What do you say? A language journey.

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Abstract. One third of stroke patients suffer from comprehension and cognitive disabilities. Thus, being able to give recovering patients an accurate indication of whether they will recover and how long recovery will take is extremely important. Our understanding of the neural mechanisms underlying recovery of language post stroke continues to remains limited. Previously, it was thought that acquired language deficits stabilised within a year of stroke onset. However, recent research has highlighted that structural adaptation continues long after stroke. Therefore, the project will aim to investigate the impact of brain structural plasticity on language recovery years after stroke. The proposed method is to model brain structural trajectories of neurologically healthy subjects on to a latent space and evaluate how far removed the latent brain structural trajectories of recovering stroke patients are. This distance evaluation will be used to quantify longitudinal language outcomes for stroke patients.

1 Introduction

Stroke can happen at any time to anyone, including babies and children. The UK has over 100, 000 stroke patients each year. Stroke occurs when blood supply to an area of the brain is stopped. As a result, brain cells experience oxygen deprivation and begin to die. Dying of the brain cells during stroke may cause a global breakdown of the neuro network [1]. This breakdown, can lead to loss of control in abilities controlled by that area of the brain. One vital control loss is related to speaking, understanding, reading and writing. As such, one third of patients tend to suffer from difficulties in comprehension and cognitive understanding post-stroke [2]. This is also referred to as aphasia.

The ability of a patient to recovery their language capabilities post-stroke is thought to depend on the total proportion of damage to the brain, whether areas that support language have been damaged and the intensity of the initial symptoms [3]. Previous research, has focused on accurately understanding and predicting language outcomes for surviving patients. Methodologies have varied from theoretical [4–6], experimental [7, 8] and more recently data-driven approaches [9–12, 3]. A large majority of the prediction focused studies have looked at whether a given patient will recovery at any given point in time. However, Pedersen, et al.[13] stated that the highest dynamic of language recovery can be observed in the first 2 weeks after onset of acute stroke, while in the later course, recovery was more prolonged. Thus, the bigger questions are what causes this delay and how do we quantify it for prediction purposes? Similarly, Saur, et al. [1] postulated that there were three phases in language recovery; global breakdown, resolution of diaschisis and normalisation of activation. They found that the re-shift of activation to compensate for damage in the brain may happen in different regions of the brain due to variability in initial damage. In their research, Xing, et al [14] found structural differences in the right hemisphere to be correlated with language outcomes after left-hemisphere stroke. They also found higher grey matter volumes in the right temporoparietal cluster for aphasics compared neurologically normal controls - attributing towards post-stroke adaptation. Hope, et al. [15] extended this for a longitudinal analysis and showed that patient language outcome changes were associated with structural adaptation in the intact right hemisphere of the brain.

However, limited progress has been made in understanding brain structural plasticity where lesions are not limited to left-hemisphere. This is predominantly due to difficulties in acquiring large sample populations and computational limitations. However, better understanding of this structural adaptation will allow for better language recovery predictions. This is because brain structure change predicts behavioural change [15].

Thus, the project will aim to investigate the **impact of brain structural plasticity on language recovery years after stroke**. The proposed method is to model brain structural trajectories of neurologically healthy subjects on to a latent space. This proposition is motivated by Ziegler, et al.[16] work in modelling the aging brain structure and its decline that helped quantify age-related differences. Using the latent representation of neurologically normal brain structure, we can evaluate how far removed the brain structure is for recovering stroke patients. This distance evaluation will be used to quantify longitudinal language outcomes for stroke patients. This proposition is motivated by Ziegler, et al. [17] research on detection of local and global gray matter abnormalities in elderly subjects for Alzheimer's disease.

The project proposal is as follows. Section II describes the main objectives for the project. Section III lays out the proposed methodology for achieving the outcomes. Section IV has a detailed overview of the data and the underlying assumptions. Finally, Section V concludes the paper with brief summary of expected impact of the research.

2 Objectives

The ability to predict long-term language outcomes for stroke patients is extremely difficult. This is due to large variation in the relative starting points for each patient e.g. damaged areas of the brain and treatments may differ. This has meant that limited progress has been made in answering how long will recovery take. Therefore, the project aims to investigate the impact of brain structural plasticity on language recovery years after stroke through the following:

- **Neuro-framework** Systematic literature review of existing models highlighting the areas that control comprehension and cognitive abilities. Investigate long-term recovery models - within stroke and other neurological diseases.
- **Theoretical formulation** Modification of the recovery model framework based on the literature review. This will be driven by the need to breakdown the phases into sub-categories either by duration or biological explanation.
- **Normal brain structural trajectory** Model the distribution of brain structural trajectories of neurologically healthy subjects on to a latent space.
- **Individual recovery predictions** Evaluate the distance in distribution of brain structure of recovering stroke patients, at each point, in contrast to neurotypical patients. This distance evaluation will be used to predict longitudinal language outcomes for stroke patients.

3 Methodology

The proposed methodology* is as follows:

- **Linear Method** Principal component analysis (PCA) for modelling the distribution of brain structural trajectories of neurologically healthy subjects on to a linear latent space.
- **Non-Linear Method** Generative adversarial networks (BIGAN) for modelling the distribution of brain structural trajectories of neurologically healthy subjects on to a non-linear latent space.

* Please note that this will be expanded and modified during the course of the project.

4 Data

The dataset comprises of ischemic and haemmorhagic stroke patients with symptoms lasting more than one week from the Predicting Language Outcome Recovery After Stroke (PLORAS) database [2]. For each patient, there is associated demographic information, high resolution T1-weighted post-stroke MRI brain scans and associated CAT behavioral test results [18]. The PLORAS dataset contains a total of $1,858$ records from 835 patients. There are $1,211$ unique assessments for spoken picture description scores and their associated MRI scan, of which 825 entries were initial assessments, and the approximately 200 were follow-ups. The following demographic features are included a) years between stroke and scan, b) whether vision is affected, c) whether hearing is affected, d) gender, e) number of lesions, f) localisation of lesion; left and right, g) years of education, h) age at stroke i) age since stroke and j) handedness.

Additionally, there are 343 healthy T1-weighted MRI brain scans with associated demographic information. MRI scans, from both stroke and healthy individuals, will be normalised before any experiments are carried out. For the non-linear approach, more data will be required.

4.1 Logistics

- Identify data sources with large samples of normal brain MRIs with demographic information
- Identify access procedure for relevant data sources
- Identify computing set-up and data normalisation procedure before the start of the project.

5 Research Impact

The hope is that by being able to better understand structural adaptation trajectories, we will be able to better understand language outcomes post-stroke.

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