NSF GROW Application

Name of Graduate Research Fellow: Teon Brooks

Fellow ID: 2011120975

Project Title: Decoding Semantics: Mending the Gap on Eye Movements and ERP research in semantic processing

Proposed international research collaborator(s): Telecom ParisTech / CNRS LTCI, INSERM-CEA Cognitive Neuroimaging Unit

Primary collaborator: Alexandre Gramfort

Additional collaborator: Christophe Pallier

Proposed Dates and Duration of Visit: July 15th, 2014 – December 15th, 2014 (Total: 5 months)

Project Summary

There is a gap in reading research on the linking hypothesis between the behavioral effects shown in eye-movement research and the physiological effects seen in the EEG and MEG literature. These two techniques work in different empirical domains, eye-movements and neurophysiological brain responses, in hopes of describing cognitive processes underlying word recognition. However, the neural timing seems to lag behavioral results.

M/EEG reading research heavily relies on rapid serial visual presentation (RSVP) for reading because there is no viable technique for addressing eye movement artifacts introduced by reading naturally. This unnatural way of reading may have added processing cost associated with it (Rayner, 1998). Given the contrast in experimental tasks between behavioral and ERP/ERF studies, it is not possible to distinguish whether differences in timing estimates for processing are a symptom of the imposed processing limits or if these measures could be reflecting different stages of lexical processing. My project focuses on addressing this issue by implementing a method for simultaneously recording eye-movements and neurophysiological responses in a naturalistic reading paradigm.

With my background in lexical processing using eye-tracking methodology, I have learned neurophysiological techniques to address the question of how reading works in the brain. I met Dr. Alexandre Gramfort of Telecom ParisTech / CNRS LTCI while collaborating on an open-source software used for M/EEG data analysis (MNE-Python). Dr. Gramfort has extensive expertise in modeling neurophysiology data and he will serve as my primary collaborator while I visit Paris. I plan to do research in Paris for five months, which will give us adequate time to develop and implement this new technique.

This approach requires modeling dipoles inferred from eye-movements, building a forward model of these dipole from their brain source to their M/EEG signal realization, and then regressing it from the neurophysiological response. This will allow for a direct comparison of these two powerful techniques. This will be beneficial to both eye-movement research and neurophysiology research of language by providing a way to align their time-courses with one another.

Project Description: Decoding Semantics: Mending the Gap on Eye Movements and ERP research in semantic processing

Introduction

My project aim is to innovate new techniques to decode semantic processing in on-line language comprehension in a naturalistic reading paradigm. Chiefly, I would like to tackle a problem plaguing the field: what is the linking hypothesis between the behavioral effects shown in eye-movement research and the physiological effects seen in the EEG and MEG literature. Under the guidance of Dr. Alexandre Gramfort with his expertise in M/EEG signal processing and statistical machine learning, and exploiting my background in language research, we propose a realistic, implementable approach expanding on some of the work we've done together.

Although there are several decades of studies on reading, we still don't know what is happening neurally when we read naturally. Language research has made significant progress in understanding visual word recognition by focusing on two powerful techniques: eye-tracking and neurophysiology recording. These two techniques work in different empirical domains, eye-movements and neurophysiological brain responses, in hopes of describing cognitive processes underlying word recognition. The eye-movement literature has provided detailed models for the behaviors evoked when reading: skipping, regressions, fixation durations, but it hasn't been able to suggest a solid linking hypothesis between the these behaviors and their cognitive underpinnings. There is still contention over the linking assumption of whether we don't move the eyes until we have finished processing (E-Z Reading serial model: Reichle et al., 1998) or that we have distributed parallel processing (SWIFT parallel model: Engbert et al., 2002), allowing movement prior to completion of lexical access. Neurophysiology models have provided insight to regions that may be implicated in lexical access (Lau et al., 2008) but the neural timing seems to lag behavioral results.

Neurophysiological research in reading overwhelmingly restricts the possible eye movements of participants to reduce the induced large motor artifacts. Due to these potential artifacts in the data, neurophysiological experiments generally employ a non-natural task of rapid serial visual presentation (RSVP), which can impose processing constraints (Rayner, 1998). These constraints include a processing load limit that is not present in normal reading, a lack of parafoveal preview benefit that aids in reading, and the inability to regress back to previous word when additional processing and repair are needed (Rayner, 1998). Given the contrast in experimental tasks between behavioral and ERP studies, it is not possible to distinguish whether differences in timing estimates for processing are a symptom of the imposed processing limits or if these measures could be reflecting different stages of lexical processing. There have only been a few studies that have tried to couple the two techniques (Kretzschmar et al., 2009; Kliegl et al., 2012), but currently, there is no strong evidence showing that the variance in eye-movements we see in reading corresponds to the variance in ERPs we see in RSVP reading tasks. Combining these two methodologies with an appropriate linking hypothesis could help tie the eye-movement data to the underlying processes that lead to them.

Sereno & Rayner (2003) points out how these two complementary methodologies contend for the title of "holy grail" in visual word recognition as they aim to solve the problems of

when, where, and why recognition occurs. Developing a method to marry eye-movement research with neurophysiological recording would be a considerable advancement to field by providing the framework to addressing the apparent timing discrepancies between the methods while clearly linking the behavior to neural computations.

