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Cortical location of saccadic and vergence oculomotor learning using fMRI

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ABSTRACT

CORTICAL LOCATION OF SACCADIC AND VERGENCE OCULOMOTOR LEARNING USING fMRI

**by
Yelda Alkan**

Motor learning is critical to the survival of a species and changes throughout life via neuroplasticity. The brain receives most of its information about the external world via the visual system. Eye movements are used to direct the visual information of interest to the fovea, the area of the retina which has the highest density of photoreceptors, and the largest amount of cortical area. This research will study how two of the five eye movement systems utilize oculomotor learning. Saccadic eye movements are used to quickly shift the fovea to objects using conjugate movements typically used during reading. The vergence system encompasses disconjugate movements of the eyes and provides perception of the depth of the objects. When a visual task is learned by a person, the latency and the peak velocity, inversely modulate according to each other under predictable and non-predictable conditions. This research will compare neural activity results during predictable and non-predictable visual conditions using Functional Magnetic Resonance Imaging (fMRI) in humans. FMRI indirectly measures neural activity by directly measuring the hemodynamics of neural responses. There were three primary results from this research; 1) activation was observed in occipital, frontal, temporal and cerebellar regions, 2) short-term neuroplasticity via recruitment and synchronization was observed in the cerebellar vermis 4/5, and 3) the frontal eye fields

within the frontal lobe had distinct areas of activity allocated for saccadic versus vergence eye movements. Activity was observed in the integration of oculo-motor functions and cognitive functions such as memory corresponding to the occipital lobe, the prefrontal cortex, the frontal lobe, and the parietal lobe of the brain was observed in subjects. Furthermore, software was written to quantify the amount of cortical area involved in different areas of activation. The saccadic and vergence systems show similarities in the use of predictive learning as well as distinct cortical locations allocated to each system. Neuroplasticity was observed which was person dependent.

**CORTICAL LOCATION OF SACCADIC AND VERGENCE OCULOMOTOR
LEARNING USING fMRI**

**by
Yelda Alkan**

**A Thesis
Submitted to the Faculty of
New Jersey Institute of Technology
In Partial Fulfillment of the Requirements for the Degree of
Master of Science in Biomedical Engineering**

Department of Biomedical Engineering

January 2008

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APPROVAL PAGE

**CORTICAL LOCATION OF SACCADIC AND VERGENCE
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TABLE OF CONTENTS

Chapter	Page
1 INTRODUCTION.....	1
1.1 Objective	1
1.2 Background Information	1
1.2.1. The Anatomy of the Eye	1
1.2.2. The Human Brain	21
1.2.3. Functional Magnetic Resonance Imaging (fMRI).....	55
2 METHODOLOGY	64
3 RESULTS	71
3.1. Regions of Activation for Subject 2 and Average of Eight Healthy Control Subjects	71
3.2 Boolean Comparison of Commonality and Differences between Saccades and Vergence	88
3.3 Oculomotor Learning	90
3.4 Quantification of Brodmann Areas for Subject 2.....	109
4 DISCUSSION	126
5 CONCLUSION	129
6 FUTURE RESEARCH	131
APPENDIX A ACTIVATED REGIONS OF SUBJECT 1 FOR SACCADE AND VERGENCE TRIALS	133
APPENDIX B ACTIVATED REGIONS OF SUBJECT 2 FOR SACCADE AND VERGENCE TRIALS	144
APPENDIX C ACTIVATED REGIONS OF SUBJECT 3 FOR SACCADE AND VERGENCE TRIALS	155

TABLE OF CONTENTS
(Continued)

Chapter	Page
APPENDIX D ACTIVATED REGIONS OF SUBJECT 4 FOR SACCADE AND VERGENCE TRIALS	162
APPENDIX E ACTIVATED REGIONS OF SUBJECT 5 FOR SACCADE AND VERGENCE TRIALS	172
APPENDIX F ACTIVATED REGIONS OF SUBJECT 6 FOR SACCADE AND VERGENCE TRIALS	182
APPENDIX G ACTIVATED REGIONS OF SUBJECT 7 FOR SACCADE AND VERGENCE TRIALS	195
APPENDIX H ACTIVATED REGIONS OF SUBJECT 8 FOR SACCADE AND VERGENCE TRIALS	205
APPENDIX I BASIC COMMAND LINES FROM AFNI	212
APPENDIX J CODE FOR MATLAB SECTION OF THE THESIS	215
REFERENCES	219

