Aristotle University of Thessaloniki
Faculty of Sciences
Department of Physics

Bachelor Thesis

Author:
Kasapakis Nikolaos[1]

Supervisor:
Prof. Theodoros Samaras[2]

Insert Title Here

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Aristotle University
of Thessaloniki
SCHOOL OF PHYSICS

[1] nkasapak@auth.gr, *https://github.com/kasapakis-nk*
[2] theosama@auth.gr

mythesis

Nikos Kasapakis

May 2024

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Abstract

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Kasapakis Nikolaos

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Περίληψη

Βάλε τίτλο εδώ

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Acknowledgements

I want to thank Proffessor Samaras, Dimitris Stoupis (include all titles), Ioanna K.

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Contents

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List of Figures

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List of Tables

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Listings

Chapter 1

Introduction

1.1 The mechanisms of Functional Magnetic Resonance Imaging

1.1.1 Blood Oxygen Level Dependent Signal *(BOLD)*

The BOLD signal , captured in fMRI detects changes in HbR driven by localized changes in brain blood flow and blood oxygenation, which are coupled to underlying neuronal activity by a process termed neurovascular coupling. fMRI relies upon the measurement of T2* relaxation, which is sensitive primarily to local concentrations of πaramagnetic HbR in venous blood, rendering the latter a naturally occurring contrast agent. Interpretation of the fMRI BOLD signal is intrinsically linked to understanding the underlying physiological and metabolic processes in the brain that modulate blood flow.

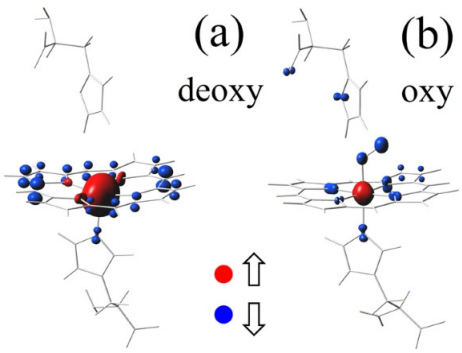

Figure 1.1: Illustation of magnetic-moment density **M(r)** for the **(a)** HbR and **(b)** HbO heme clusters at $T = 150K$. The magnitude of **M(r)** at an atomic site is proportional to the volume of the bubble at that site [1] Fig. 2 p.2).

The BOLD effect related to neural activity arises because of two distinct phenomena. The first is that when hemoglobin (Hb)-the molecule in blood that carries oxygen-lose the oxygen to become HbR, its magnetic properties change in a subtle way: HbR is paramagnetic, and alters the magnetic susceptibility of blood, whereas HbO and the surrounding tissue H_2O are diamagnetic Figure 1.1. The difference in susceptibility between blood vessels and the surrounding tissue creates local magnetic field distortions that decrease the net Magnetic Resonance (MR) signal. In the brain, a typical Oxygen Extraction Fraction (OEF)-the fraction of O_2 carried by an element of blood that is removed in passing through the capillary bed-is approximately 40% and in a 3 T magnetic field this level of HbR in the veins and capillaries is sufficient to reduce the MR signal by about 10% in the baseline state, compared to what it would be if no HbR was present.

The combination of the aforementioned with the biophysical phenomenon, that when a brain area is activated, the blood flow increases-via a process called the haemodynamic response-to a greater degree than the oxygen metabolic rate, produces a useful basis for an experimental signal aqcuisition technique. The second phenomenon leads to a reduction in the OEF, a seemingly paradoxical scenario in which the venous blood is more oxygenated, despite the increase in oxygen metabolic rate, because the blood flow has increased to a greater extent. Taken together, these two phenomena produce the BOLD effect, a local increase in the MR signal due to a reduction in the OEF during increased neural activity. [2]

A prevailing misconception is that BOLD provides a direct measurement of neuronal oxygen

consumption. However, this is generally not the case; classic positive BOLD signals, seen in response to functional stimuli, represent a decrease in HbR and thus an overoxygenation of the responding region [3]. These positive BOLD responses correspond to a local, actively actuated, increase in blood flow and volume, which brings blood in sufficient excess to increase local oxygenation levels [4]. This response typically begins within about 500ms and peaks 3-5 seconds after stimulus onset Figure 1.2, even for short stimuli lasting less than 1 second, with more complex dynamics for prolonged stimuli.