Collaboration

My previous research Brooks & Gordon (prep) focuses on lexical processing in sentence reading using eye-tracking methodology. Here, I looked at the role of the internal structure of words in reading by varying the level of semantic relatedness, a metric describing how similar in meaning two words are, of a word's parts to the word's overall meaning (e.g. CAR in carwash vs. HOG in hogwash), chiefly using compound words. This work has been expanded to a different experimental modality (MEG) to closely track the different stages in lexical processing associated with compound words, most critically stages of morphological processing (decomposition and re-composition). My primary collaborator will be Dr. Alexandre Gramfort of Telecom ParisTech / CNRS LTCI. While learning the techniques of MEG, I first met Dr. Gramfort when I began collaborating on the software package responsible for the data analysis (MNE-Python). The MNE-Python Project, part of the MNE Gramfort et al. (2013b), is an open-source collaboration for MEG and EEG data analysis (www.martinos.org/mne) and we have an established working relationship over the past year leading to a joint publication Gramfort et al. (2013a). We have planned to expand my work on lexical processing on compound words to implement new machine learning techniques to decode the semantic processing when recognizing words (Aim 1). Using an existing data set, we will quickly begin our collaboration by building a classifier to identify brain signals sensitive to the variation in the semantic relatedness within a word. This will culminate my body of research on compound words, providing linked behavioral and physiological evidence supporting a model of the role of word structure in comprehension. For Aim 1, we plan to use and further expand the advanced decoding methods offered by the MNE software (http://martinos.org/mne/dev/auto_examples/index.html#decoding-mvpa).

To strengthen the validity across these complementary methodologies in language comprehension, we plan to devise a method for simultaneously recording eye-movements and neurophysiological responses (Aim 2). Promising an additional benefit for training, Dr. Gramfort has an already established collaborative relationship with Dr. Christophe Pallier of Neurospin, who has expertise in neuroimaging of language and would be an additional collaborator while in France. **My stay in Paris** would be from July 15th 2014 to December 15th 2014. This would provide enough time to develop the methods needed to accomplish these aims and use this collaboration as the foundation for my dissertation work. My familiarity with eye-movements along with Dr. Gramfort's extensive expertise in modeling neurophysiology data make our collaboration very valuable and viable. Here, we seek to mend the gap between the eye-movement and neurophysiology literature by developing a method for combining eye-movement methodologies with neurophysiological recordings.

Our approach for resolving eye movements while reading will work based on the following. 1. we model ocular globes with electrical dipoles whose orientations can be inferred from the eye tracking data. 2. we compute forward models of these dipole using realistic head volume conductor models. 3. we use the computed predicted MEG signals as regressors to inform

the estimation of eye movement and regress out the noise. We plan to validate this model using a robust Cloze-probability language task where we will seek to identify correspondent behavioral effects concurrent with neurophysiological measures.

Facilities in France

Telecom ParisTech / CNRS LTCI, INSERM-CEA Cognitive Neuroimaging Unit

Eye-movement Data Acquisition

Eye-movement data will be collected using a SR-Research Eyelink 1000. This high-speed infrared camera has temporal sampling of 1000Hz, with a spatial resolution of 0.01 degrees. The eye-tracker is mounted inside the MEG chamber.

MEG Data Acquisition

MEG data will be collected using a research-only 306-channel TRIUX MEG system (Elekta Neuromag).

Motivation

Eye-tracking while reading focuses on fixation durations as the primary dependent measures. These fixations are typically clustered into different stages of processing. Clifton et al. (2007) proposes that single-fixation, first-fixation and gaze duration index word identification whereas regression-path duration may index text integration. Rayner (1998) discusses how these reading time measures may underlie discrete cognitive processes. Using the findings from Meyer & Schvaneveldt (1971)'s semantic priming paradigm, Ehrlich & Rayner (1981) was able to demonstrate that eye-fixation durations were inversely proportional to the Cloze probability of the sentence. Reichle et al. (1998) models these eye-movements in a computational model linking fixations and saccades to recognition and incremental integration. Although these models make clear predictions for eye-movement behavior, they do not provide a clear link with the correspondent cognitive processes.

Neurophysiological brain responses have been used to index stages of word recognition with much more focus on a particular event-related potential, the N400. Lau et al. (2008) proposes that N400 relates to lexical access and that there is a semantic network of brain regions involved in recognizing and retrieving the meaning of a word. Earlier findings from Kutas & Hillyard (1984) show that semantic violation or word expectancy can affect the N400. They found that N400 amplitudes were inversely proportional to the Cloze probability of the sentence. The time-course of lexical access as measured by the N400 neurophysiological response seem to trail that indicated by eye-movement responses by 100-150ms. Both eye-tracking and neurophysiology show convergent effects of Cloze probability on lexical access but these temporally disjointed results do not speak to a clear time-course model.