LIST OF FIGURES

Figure		Page
1.1	The structure of the eye.....	4
1.2	Rods and cons.....	4
1.3	The types of cells that form the retina.....	7
1.4	The visual pathway.....	7
1.5	The extraocular muscles.....	9
1.6	The parameters of the smooth pursuit movements.....	12
1.7	The representation of the parameters related to saccades.....	14
1.8	Example of vergence responses to 4 deg step changes.....	16
1.9	The model for representation of The Dual Mode Theory.....	16
1.10	Cortical pathways for saccadic eye movements in the monkey.....	20
1.11	Essential regions and pathways for saccade control.....	21
1.12	Lateral, medial, and inferior surfaces of the frontal lobe.....	23
1.13	Lateral and medial surface of the parietal lobe.....	24
1.14	Lateral, medial, and inferior surfaces of the temporal lobe.....	25
1.15	Lateral, medial and inferior surfaces of the occipital lobe.....	25
1.16	Areal map of the human cerebral cortex a) lateral b) medial views.....	51
1.17	Areal map of the myelogenetic areas in the human cerebral cortex a)lateral b) medial views.....	51
1.18	The orientation of protons relative to without RF pulse and with RF pulse.....	56
1.19	The hemodynamics of the blood with its changing characteristics depending on neural activation.....	59
1.20	The formation of BOLD signal.....	60

LIST OF FIGURES
(Continued)

Figure		Page
1.21	Start of Blood Oxygenation Level Dependent (BOLD) Imaging.....	62
1.22	Brain activity occurred under application of visual task and darkness.....	62
1.23	Activation on primary visual cortex.....	63
2.1	MRI compatible ISCAN monitor stand.....	64
2.2	ISCAN software was used for recording eye movements.....	65
2.3	Red and green glasses for subjects to achieve vergence eye movements...	65
2.4	Visual display in magnet.....	67
2.5	Representation of saccadic visual stimuli depending on Box Car Protocol.....	68
2.6	Representation of stimuli for vergence eye movements depending on Box Car Protocol.....	69
3.1	Image 55 for Saccade trials 1,4, and 6.....	72
3.2	Image 58 for Saccade trials 1,4, and 6.....	72
3.3	Image 67 for Saccade trials 1,4, and 6.....	73
3.4	Image 70 for Saccade trials 1,4, and 6.....	73
3.5	Image 76 for Saccade trials 1,4, and 6.....	74
3.6	Image 77, 80, and 97 for Saccade trials 1, 4, and 6, respectively.....	74
3.7	Image 86 for Saccade trials 1,4, and 6.....	75
3.8	Image 95 for Saccade trials 1,4, and 6.....	75
3.9	Image 103 for Saccade trials 1,4, and 6.....	76
3.10	Image 114 for Saccade trials 1,4, and 6.....	76
3.11	Image 55 for Vergence trials 2, 3, 5, and 7.....	77

**LIST OF FIGURES
(Continued)**

Figure	Page
3.12 Image 58 for Vergence trials 2, 3, 5, and 7.....	77
3.13 Image 67 for Vergence trials 2, 3, 5, and 7.....	78
3.14 Image 70 for Vergence trials 2, 3, 5, and 7.....	78
3.15 Image 76 for Vergence trials 2, 3, 5, and 7.....	79
3.16 Image 80 for Vergence trials 2, 3, 5, and 7.....	79
3.17 Image 86 for Vergence trials 2, 3, 5, and 7.....	80
3.18 Image 95 for vergence trials 2, 3, 5, and 7.....	80
3.19 Image 103 for vergence trials 2, 3, 5, and 7.....	81
3.20 Image 114 for Vergence trials 2, 3, 5, and 7.....	81
3.21 Image 50 for averaged data from eight subjects.....	82
3.22 Image 55 for averaged data from eight subjects.....	82
3.23 Image 58 for averaged data from eight subjects.....	83
3.24 Image 67 for averaged data from eight subjects.....	83
3.25 Image 70 for averaged data from eight subjects.....	84
3.26 Image 76 for averaged data from eight subjects.....	84
3.27 Image 80 for averaged data from eight subjects.....	85
3.28 Image 86 for averaged data from eight subjects.....	85
3.29 Image 95 for averaged data from eight subjects.....	86
3.30 Image 103 for averaged data from eight subjects.....	86
3.31 Image 114 for averaged data from eight subjects.....	87
3.32 Areas in Common to Vergence and Saccades.....	88

**LIST OF FIGURES
(Continued)**

Figure		Page
3.33	Areas activation in Saccade Experiment but NOT Vergence Experiment.....	89
3.34	Areas activation in Vergence Experiment but NOT Saccade Experiment.....	90
3.35	Image 55 for saccade trials 1, 4, and 6 of subject 2 for observing growing of regions.....	91
3.36	Image 58 for saccade trials 1, 4, and 6 of subject 2 for observing growing of regions.....	91
3.37	Image 67 for saccade trials 1, 4, and 6 of subject 2 for observing growing of regions.....	92
3.38	Image 70 for saccade trials 1, 4, and 6 of subject 2 for observing growing of regions.....	92
3.39	Image 76 for saccade trials 1, 4, and 6 of subject 2 for observing growing of regions.....	93
3.40	Image 77 for saccade trials 1, 4, and 6 of subject 2 for observing growing of regions.....	93
3.41	Image 86 for saccade trials 1, 4, and 6 of subject 2 for observing growing of regions.....	94
3.42	Image 95 for saccade trials 1, 4, and 6 of subject 2 for observing growing of regions.....	94
3.43	Image 103 for saccade trials 1, 4, and 6 of subject 2 for observing growing of regions.....	95
3.44	Image 114 for saccade trials 1, 4, and 6 of subject 2 for observing growing of regions.....	95
3.45	Image 55 for vergence trials 2, 3, 5 and 7 of subject 2 for observing growing of regions.....	96
3.46	Image 58 for vergence trials 2, 3, 5 and 7 of subject 2 for observing growing of regions.....	96

