**July 13th, 2018**

**Proposal for a review paper on MOBI by our combined CNL team:**

**Working Title:** Time to move: the promise of mobile brain-body imaging (MOBI) approaches in health and disease.

**Plan of attack:** We will divide the writing into 400-500 word blocks centered on specific sub-sections/themes and assign one writer to each of these themes. I have made a preliminary attempt at a division of labour below, but this is meant as a framework to be reacted to and not as a definitive plan.

**Proposed structure and thematic divisions:**

1. General Introduction to the paper and MOBI background ***Foxe and Molholm***
2. “The cutting edge” from MOBI2018 ***David Richardson***
3. Tracking gaze and saccadic ballistics during natural motion ***Ed Freedman***
4. Applications of MOBI in Aging to assess both fall risk and in AD prediction ***Brenda Malcolm***
5. Application of MOBI technologies in multiple disease models ***Filip De Sanctis***
6. What can we learn from the deeper history of NHP work ***Kevin Mazurek***
7. New computational approaches to handle/model/integrate massive data streams ***John Butler***
8. Future Directions and aspirations for the technique ***The Whole Team***

**Notes/Questions:** Please take a look and let me know if there are sections missing or whether revisions to proposed sections should be made. For example, should there be a specific section on oscillatory mechanisms? Also, please let me know if you are “in” or “out”? Are there other people who we should approach to contribute?

**Proposed Timetable:**

1. 400-500 word first rough draft due **September 3rd, 2018**
2. De Sanctis/Foxe/Molholm will integrate sections **September 17th, 2018**
3. The whole team will flesh out sections and respond to queries **September 28th, 2018**
4. De Sanctis/Foxe/Molholm will perform 2nd integration and polish **October 8th, 2018**
5. Final Edits by The Whole team and submission **October 22nd, 2018**

New computational approaches to handle/model/integrate massive data streams

The recent progress in mobile brain imaging has been facilitated by an improvement in wet and dry electrodes (FIND CITE). Event related studies have been very informative about the processing of secondary task while walking. Time frequency and time warping analysis has been able used to investigate power changes in frequency bands during the gait cycle. These approaches have been developed the field

In the controlled virtual reality environment there is a plethora of ways of recording different aspects of movement such as body tracking, object tracking, footfalls and interactions, auditory, visual, stimuli, responses, eye tracking.

This has been due to an improvement of the signal to noise of active electrodes. And the improvement of dry electrodes (cite Debener ear, Makeig mate, MUSE).

But electrodes alone are not the reason, there have also be ingeniuous ways of recording the movement data such as force sensors, to the introduction of lab streaming layer to combine and time stamp information from different sources such as body tracking data and video data (cite).

One way to address this is focus on one or two outcomes of mobile brain interactions such as gait cycle nad

Have good electrodes is not enough, the combination of data is vital and more

When one wishes to investigate neurological markers of effects that are at the millisecond level.

Which has allowed for the investigation of evoked response of a dual task stimuli or the investation of a the time-frequency of a gait cycle but this is the tip of the analysis iceberg for mobile brain imaging.

The more lightweight

While in the real world it is even more as there is the whole world to ineract and record

To truly leverage the richness of this data new analysis aproahces need to be considered

From different sources in vr the combination of tracking data, biosensors

Synchronization of timing is of upmost importance for EEG as a slippage in time can result in the negation of effects

In the real world this is even hard as the use of portable equipment communicating over Bluetooth of other methods which are not prone

Filtering

An important development in the processing of signals the leading example of this is ICA (Makeig, Nolan) which enables the separation of signals from different sources such as mucles and cortical sources (Gramman). This further allows for

On lower montage systems CSD is not

Electrophysiological experiments have been primarily dominated by evoked potentials which requires the repetition of a class of stimuli many times with or without a response. This has been very fruitful in understanding the neurophysiological underpinnings of many different things but MoBi imaging needs to move beyond it, pun intended. Walking is inherently a multisensory (Campos) combing together visual, auditory, somatosensory, vestibular and proprioceptive information. Two possible approaches to investigating the continuous signal that have yield promising results in other aspects could be useful in MoBI. The first approach use the spread spectral analysis has been used to extract the temporal response function from continuously varying visual information ([Lalor *et al.*, 2006](#_ENREF_3)), speech ([Lalor & Foxe, 2010](#_ENREF_2)) and multisensory ([Crosse *et al.*, 2015](#_ENREF_1)). It has also been shown to be able to parse the temporal response function for multiple input signals ([O'Sullivan *et al.*, 2016](#_ENREF_4)). This would be extended to a rich environment to identify what aspects of the environment the participant is attending to waxes and wanes from different sensory information such as the sound of the speech, the sunlight in the tree, the proprioceptive input from walking. The second approach was the use of ICA and LORETA to parsing the course of a continuous video In a similar vein but using a different approach ([Whittingstall *et al.*, 2010](#_ENREF_5)) used ……….. The two approaches together would be able to both localize and analyse the temporal response of different continuous signals.

Machine learning methods such as artificial neural networks or other methods might also be useful to analyse this large data. Real time interaction using neural networks to address the complexity of the data and to ensure it is assessed in the needed time has been used for epilisepes could be adapted for the MOBI.

This method has been used to identify spikes

1. Technology
   1. Wet electrodes
   2. Dry electrodes
2. Combination of Signals
   1. Lab streaming layer
   2. Force sensorys
3. Analysis
   1. ICA
   2. CSD
   3. Source Analysis
   4. Time frequency analysis
4. Stimuli
   1. visual,
   2. vestibular,
   3. auditory,
   4. somatosensory,
   5. proprioception
   6. smell
5. Analysis Methods
   1. GLM
   2. TRF
   3. Machine Learning
   4. Multiple input multiple output

Crosse, M.J., Butler, J.S. & Lalor, E.C. (2015) Congruent Visual Speech Enhances Cortical Entrainment to Continuous Auditory Speech in Noise-Free Conditions. *The Journal of neuroscience : the official journal of the Society for Neuroscience*, **35**, 14195-14204.

Lalor, E.C. & Foxe, J.J. (2010) Neural responses to uninterrupted natural speech can be extracted with precise temporal resolution. *The European journal of neuroscience*, **31**, 189-193.

Lalor, E.C., Pearlmutter, B.A., Reilly, R.B., McDarby, G. & Foxe, J.J. (2006) The VESPA: a method for the rapid estimation of a visual evoked potential. *Neuroimage*, **32**, 1549-1561.

O'Sullivan, A.E., Crosse, M.J., Di Liberto, G.M. & Lalor, E.C. (2016) Visual Cortical Entrainment to Motion and Categorical Speech Features during Silent Lipreading. *Frontiers in human neuroscience*, **10**, 679.