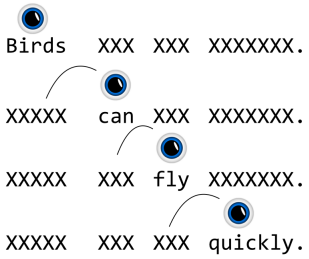

Figure 1: Gaze-Contingent, Moving Window Paradigm

Design

Four-word simple sentences will be constructed to minimally contrast Cloze probability and semantic relatedness. Each sentence will be constructed with the first word being an animate entity and the third word describing a quality of this entity. We will use Latent Semantic Analysis Landauer et al. (1998) to calculate high and low semantic relationships between these words for our semantic relatedness contrast.

High Semantic Relatedness

(1) Birds can fly quickly.

(2) Birds can tweet quickly.

Low Semantic Relatedness

(3) Birds can fall quickly.

(4) Birds can die quickly.

We will then calculate high and low probable continuations from the two words to the verb in each sentence, which is the target word for the ERP analysis. 3-gram frequency information from the Corpus of Contemporary American English Davies (008) would serve to quantify the expectation for the verb, given the subject, yielding our Cloze probability contrast at the verb (the final word in each sentence will be equi-probable given the first 3 words across the contrast (1-4)). In the example, (1) presents a much more expected continuation from the first two words than (2), and (3) is more expected than (4).

Task

Participants are asked to read a series of sentence, each of which is followed by a comprehension question. A gaze-contingent, moving window paradigm will be implemented to control for visual input (Just et al., 1982).

Method

We will use the fixation measures mentioned above from Clifton et al. (2007) to define time regions of interest in eye-tracking data. To interpret our MEG data, we will use our approach to resolving eye movements while reading. This will involve modeling dipoles generated the eye-movements inferring its orientations from the eye-tracking data, computing a forward model of how these dipoles would manifest as an MEG signal, then regressing out the movements from the forward model's estimation. The MEG response surrounding the saccade to and from the verb is the crucial dependent neurophysiological measure.

Predictions

We will evaluate the response to reading the third word in these sentences. Given the findings in prior research, we expect to replicate findings of gaze duration reduction for increasing Cloze-probability and for increasing semantic relatedness independently. Of interest for models of prediction in reading is whether semantic relatedness significantly modulates gaze duration in situations of high and low prediction, or whether semantic relatedness is only relevant in cases of high prediction.

To link the eye-tracking and MEG results, we would ask what MEG signal time-locked to the saccade to the verb shows an amplitude modulation that correlates with the behavioral reduction in gaze duration. If gaze reduction and the N400 really reflect that same processing – lexical access, for example – in this paradigm we would expect an early N400-type effect that parallels the latency of the saccade. However, if the N400-type response modulation occurs later, after the saccade from the verb, the cognitive trigger for the saccade might not be reflected in the N400-type response. Rather, we might expect to find correlations of gaze reduction with modulation of MEG responses from other, non-N400-type, brain areas and latencies. For example, if prediction for the verb pre-activates aspects of the orthographic form of the verb, gaze duration might correlate with modulation of the MEG M170 response.

Summary

The research proposed seeks to bring together two separate lines of research, eye-tracking and neurophysiology, by combining both methodologies simultaneously. Correlations between the two types of data in the same experiment should lead to a linking hypothesis tying eye movements to underlying cognitive and neurocognitive processing in real-time. Neurophysiology would be benefit from an explanation of the apparent lag of event-related responses with respect to eye movements. These techniques could finally solve questions about levels of processing in word recognition and their sequential or parallel computation by providing reliable time-course information about processing at different levels of analysis. This collaboration would become the springboard for my dissertation research as it would culminate a body of my research on lexical processing of compound words while expanding my research topic to semantic processing of sentences.

References

Brooks, T. L. & Gordon, P. C. (in prep). Transparent effects of partial priming in compound words. *tbd*.

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Davies, M. (2008-). The corpus of contemporary american english: 450 million words, 1990-present.

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Gramfort, A., Luessi, M., Larson, E., Engemann, D. A., Strohmeier, D., Brodbeck, C., Goj, R., Jas, M., Brooks, T., Parkkonen, L., & Hämäläinen, M. (2013a). Meg and eeg data analysis with mne-python. *Frontiers in Neuroscience*, 7(267).

Gramfort, A., Luessi, M., Larson, E., Engemann, D. A., Strohmeier, D., Brodbeck, C., Parkkonen, L., & Hämäläinen, M. S. (2013b). Mne software for processing meg and eeg data. *Neuroimage*.

Just, M. A., Carpenter, P. A., & Woolley, J. D. (1982). Paradigms and processes in reading comprehension. *J Exp Psychol Gen*, 111(2), 228–38.

Kliegl, R., Dambacher, M., Dimigen, O., Jacobs, A. M., & Sommer, W. (2012). Eye movements and brain electric potentials during reading. *Psychol Res*, 76(2), 145–58.

Kretzschmar, F., Bornkessel-Schlesewsky, I., & Schlesewsky, M. (2009). Parafoveal versus foveal n400s dissociate spreading activation from contextual fit. *Neuroreport*, 20(18), 1613–8.

Kutas, M. & Hillyard, S. A. (1984). Brain potentials during reading reflect word expectancy and semantic association. *Nature*, 307(5947), 161–3.

Landauer, T. K., Foltz, P. W., & Laham, D. (1998). An introduction to latent semantic analysis. *Discourse Processes*, 25(2-3), 259–284.

