Some Results on Dynamic Causal Modeling of Auditory Hallucinations

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Abstract. Hallucinations, and more specifically auditory hallucinations (AH), are a perplexing phenomena experienced by many people. Though they are a clinical symptom in some mental diseases, such as Schizophrenia, they are also experienced by normal, healthy persons. There are several models of the mechanics happening in the brain leading to hallucinations, which involve auditory, language and emotion regions. On the other hand, there is not much empirical evidence due to the evanescence of the phenomena, and the difficulty to capture meaningful data. Recent works on resting state functional Magnetic Resonance Imaging (rs-fMRI) data, are providing confirmation of some brain localizations. Dynamic Causal Modeling (DCM) provides estimations of neural effective connectivity parameters from the experimental fMRI data, and recently has been proposed to work on rs-fMRI data. We provide preliminar results on a dataset that recently has been useful to find confirmation of AH model effects.

1 Introduction

Advances in neuroimaging have made the study of the brain more accessible, bringing more extensive and detailed information. New discoveries about brain networks and its behaviors offer an enhanced understanding of several neural conditions that have been quite obscure until now. In this new research environment, the pathophysiological models of neural conditions have been reformulated in order to integrate all the recent knowledge. However, these models are still quite simplistic as there is little room for experimentation in this area due to legal and ethical constraints.

Hallucinations are neural conditions of strong public interest, specially Auditory Hallucinations (AH), whose modeling has experienced a remarkable advance in the late years. Hallucinations are a particularly complex phenomena, involving complex interaction of many brain areas. The specific characteristics of each type of hallucination makes it difficult to achieve a unique model. Hallucinations cannot be observed from outside the patient and, therefore, need some kind of feedback from the studied individual potentially lowering the accuracy of the extracted data due to subjectivity. Computational models offering predictions that can be validated against real data, perhaps constructed following the
paradigm of multi-agent system modeling \cite{8,15,11} where agent interaction mimics the functional connection between brain regions leading to the generation of hallucinations, are highly desirable. However, there is only one approach right now that may provide some insights into the dynamics of the brain connectivity from empirical data. This approach is the Dynamic Causal Model \cite{3} provided in the SPM package for neuroimage processing. This approach was initially proposed for task oriented fMRI experiments, but recently it has been proposed for rs-fMRI \cite{4}.

**Intended Contribution.** The aim of the work in this article, which is in its initial stages, is to search into the effective connections that can be discovered from rs-fMRI data looking for differences between people with and without AH. The dataset already explored \cite{2} to find discriminant features has been analysed by the DCM approach, with some difficulties because the program is not tailored for dealing with rs-fMRI, despite recent claims \cite{4}. We report results showing some differences between hallucinating and non-hallucinating subjects. The paper contents are as follows: Section 2 provides some background information. Section 3 comments the the abstract functional model. Section 4 presents a detailed anatomical model. Section 5 gives a short review of DCM. Section 6 provides preliminary results of ongoing analysis. Section 7 gives some conclusions.

## 2 Background

**Definition of AH.** Hallucinations are defined as any perceptual experience in the absence of external stimuli and sufficiently compelling to resemble a veridical perception. They may involve any sense. They are often regarded as a symptom of mental illness, but they are not necessarily clinical \cite{1}. Auditory (AH) and visual hallucinations (VH) are most prevalent in psychiatric disorders, but auditory verbal hallucinations (AVH) are not uncommon in the general healthy population, with prevalence estimates ranging between 3 and 15\% \cite{6,14}. The most widely studied patient group suffering AH are the schizophrenia patients \cite{9,13,7}, although some studies have been carried in other clinical patients \cite{12,1} and healthy individuals with hallucinations \cite{14}. It has been proposed that comparison of patients and healthy persons with a history of hallucinations may allow to identify a hallucination brain fingerprint which will help to understand further complex psychiatric illnesses who have hallucinations as a core symptom \cite{6}. In this article we focus our work on AH as they are the most widely present in the variety of mental conditions where hallucinations have been reported, both clinical and non-clinical.

**Evidences in the Literature.** The mechanism of AH generation are not clear yet. Nonetheless, they seem to involve several alterations in grey matter volume, activation, and functional connectivity of a brain regions’ network \cite{1}. One of the most widely studied aspects of hallucination prone brains is lateralization. Several studies have reported a reversed lateralization of cerebral activity during AVH, showing right inferior frontal activation when left could be expected,