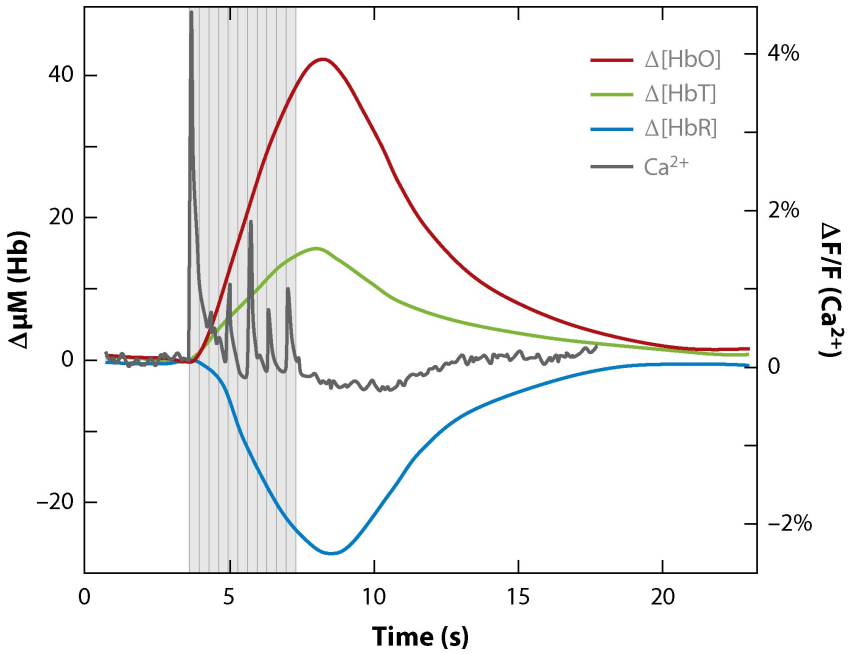

Figure 1.2: Stimulus-evoked response in somatosensory cortex of rats. Noteably, there is a distinct increase in HbT corresponding to vessel dilation and an increase in the number of red blood cells per unit volume of cortex, consistent with an increase in blood flow. HbO increases while HbR decreases, indicating a net overoxygenation of the region. The fMRI BOLD is sensitive to changes in HbR, where stimulus-evoked "positive BOLD" corresponds to the decrease in HbR shown here [5] Fig. 2 p.4).

A range of cellular mechanisms, including astrocytes, pericytes, and interneurons, have been proposed to play a role in neurovascular coupling.[6]. For classical interpretation of BOLD signals, it is assumed that neurovascular coupling is so robust that any increase in neuronal activity generates a proportional increase in local blood flow, irrespective of brain region, brain development, and pathological state [7].

1.1.2 The HCP WM task experiment

The data manipulated in this project has been obtained from the Human Connectome Project (HCP) database, whose overarching purpose is to acquire and share data about the structural and functional connectivity of the human brain. One of the major categories of data in the HCP refers to Task-Evoked Functional Magnetic Resonance Imaging (tfMRI) which assesses seven domains that sample the diversity of neural systems of interest, to a wide range of individuals in the field: 1) visual, motion, somatosensory, and motor systems; 2) category specific representations; 3) working memory or cognitive control systems; 4) language processing (semantic and phonological processing); 5) social cognition (Theory of Mind); 6) relational processing; and 7) emotion processing. **cite Barch2013, cite HCP somehow?**

The domain which is presently being examined is that of WM tasks which is combined with category specific representation tasks into the following, single task paradigm. Stimuli were projected onto a computer screen behind the subject's head within the imaging chamber. The screen was viewed by a mirror positioned approximately 8 cm above the subject's face. Participants were presented with blocks of trials that consisted of pictures of places, tools, faces and body parts (non-mutilated parts of bodies with no "nudity"). Within each run, the four different stimulus types were presented in seperate blocks. Also, within each run, half of the blocks use a 2-back WM task and half use a 0-back WM task (as a working memory comparison). A 2.5 second cue indicated the task type (and target for 0-back) at the start of the block. Each of the two runs contains eight task blocks (10 trials of 2.5 seconds each, for 25 seconds) and four fixation blocks (15 seconds). On each trial, the stimulis is presented for 2 seconds, followed by a 500ms inter-task interval (ITI). The procedure is showcased in order in Figure 1.3.

Segment Type	Duration (s)	N-Back Paradigm	Target Category
Setup	10	-	-
Cue	2.5	-	-
Task	25	2-Back	Body
Cue	2.5	-	-
Task	25	0-Back	Face
Fixation	15	-	-
Cue	2.5	-	-
Task	25	2-Back	Tools
Cue	2.5	-	-
Task	25	0-Back	Body
Fixation	15	-	-
Cue	2.5	-	-
Task	25	0-Back	Place
Cue	2.5	-	-
Task	25	2-Back	Face
Fixation	15	-	-
Cue	2.5	-	-
Task	25	0-Back	Tools
Cue	2.5	-	-
Task	25	2-Back	Place
Fixation	15	-	-

Figure 1.3: Display of the exact sequece of events during the WM task paradigm.

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Chapter 2

Category-Specific Data - MVPA

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Chapter 3

Software Architecture

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Chapter 4

Classification Results

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Chapter 5

Discussion & Conclusions

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Acronyms

BOLD Blood-Oxygen-Level-Dependent

fMRI Functional Magnetic Resonance Imaging

Hb hemoglobin

HbO Oxyhemoglobin

HbR deoxyhemoglobin

HbT total hemoglobin

HCP Human Connectome Project

ITI inter-task interval

MR Magnetic Resonance

OEF Oxygen Extraction Fraction

tfMRI Task-Evoked Functional Magnetic Resonance Imaging

WM Working Memory

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