Lau, E. F., Phillips, C., & Poeppel, D. (2008). A cortical network for semantics: (de)constructing the n400. *Nat Rev Neurosci*, 9(12), 920–33.

Meyer, D. E. & Schvaneveldt, R. W. (1971). Facilitation in recognizing pairs of words: evidence of a dependence between retrieval operations. *J Exp Psychol*, 90(2), 227–34.

Rayner, K. (1998). Eye movements in reading and information processing: 20 years of research. *Psychol Bull*, 124(3), 372–422.

Reichle, E. D., Pollatsek, A., Fisher, D. L., & Rayner, K. (1998). Toward a model of eye movement control in reading. *Psychol Rev*, 105(1), 125–57.

Sereno, S. C. & Rayner, K. (2003). Measuring word recognition in reading: eye movements and event-related potentials. *Trends Cogn Sci*, 7(11), 489–93.

Budget

Roundtrip flight: New York → Paris (July-December 2014) $1500

Ground Transportation: $100

Neurobiology of Language Conference: Amsterdam (November 2014) $600

Registration Fees: $200

Hotel: upon arrival $300

Relocation cost: $1000

Subject Testing: $500

European Conference on Eye Movements: Sweden (August 2014) $600

Registration Fees: $200

Budget Justification

The proposed stay is Paris is for July 1th, 2014 to December 15th, 2014 (five months). The funding is requested for a round-trip flight, transportation to and from the airport and a hotel stay for the night immediately following my arrival in Paris. I plan to attend the European Conference on Eye Movements in Sweden, which is quite relevant for the work I am proposing. I have set aside a budget for subject testing for proposed experiment. Toward the end of my stay, I plan to attend the Society for Neurobiology of Language Conference in Amsterdam, as this too, is a conference quite pertinent for my proposed research.

January 2014

Curriculum Vitae

Teon Brooks
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Education

New York University — New York, NY
Ph.D. candidate in experimental psychology, expected 2016

The University of North Carolina at Chapel Hill — Chapel Hill, NC
B.S. in psychology and linguistics, December 2009

Selected Fellowships

National Science Foundation Graduate Research Fellowship — 2011-Present
New York University Opportunity Fellowship — 2011-Present
New York University MacCracken Fellowship — 2011-Present

Selected Awards

Society of Multivariate Experimental Psychology Travel Award — 2013
Society for Neurobiology of Language Travel Award — 2011, 2013
Mary and Maurice Julian Scholarship — 2006-2009
Carolina Covenant Scholarship — 2006-2009

Professional Organizations

Cognitive Neuroscience Society

Research Experience

New York University — New York, NY
Graduate Student in cognitive neuroscience: psycholinguistics — 2011-Present
Advisors: Dr. Alec Marantz

The University of North Carolina at Chapel Hill — Chapel Hill, NC
Undergraduate Research Assistant in psycholinguistics — 2008-2011
Advisor: Dr. Peter C. Gordon
Undergraduate Research Assistant in neuronal apoptosis — 2007-2008
Advisor: Dr. Mohanish Deshmukh

Teaching Experience

New York University — New York, NY
Teaching Assistant in cognitive neuroscience lab — Fall 2012
Professor: Dr. David Poeppel
New York Cares at I Have a Dream Foundation — New York, NY
Volunteer SAT Prep Tutor — January 2013-May 2013
Team Leader: Christine Little
New York Cares at The Educational Alliance — New York, NY
Volunteer Math Games Tutor — January 2013-June 2013
Team Leader: Marcia Bunda

Publications

A. Gramfort, M. Luessi, E. Larson, D. Engemann, D. Strohmeier, C. Brodbeck, R. Goj, M. Jas, **T. Brooks**, L. Parkkonen, M. Hämäläinen, MEG and EEG data analysis with MNE-Python, Frontiers in Neuroscience, Dec. 2013

Conference Poster Presentations

Brooks, T., Garcia, D., Marantz, A., Pylkkänen, L. (April 2013). Combinatorial Effects within Compound Words during Visual Word Recognition. **Proceedings of the 20th annual Cognitive Neuroscience Society Meeting**, San Francisco, CA.

Brooks, T., Gordon, P. (March 2011). Sentential Support for Morpho-Orthographic Decomposition during Visual Word Recognition. **Proceedings of the 24th annual CUNY conference on Human Sentence Processing**, Stanford, CA.

Brooks, T., Kim, J., Gordon, P. (March 2010). Transparent Effects of Partial Priming on Compounds. **Proceedings of the 23rd annual CUNY conference on Human Sentence Processing**, p. 98. New York, NY.

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NSF GROW Award Program

RE: Application of NSF Graduate Fellow Teon Brooks

1/8/14

Dear NSF,

I write as Teon's academic advisor to endorse his proposal to spend a semester in Paris on a GROW award, working with Alex Gramfort and Christophe Pallier. Teon is in the middle of his third year in the PhD program in Psychology at NYU, and he's completing all the requirements for the degree on time. This year, he needs to assess which of the areas of research he's been involved with he'd like to take on for his dissertation research. Teon has decided that he would like to combine cognitive modeling of language processing with work on the analysis of electrophysiological data in order to make progress on the hard problem of linking EEG and MEG measures on the one hand to behavior (like reaction time measures) in experiments and on the other to computationally explicit cognitive models that incorporate linguistic theories of cognitive representation. How does modulation of the amplitude of an evoked ERP or MEG response, for example, connect to modulation of RT or of eye-movements in an experimental paradigm and what do any of these measures tell us about the cognitive processes of, e.g., lexical access or semantic combination? The research that Teon proposes for Paris represents an excellent first step to answering these questions.

