University of Victoria | Graduate Studies

Notice of the Final Oral Examination
for the Degree of Doctor of Philosophy

of

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## "Statistical Methods for Neuroimaging Data Analysis and Cognitive Science"

Department of Mathematics and Statistics

Wednesday, April 24, 2019
1:00 P.M.
Clearihue Building
Room B007

Supervisory Committee:
Dr. Farouk Nathoo, Department of Mathematics and Statistics, University of Victoria (Supervisor)
Dr. Laura Cowen, Department of Mathematics and Statistics, UVic (Member)
Dr. Michael Masson, Department of Psychology, UVic (Outside Member)

External Examiner:
Dr. Marc Fredette, Decision Science, HEC Montreal

Chair of Oral Examination:
Dr. Cornelis van Kooten, Department of Economics, UVic

Dr. David Capson, Dean, Faculty of Graduate Studies

## Abstract

This thesis presents research focused on developing statistical methods with emphasis on tools that can be used for the analysis of data in neuroimaging studies and cognitive science. The first contribution addresses the problem of determining the location and dynamics of brain activity when electromagnetic signals are collected using magnetoencephalography (MEG) and electroencephalography (EEG). We formulate a new spatiotemporal model that jointly models MEG and EEG data as a function of unobserved neuronal activation. To fit this model we derive an efficient procedure for simultaneous point estimation and model selection based on the iterated conditional modes algorithm combined with local polynomial smoothing. The methodology is evaluated through extensive simulation studies and an application examining the visual response to scrambled faces.

In the second contribution we develop a Bayesian spatial model for imaging genetics developed for analyses examining the influence of genetics on brain structure as measured by MRI. We extend the recently developed regression model of Greenlaw et al. (*Bioinformatics*, 2017) to accommodate more realistic correlation structures typically seen in structural brain imaging data. We allow for spatial correlation in the imaging phenotypes obtained from neighbouring regions in the same hemisphere of the brain and we also allow for correlation in the same phenotypes obtained from different hemispheres (left/right) of the brain. This correlation structure is incorporated through the use of a bivariate conditional autoregressive spatial model. Both Markov chain Monte Carlo (MCMC) and variational Bayes approaches are developed to approximate the posterior distribution and Bayesian false discovery rate (FDR) procedures are developed to select SNPs using the posterior distribution while accounting for multiplicity. The methodology is evaluated through an analysis of MRI and genetic data obtained from the Alzheimer's Disease Neuroimaging Initiative (ADNI) and we show that the new spatial model exhibits improved performance on real data when compared to the non-spatial model of Greenlaw et al. (2017).

In the third and final contribution we develop and investigate tools for the analysis of binary data arising from repeated measures designs. We propose a Bayesian approach for the mixed-effects analysis of accuracy studies using mixed binomial regression models and we investigate techniques for model selection. Software and examples in R and JAGS for implementing the proposed analysis are described and available at https://v2south.github.io/BinBayes/.