

DISTRIBUTION A: Distribution approved for public release.

Air Force Research Laboratory
Air Force Office of Scientific Research
European Office of Aerospace Research and Development
Unit 4515 Box 14, APO AE 09421

REPORT DOCUMENTATION PAGE

Form Approved
OMB No. 0704-0188

1. REPORT DATE *(DD-MM-YYYY)*
25-07-2019

2. REPORT TYPE
Final

3. DATES COVERED *(From - To)*
15 Nov 2015 to 14 Nov 2017

4. TITLE AND SUBTITLE
NeuroFalcon Neurotechnology for Fast Assessment of Loss of CONsciousness

5a. CONTRACT NUMBER

5b. GRANT NUMBER
FA9550-16-1-0035

5c. PROGRAM ELEMENT NUMBER
61102F

6. AUTHOR(S)
Oren Shriki

5d. PROJECT NUMBER

5e. TASK NUMBER

5f. WORK UNIT NUMBER

7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES)
BEN GURION UNIVERSITY OF THE NEGEV
1 BEN-GURION BLVD.
BEER SHEVA, 84105 IL

8. PERFORMING ORGANIZATION REPORT NUMBER

9. SPONSORING/MONITORING AGENCY NAME(S) AND ADDRESS(ES)
EOARD
Unit 4515
APO AE 09421-4515

10. SPONSOR/MONITOR'S ACRONYM(S)
AFRL/AFOSR IOE

11. SPONSOR/MONITOR'S REPORT NUMBER(S)
AFRL-AFOSR-UK-TR-2019-0036

12. DISTRIBUTION/AVAILABILITY STATEMENT
A DISTRIBUTION UNLIMITED: PB Public Release

13. SUPPLEMENTARY NOTES

14. ABSTRACT
The aim of the effort was to find neural markers for G LOC detection using EEGs. Data was collected fromnine subjects at Brooke's AFB. Of these, three subjects experienced G LOC and one subject experienced A LOC. The examination of EEG data from subjects who experienced G LOC indicated increased activity in the delta band 3 sec prior to the G LOC event in all electrodes. Due to lack of IRB approval, the study was terminated at the end of the first year.

15. SUBJECT TERMS
EEG, cognition, G LOC, machine learning algorithm

16. SECURITY CLASSIFICATION OF: a. REPORT	b. ABSTRACT	c. THIS PAGE	17. LIMITATION OF ABSTRACT	18. NUMBER OF PAGES	19a. NAME OF RESPONSIBLE PERSON
Unclassified	Unclassified	Unclassified	SAR		IYER, NANDINI
					19b. TELEPHONE NUMBER *(Include area code)* 44 1895 616161

"NeuroFalcon" – Neurotechnology for Fast Assessment of Loss-of-CONsciousness

Final Scientific Report

PI: Dr. Oren Shriki

Dept. of Cognitive and Brain Sciences, Ben-Gurion University of the Negev, Israel

This report is not very different from the one submitted during Nov. 2016, at the end of the first year. Due to obstacles with the IRB approval (related to the FWA), the project did not receive budget for years 2 and 3.

We developed codes for applying two metrics of signal complexity, which are expected to be highly informative about the state of consciousness[1].:

1. MSE – Multi-Scale Entropy[2,3]
2. LZC – Lempl-Ziv Complexity[1,4-6]

However, to test the utility of these metrics for G-LOC detection and apply statistical tests, we first need to obtain several datasets of EEG during G-LOC. We will be happy to collaborate on existing G-LOC EEG data from past experiments that were performed at the AFRL (this could be done under the recent data-exchange agreement between the USAF and the IAF).

We collected EEG data from 9 subjects at Brooks City Base. Three subject experienced G-LOC and one subject experienced A-LOC. Below we show results from one subject, who experienced G-LOC after ~8 seconds at 9G. Figure 1 depicts the original EEG (blue) and a low-pass filtered version (red) in 16 electrodes. Increased activity in the delta band is detected around 3 seconds prior to the G-LOC event in almost all electrodes.