At NYU, Teon can interact and collaborate with a set of research groups that combine linguistic theory with behavioral and evoked response experiments, but these groups are consumers of MEG analysis methods rather than producers of the kinds of techniques that Gramfort is developing in Paris. The proposed collaboration would provide further training for Teon on computational and data analysis techniques while allowing him to contribute his psycholinguistic and linguistic experience to the development of appropriate paradigms for the proposed research. Teon has an unusually broad set of talents developed from his various previous collaborations, including expertise at EEG, MEG and eye-tracking methods. His work on the MNE-Python analysis pipeline also helped develop his programming and analytic skills. The work he proposes for Paris would set the stage for an important dissertation, addressing the neural and cognitive mechanisms behind word recognition in sentential contexts in a way that unifies data from eye-tracking, button pressing, and evoked response EEG/MEG research.

The neurolinguistics labs at NYU have enjoyed cooperation and collaboration with research groups in Paris over the years, including cooperation on a conference on MEG

analysis methods for work on language held in Paris a few years ago. With his experience with neuro and psycholinguistics and his participation in past NYU-Paris cooperative efforts, Christophe Pallier represents an ideal partner for the proposed research collaboration between Teon and Alex Gramfort. Given the experience of the NYU group with the Paris research, we feel quite confident that Teon's stay in Paris would be rewarding for his research and for our research teams.

Sincerely,

Alec Marantz
Professor of Linguistics and Psychology

Alexandre Gramfort
Assistant Professor
TSI Dept., Telecom ParisTech, CNRS LTCI
37-39 Rue Dareau, 75014 Paris, France

Paris, Jan. 4th, 2014

Object : letter to support Mr. Teon Brooks' application to the NSF GROW Program 2014

Dear Sir or Madam,

The year 2013 was the beginning of a fruitful collaboration between Mr. Teon Brooks at NYU and myself in Paris. This was motivated by common interests in modern EEG and MEG data processing tools and was done via the academic open source software MNE-Python (http://martinos.org/mne/). A project that I initiated in 2011 while working at Harvard MGH in Boston, and that now benefits from an international team of contributors (NYU, Aalto University, Univ. Washington, CEA Saclay, Telecom ParisTech, Juelich Neuroscience center among others). This joint work lead to a publication in Dec. 2013.

The GROW program in 2014 is for both of us, a unique opportunity to facilitate this collaboration and to tackle an ambitious project on the *decoding of semantic processing in on-line language comprehension in a naturalistic reading paradigm*. This project to be successful will require my expertise: advanced signal processing to work with eye tracking data, careful modeling of the electro-magnetic artifacts induced by eye movements and statistical machine learning to characterize the neural responses using EEG and MEG measurements.

This research project is of interest to me, and is in many ways relevant and timely. The TSI department at Telecom ParisTech will provide Mr. Brooks with the necessary tools for the project to be successfully carried out in due time and will support him financially.

I hope the GROW program will support this application and make this unique opportunity to strengthen my collaboration with Mr. Brooks a success.

Sincerely,

Dr. Alexandre Gramfort

Alexandre Gramfort, Ph.D.

A) Professional Preparation

Ecole Polytechnique	Mathematics/Computer Science	B.S./ 2004
Telecom ParisTech / ENS Cachan	Applied Mathematics	M.S./ 2006
INRIA / ENS ULM	Signal and Image processing	Ph.D./ 2009
INRIA / CEA Saclay	Post-doc	2009-2010
MGH/Harvard Medical School	Post-doc	2010-2011

B) Appointments

Positions and Employment

2012 -	Institut Mines-Telecom, Telecom ParisTech CNRS LTCI, Assistant Professor (Research)
2012 -	Scientific consultant at CEA Saclay Neurospin (Research)
2010-2011	Post-Doctoral Fellow, Martinos Center for Brain Imaging, Mass. General Hospital
2009-2010	Post-Doctoral Fellow, INRIA Saclay, Neurospin CEA Saclay

Honors

2012	Young investigator award with D. Strohmeier 18th international Biomag conf., Paris, France
2011	Young investigator award with D. Strohmeier at the NFSI conference, Banff, Canada
2011	Travel Award at Human Brain Mapping conference '2011, Quebec, Canada
2010	Young investigator award 17th international Biomag conf., Dubrovnik, Croatia
2009	PhD award in the category "interdisciplinary research" by EADS Foundation
2009	Student travel award "Workshop on Inverse Problems in Brain Imaging and Multimodal Fusion", CRM, Université de Montreal

C) Publications

Five publications most closely related to the proposed project.

