Explainable Dementia Prediction Using Functional Neuroimages and Risk Factors

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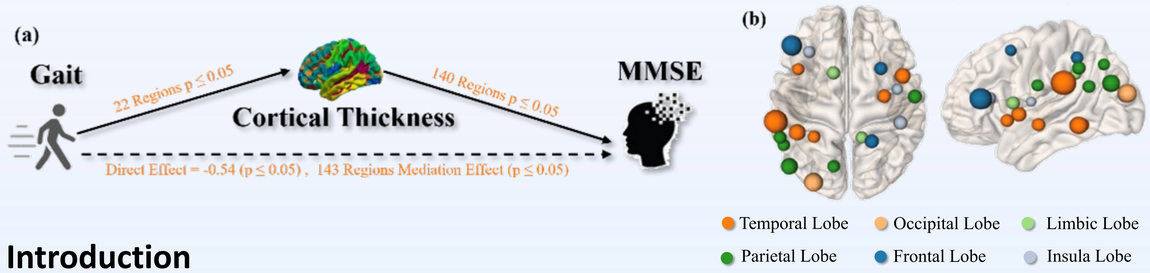
INTRODUCTION & OBJECTIVES



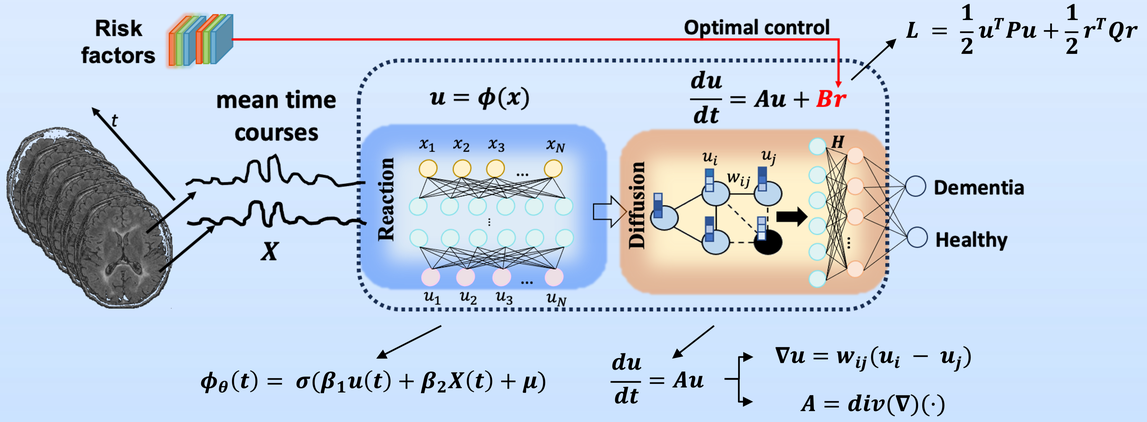
Introduction

A growing body of evidence suggests that dementia is a result of the complex interplay between neurodegenerative and cerebrovascular processes, influenced by genetic, demographic, and lifespan environmental exposures. Current dementia prediction work relies on either biomarkers or itemized risk factors, lacking an integrated understanding of how neurobiological mechanisms interact with non-modifiable and modifiable risk factors and lead to diverse neurodegeneration trajectories.

Objectives

Develop and validate a deep systems biology model that integrates functional neuroimaging data with risk factors, including those associated with health disparities, to analyze the synergistic effects of health disparities and risk factors on dementia across diverse populations.

METHODS



Deep RDM

- A reaction module for projecting the observed functional signals *X* to a latent state *u.*
- A diffusion module to model the transition of brain fluctuation states over time.
- A control module to characterize the effect of health disparity and risk factors on the state of each brain region with the notion of optimal control.
- By concatenating the MLPs (for reaction process) and GNN (for diffusion process), we are able to predict the evolution of brain states *u(t)* over time and use the terminal state u_T to predict dementia risk via supervised learning.

EXPERIMENTS

Data

We evaluated the dementia prediction accuracy and explored the multi-factorial mechanism of dementia risks on the Alzheimer's Disease Neuroimaging Initiative (ADNI) dataset. To ensure the availability of demographic factors, medical history, and functional neuroimages for each subject, we selected 250 samples from ADNI and processed the neuroimages with AAL atlas.

Prediction Accuracy & Ablation Study

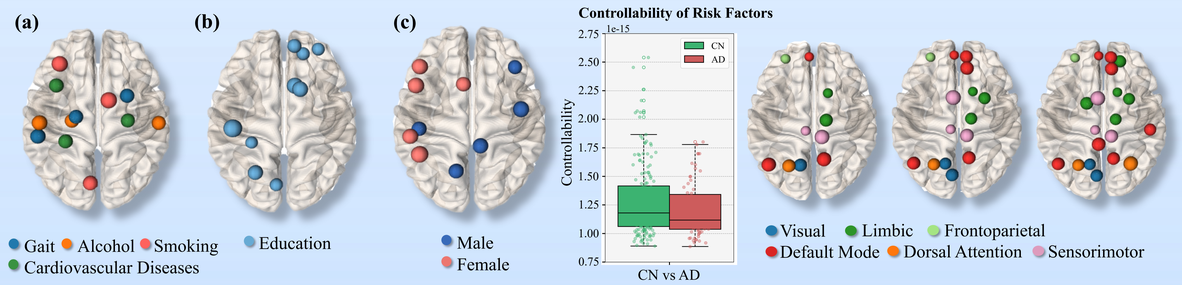
- Health disparity and risk factors contribute substantially to imaging-based diagnoses.
- Our model achieves the highest prediction accuracy with the control constraint.

Age	71.69 ± 6.99
Gender	52.80% Female
Education	16.05 ± 2.71
Gait	10.00% Abnormal
Cardiovascular Disease	62.40% Have Cardiovascular Disease
Other Neurological Diseases	38.40% Have Other Neurological Diseases
Psychiatric Disorders	36.00% Have Psychiatric Disorders
Alcohol Abuse	4.80% Have Alcohol Abuse
Drug Abuse	1.20% Have Drug Abuse
Smoking Status	38.40% Smoke
Dementia Label	29.20% Dementia

Methods	Input	Accuracy
SVM	BOLD	66.00%
	BOLD + Risk Factors	70.80%
RNN	BOLD	61.33%
	BOLD + Risk Factors	70.97%
Neuro-RDM	BOLD	71.00%
	BOLD + Risk Factors	73.14%
Our Method	w/o (LQR)	73.27%
	w/ (LQR)	74.22%

Dementia Risk Factors

The *B* matrix elucidates the influence of each factor on the dynamic functional states of individual brain regions.



A System-Level Understanding of Brain Vulnerability Upon Health Disparities

Following the notion of controllability, we calculated the smallest eigenvalue of controllability matrix $C = [B\ AB\ A^2B\ \dots\ A^{T-1}B]$ for each subject to examine the vulnerability of brain function at each region to health disparity factors.

ACKNOWLEDGMENTS

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