To obtain a better resolution for the instantaneous changes in delta waves, we performed a wavelet-based time-frequency analysis (Fig. 2). This analysis better highlights the relevant spectral changes, as evident in electrodes C4 and PO7. The analysis also suggests that these electrodes may be more informative about G-LOC than others, which may prove useful for future applications in pilot helmets.

One limitation of the aquired data is related to the synchronization between the video and the EEG signal. Precise synchronization was hard to achieve, limiting the interpretation of other datasets. An important lesson was to take care for a more accurate synchronization. Indeed, using internal budgets, we recently traveled with IAF cadets to a centrifuge facility in Germany and using a dedicated camera we manged to collect synchronized video-EEG.

My lab still continues to work on this project and we are now in the process of trying to obtain other sources of funding. We also know that BGU is in the process of obtaining FWA, which could allow the continuation of this project under Federal funding in the future.

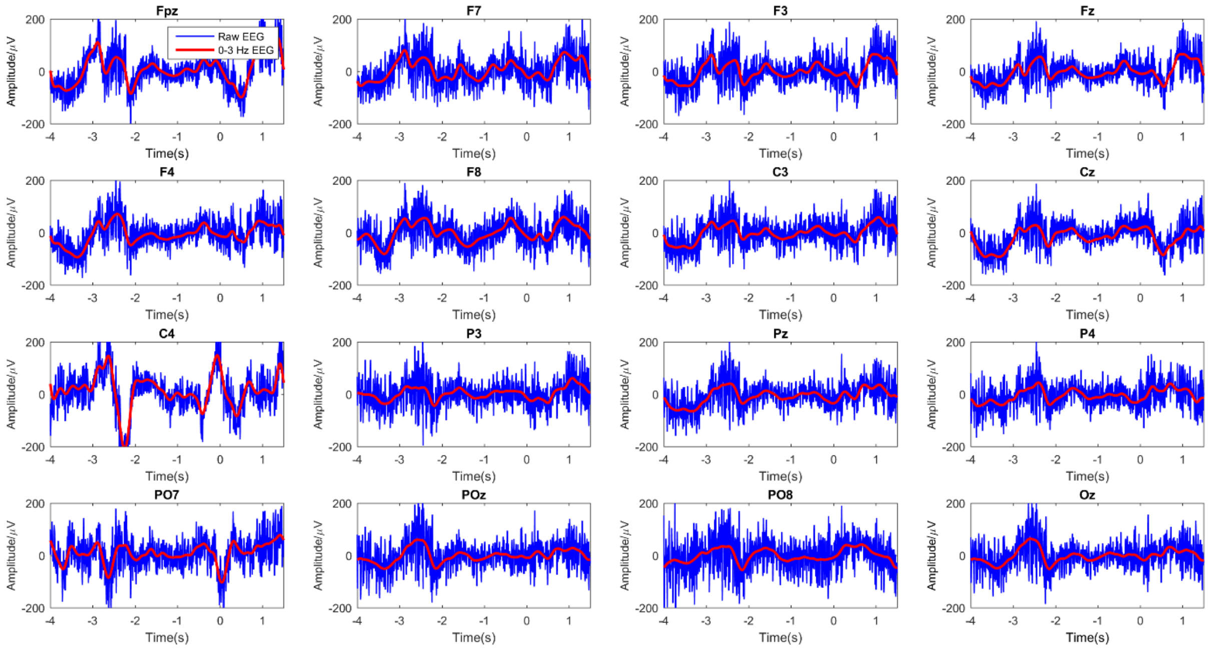

Figure 1: EEG signal prior to G-LOC. Blue: Raw EEG signal, Red: EEG signal after low-pass filtering at 3 Hz in order to highlight the low frequency activity. The 0 time-point represents the G-LOC event.