1. **A. Gramfort**, M. Luessi, E. Larson, D. Engemann, D. Strohmeier, C. Brodbeck, R. Goj, M. Jas, T. Brooks, L. Parkkonen, M. Hämäläinen, MEG and EEG data analysis with MNE-Python, Frontiers in Neuroscience, Dec. 2013
2. **A. Gramfort**, T. Papadopoulo, E. Olivi and M. Clerc, OpenMEEG: opensource software for quasistatic bioelectromagnetics, BioMedical Engineering OnLine 2010, 9:45
3. **A. Gramfort**, D. Strohmeier, J. Haueisen, M. Hamalainen, M. Kowalski, Time-frequency mixed-norm estimates: Sparse M/EEG imaging with non-stationary source activations, Neuroimage, 2013
4. E. Lau, **A. Gramfort**, M. Hämäläinen, G. Kuperberg, Automatic Semantic Facilitation in Anterior Temporal Cortex Revealed through Multimodal Neuroimaging, Journal of Neuroscience, 2013
5. J-R. King, **A. Gramfort**, A. Schurger, L. Naccache, S. Dehaene, Two distinct dynamic modes subtend the detection of unexpected sounds, PLoS One, (in press)

Five other significant publications.

1. **A. Gramfort**, M. Kowalski, M. Hämäläinen, Mixed-norm estimates for the M/EEG inverse problem using accelerated gradient methods, Physics in Medicine and Biology 57, 7 (2012) 1937-1961
2. **A. Gramfort**, M. Luessi, E. Larson, D. Engemann, D. Strohmeier, C. Brodbeck, L. Parkkonen, M. Hämäläinen, MNE software for processing MEG and EEG data, NeuroImage
3. S. Khan, **A. Gramfort**, N. Shetty, M. Kitzbichler, S. Ganesan, J. Moran, S. Lee, J. Gabrieli, H. Tager-Flusberg, R. Joseph, M. Herbert, M. Hämäläinen, T. Kenet, Local and long-range functional connectivity is reduced in concert in autism spectrum disorders, Proceedings of the National Academy of Sciences (PNAS), 2013

4. R. Jenatton, **A. Gramfort**, V. Michel, G. Obozinski, E. Eger, F. Bach, B. Thirion, Multi-scale Mining of fMRI data with Hierarchical Structured Sparsity, SIAM Journal on Imaging Sciences 5, 3 (2012) 835-856.
5. G. Varoquaux, **A. Gramfort**, B. Thirion, Small-sample brain mapping: sparse recovery on spatially correlated designs with randomization and clustering, International Conference on Machine Learning (ICML conf.) (2012).

D) Synergistic Activities

1. **Principal author and maintainer of the MNE Python software project:** http://martinos.org/mne.
2. **Principal author of the software project OpenMEEG used for M/EEG forward modeling.** Available in popular academic software (Brainstorm and Fieldtrip) and for direct download at: http://openmeeg.gforge.inria.fr
3. **Lecturer on the fundamentals of M/EEG data processing** (Aalto university Jan. 2013, Trento CIMEC Oct. 2013, Paris ICM Dec. 2013, Karolinska Institute Stockholm Jan. 2014).

E) Collaborators & Other Affiliations

Collaborators

Van Wassenhove, V. (CEA Saclay, France); **Pallier, C.** (CEA Saclay, France); **Thirion, B**. (INRIA Saclay, France); **Varoquaux, G**. (INRIA Saclay, France); **Bach, F.** (INRIA Rocquencourt, France); **Ghuman, A.** (UMPC, Pittsburg); **Lau, E** (University of Maryland); **Hämäläinen, M.S.** (Martinos Center, MGH); **Baillet, S** (Mc Gill MNI, Montreal)

Graduate Advisors and Postdoctoral Sponsors.

Graduate Advisors: Maureen Clerc & Olivier Faugeras, INRIA Sophia-Antipolis, France
Post-doc Sponsor: Bertrand Thirion, INRIA CEA Saclay, France
Post-doc Sponsor: Matti Hämäläinen, Mass General Hospital, Boston, MA

Co-Mentored Graduate Students

Daniel Strohmeier	University of Ilmenau, Germany
Fabian Pedregosa	INRIA Saclay

AUTHORIZED ORGANIZATIONAL REPRESENTATIVE CERTIFICATIONS

NSF Graduate Research Fellowship Program
Graduate Research Opportunities Worldwide (GROW)

Certification for Authorized Organizational Representative

By signing the Certification Pages, the Authorized Organizational Representative (AOR) is: (1) certifying that statements made herein are true and complete to the best of his/her knowledge; and (2) agreeing to accept the obligation to comply with NSF award terms and conditions if an award is made as a result of this application. Further, the applicant is hereby providing certifications regarding conflict of interest (when applicable), drug-free workplace, debarment and suspension, nondiscrimination, responsible conduct of research, and Federal tax obligations as set forth in the *NSF Proposal & Award Policies & Procedures Guide, Part I: the Grant Proposal Guide (GPG)*. Willful provision of false information in this application and its supporting documents or in reports required under an ensuing award is a criminal offense (U. S. Code, Title 18, §1001).

Conflict of Interest Certification

When the proposing organization employs more than fifty persons, the Authorized Organizational Representative (or equivalent) is required to complete the following certification regarding Conflict of Interest:

By signing the Certification Pages, the AOR is certifying that the organization has implemented a written and enforced conflict of interest policy that is consistent with the provisions of the NSF Proposal & Award Policies & Procedures Guide, Part II,Award & Administration Guide (AAG) Section IV.A; that to the best of his/her knowledge, all financial disclosures required by that conflict of interest policy have been made; and that all identified conflicts of interest will have been satisfactorily managed, reduced or eliminated prior to the organization's expenditure of any funds under the award, in accordance with the organization's conflict of interest policy. Conflicts which cannot be satisfactorily managed, reduced or eliminated must be disclosed to NSF.

Drug Free Work Place Certification

Instructions for Certification

1. By signing the Certification Pages the AOR is providing the certifications set out below.
2. The certification set out below is a material representation of fact upon which reliance was placed when the agency determined to award the grant. If it is later determined that the grantee knowingly rendered a false certification, or otherwise violates the requirements of the Drug-Free Workplace Act, the agency, in addition to any other remedies available to the Federal Government, may take action authorized under the Drug-Free Workplace Act.

Certification Regarding Drug-Free Workplace Requirements

The grantee certifies that it will or will continue to provide a drug-free workplace by:

(a) Publishing a statement notifying employees that the unlawful manufacture, distribution, dispensing, possession or use of a controlled substance is prohibited in the grantee's workplace and specifying the actions that will be taken against employees for violation of such prohibition;

(b) Establishing an ongoing drug-free awareness program to inform employees about --

(1) The dangers of drug abuse in the workplace;

(2) The grantee's policy of maintaining a drug-free workplace;

(3) Any available drug counseling, rehabilitation and employee assistance programs; and

(4) The penalties that may be imposed upon employees for drug abuse violations occurring in the workplace;

(c) Making it a requirement that each employee to be engaged in the performance of the grant be given a copy of the statement required by paragraph (a);

(d) Notifying the employee in the statement required by paragraph (a) that, as a condition of employment under the grant, the employee will --

(1) Abide by the terms of the statement; and

(2) Notify the employer in writing of his or her conviction for a violation of a criminal drug statute occurring in the workplace, no later than five calendar days after such conviction;

(e) Notifying the agency in writing, within 10 calendar days after receiving notice under subparagraph (d)(2) from an employee or otherwise receiving actual notice of such conviction.

Employers of convicted employees must provide notice, including position title, to every grant officer or other designee on whose grant activity the convicted employee was working, unless the Federal agency has designated a central point for the receipt of such notices. Notice shall include the identification number(s) of each affected grant;

(f) Taking one of the following actions, within 30 calendar days of receiving notice under subparagraph (d)(2), with respect to any employee who is so convicted--

(1) Taking appropriate personnel action against such an employee, up to and including termination, consistent with the requirements of the Rehabilitation Act of 1973, as amended; or

(2) Requiring such employee to participate satisfactorily in a drug abuse assistance or rehabilitation program approved for such purposes by a Federal, State, or local health, law enforcement, or other appropriate agency;

(g) Making a good faith effort to continue to maintain a drug-free workplace through implementation of paragraphs (a), (b), (c), (d), (e) and (f).

Debarment and Suspension Certification

Instruction on Certification Regarding Debarment and Suspension

1. By signing the Certification Pages, the AOR is providing the certification set out below.
2. The inability of a person to provide the certification required below will not necessarily result in denial of participation in this covered transaction. The prospective participant shall submit an explanation of why it cannot provide the certification set out below. The certification or explanation will be considered in connection with the department or agency's determination whether to enter into this transaction. However, failure of the prospective primary participant to furnish a certification or an explanation shall disqualify such person from participation in this transaction.
3. The certification in this clause is any material representation of fact upon which reliance was placed when the department or agency determined to enter into this transaction. If it is later determined that the prospective primary participant knowingly rendered an erroneous certification, in addition to other remedies available to the Federal Government, the department or agency may terminate this transaction for cause or default.
4. The prospective primary participant shall provide immediate written notice to the department or agency to whom this proposal is submitted if at any time the prospective primary participant learns

that its certification was erroneous when submitted or has become erroneous by reason of changed circumstances.

5. The terms covered transaction, debarred, suspended, ineligible, lower tier covered transaction, participant, person, primary covered transaction, principal, proposal, and voluntarily excluded, as used in this clause, have the meanings set out in the Definitions and Coverage sections of the rules implementing Executive Order 12549. You may contact the department or agency to which this proposal is being submitted for assistance in obtaining a copy of those regulations.
6. The prospective primary participant agrees by submitting this proposal that, should the proposed covered transaction be entered into, it shall not knowingly enter into any lower tier covered transaction with a person who is debarred, suspended, declared ineligible, or voluntarily excluded from participation in this covered transaction, unless authorized by the department or agency entering into this transaction.
7. The prospective primary participant further agrees by submitting this proposal that it will include the clause titled "Certification Regarding Debarment, Suspension, Ineligibility and Voluntary Exclusion - Lower Tier Covered Transaction", provided by the department or agency entering into this covered transaction, without modification, in all lower tier covered transactions.
8. A participant in a covered transaction may rely upon a certification of a prospective participant in a lower tier covered transaction that it is not debarred, suspended, ineligible, or voluntarily excluded from the covered transaction, unless it knows that the certification is erroneous. A participant may decide the method and frequency by which it determines the eligibility of its principals. Each participant may, but is not required to, check the Nonprocurement List.
9. Nothing contained in the foregoing shall be construed to require establishment of a system of records in order to render in good faith the certification required by this clause. The knowledge and information of a participant is not required to exceed that which is normally possessed by a prudent person in the ordinary course of business dealings.
10. Except for transactions authorized under paragraph 6 of these instructions, if a participant in a covered transaction knowingly enters into a lower tier covered transaction with a person who is suspended, debarred, ineligible, or voluntarily excluded from participation in this transaction, in addition to other remedies available to the Federal Government, the department or agency may terminate this transaction for cause or default.