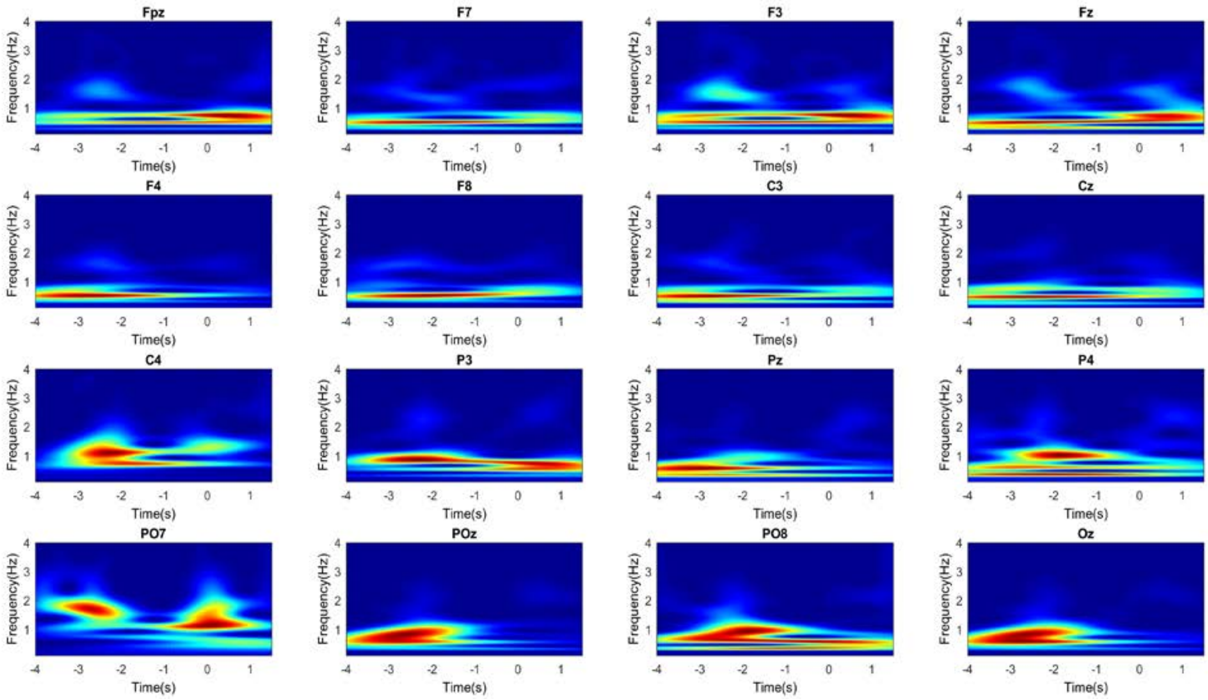

Figure 2: Wavelet time-frequency analysis for highlighting changes in the low frequency components prior to G-LOC. Increased activity in the range of 1-2 Hz is detected 3 seconds prior to the G-LOC event.

1 Casali, A. G., Gosseries, O., Rosanova, M., Boly, M., Sarasso, S., Casali, K. R., Casarotto, S., Bruno, M.-A., Laureys, S. & Tononi, G. A theoretically based index of consciousness independent of sensory processing and behavior. *Science translational medicine* **5**, 198ra105-198ra105 (2013).

2 Costa, M., Goldberger, A. L. & Peng, C.-K. Multiscale entropy analysis of complex physiologic time series. *Physical review letters* **89**, 068102 (2002).

3 Kang, X., Jia, X., Geocadin, R. G., Thakor, N. V. & Maybhate, A. Multiscale entropy analysis of EEG for assessment of post-cardiac arrest neurological recovery under hypothermia in rats. *IEEE Trans. Biomed. Eng.* **56**, 1023-1031 (2009).

4 Lempel, A. & Ziv, J. On the complexity of finite sequences. *IEEE Transactions on information theory* **22**, 75-81 (1976).

5 Abásolo, D., Hornero, R., Gómez, C., García, M. & López, M. Analysis of EEG background activity in Alzheimer's disease patients with Lempel–Ziv complexity and central tendency measure. *Med. Eng. Phys.* **28**, 315-322 (2006).

6 Aboy, M., Hornero, R., Abásolo, D. & Álvarez, D. Interpretation of the Lempel-Ziv complexity measure in the context of biomedical signal analysis. *IEEE Trans. Biomed. Eng.* **53**, 2282-2288 (2006).