Certification

(1) The prospective primary participant certifies to the best of its knowledge and belief, that it and its principals: (a) Are not presently debarred, suspended, proposed for debarment, declared ineligible, or voluntarily excluded from a covered transaction by any Federal department or agency; (b) Have not within a three-year period preceding this proposal been convicted of or had a civil judgment rendered against them for commission of fraud or a criminal offense in connection with obtaining, attempting to obtain, or performing a public (Federal, State or local) transaction or contract under a public transaction; violation of Federal or State antitrust statutes or commission of embezzlement, theft, forgery, bribery, falsification or destruction of records, making false statements, or receiving stolen property; (c) Are not presently indicted for or otherwise criminally or civilly charged by a governmental entity (Federal, State or local) with commission of any of the offenses enumerated in paragraph (1)(b) of this certification; and (d) Have not within a three-year period preceding this application/proposal had one or more public transactions (Federal, State or local) terminated for cause or default.

(2) Where the prospective primary participant is unable to certify to any of the statements in this certification, such prospective participant shall include an explanation with this proposal.

Certification Regarding Nondiscrimination

Instructions for Nondiscrimination Certification

1. In accordance with NSF policy, by signing the Certification Pages, the AOR is providing the requisite Certification of Compliance with National Science Foundation Nondiscrimination Regulations and Policies. This Certification sets forth the nondiscrimination obligations with which all awardees must comply. These obligations also apply to subrecipients, subgrantees, and subcontractors under the award. The proposer therefore, shall obtain the NSF Nondiscrimination Certification from each organization that applies to be, or serves as a subrecipient, subgrantee or subcontractor under the

award (for other than the provision of commercially available supplies, materials, equipment or general support services) prior to entering into the subaward arrangement.

2. The AOR shall provide immediate notice to the Foundation if at any time the proposer learns that its certification was erroneous when submitted, or has become erroneous by reason of changed circumstances.

Certification of Compliance with National Science Foundation Nondiscrimination Regulations and Policies

By signing the Certification Pages, the AOR hereby certifies that the organization will comply with Title VI of the Civil Rights Act of 1964 (42 USC § 2000d), Title IX of the Education Amendments of 1972 (20 USC §§ 1681 et seq.), the Rehabilitation Act of 1973 (29 USC § 794), the Age Discrimination Act of 1975 (42 USC §§ 6101 et seq.) and all regulations and policies issued by NSF pursuant to these statutes.

To that end, in accordance with the above-referenced nondiscrimination statutes, and NSF's implementing regulations and policies, no person in the United States shall, on the ground of race, color, national origin, sex, disability, or age, be excluded from participation in, be denied the benefits of, or be otherwise subjected to discrimination under any program or activity for which the Proposer receives Federal financial assistance from the Foundation; and HEREBY CERTIFIES THAT it will immediately take any measures necessary to effectuate this agreement.

If any real property or structure thereon is provided or improved with the aid of Federal financial assistance extended to the Proposer by the Foundation, this Certification shall obligate the Proposer, or in the case of any transfer of such property, the transferee, for the period during which the real property or structure is used for a purpose for which the Federal financial assistance is extended or for another purpose involving the provision of similar services or benefits. If any personal property is so provided, this Certification shall obligate the Proposer for the period during which it retains ownership or possession of the property. In all other cases, this Certification shall obligate the Proposer for the period during which the Federal financial assistance is extended to it by the Foundation.

THIS CERTIFICATION is given in consideration of and for the purpose of obtaining any and all Federal grants, cooperative agreements, loans, contracts, property, discounts or other Federal financial assistance extended after the date hereof to the Proposer by the Foundation, including installment payments after such date on account of applications for Federal financial assistance which were approved before such date. The Proposer recognizes and agrees that such Federal financial assistance will be extended in reliance on the representations and agreements made in this Certification, and that the United States shall have the right to seek judicial enforcement of this Certification. This Certification is binding on the Proposer, its successors, transferees, and assignees.

[redacted]

By signing these certifications, I certify that the statements made herein are true and complete to the best of my knowledge and belief, and I agree to comply with any resulting terms if I accept an award. I am aware that any false, fictitious, or fraudulent statements or claims may subject me to criminal, civil, or administrative penalties. (U.S. Code, Title 18, Section 1001)

Richard L Lewis | 1/8/2014

Name | Date

New York University

Organization

Director, Office of Sponsored Programs

Title

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Email Address