**LIST OF FIGURES
(Continued)**

Figure		Page
3.47	Image 67 for vergence trials 2, 3, 5 and 7 of subject 2 for observing growing of regions.....	97
3.48	Image 70 for vergence trials 2, 3, 5 and 7 of subject 2 for observing growing of regions.....	97
3.49	Image 76 for vergence trials 2, 3, 5 and 7 of subject 2 for observing growing of regions.....	98
3.50	Image 80 for vergence trials 2, 3, 5 and 7 of subject 2 for observing growing of regions.....	98
3.51	Image 86 for vergence trials 2, 3, 5 and 7 of subject 2 for observing growing of regions.....	99
3.52	Image 95 for vergence trials 2, 3, 5 and 7 of subject 2 for observing growing of regions.....	99
3.53	Image 103 for vergence trials 2, 3, 5 and 7 of subject 2 for observing growing of regions.....	100
3.54	Image 114 for vergence trials 2, 3, 5 and 7 of subject 2 for observing growing of regions.....	100
3.55	Image 55 for saccade trials 1, 3, and 5 of subject 7 for observing increase in intensity.....	101
3.56	Image 58 for saccade trials 1, 3, and 5 of subject 7 for observing increase in intensity.....	101
3.57	Image 67 for saccade trials 1, 3, and 5 of subject 7 for observing increase in intensity.....	102
3.58	Image 70 for saccade trials 1, 3, and 5 of subject 7 for observing increase in intensity.....	102
3.59	Image 80 for saccade trials 1, 3, and 5 of subject 7 for observing increase in intensity.....	103
3.60	Image 86 for saccade trials 1, 3, and 5 of subject 7 for observing increase in intensity.....	103

**LIST OF FIGURES
(Continued)**

Figure		Page
3.61	Image 103 for saccade trials 1, 3, and 5 of subject 7 for observing increase in intensity.....	104
3.62	Image 114 for saccade trials 1, 3, and 5 of subject 7 for observing increase in intensity.....	104
3.63	Image 55 for vergence trials 2, 4, and 6 of subject 7 for observing increase in intensity.....	105
3.64	Image 58 for vergence trials 2, 4, and 6 of subject 7 for observing increase in intensity.....	105
3.65	Image 67 for vergence trials 2, 4, and 6 of subject 7 for observing increase in intensity.....	106
3.66	Image 70 for vergence trials 2, 4, and 6 of subject 7 for observing increase in intensity.....	106
3.67	Image 80 for vergence trials 2, 4, and 6 of subject 7 for observing increase in intensity.....	107
3.68	Image 86 for vergence trials 2, 4, and 6 of subject 7 for observing increase in intensity.....	107
3.69	Image 103 for vergence trials 2, 4, and 6 of subject 7 for observing increase in intensity.....	108
3.70	Image 114 for vergence trials 2, 4, and 6 of subject 7 for observing increase in intensity.....	108
3.71	Image 58 for saccade trials 1, 4, and 6 of subject 2 before MatLab application for Brodmann area 17.....	110
3.72	Image 58 for saccade trials 1, 4, and 6 of subject 2 after tracing of boundaries for Brodmann area 17.....	110
3.73	Image 58 for saccade trials 1, 4, and 6 of subject 2 after cropping the traced regions for Brodmann area 17.....	111
3.74	Image 58 for saccade trials 1, 4, and 6 of subject 2 before MatLab application for components of basal ganglia.....	111

**LIST OF FIGURES
(Continued)**

Figure		Page
3.75	Image 58 for saccade trials 1, 4, and 6 of subject 2 after tracing of boundaries for components of basal ganglia.....	112
3.76	Image 58 for saccade trials 1, 4, and 6 of subject 2 after cropping the traced regions for components of basal ganglia.....	112
3.77	Image 86 for saccade trials 1, 4, and 6 of subject 2 before MatLab application for Brodmann area 9.....	113
3.78	Image 86 for saccade trials 1, 4, and 6 of subject 2 after tracing of boundaries for Brodmann area 9.....	113
3.79	Image 86 for saccade trials 1, 4, and 6 subject 2 after cropping the traced regions for Brodmann area 9.....	114
3.80	Image 103 for saccade trials 1, 4, and 6 subject 2 before MatLab application for Brodmann area 8.....	114
3.81	Image 103 for saccade trials 1, 4, and 6 of subject 2 after tracing of boundaries for Brodmann area 8.....	115
3.82	Image 103 for saccade trials 1, 4, and 6 of subject 2 after cropping the traced regions for Brodmann area 8.....	115
3.83	Image 103 for saccade trials 1, 4, and 6 of subject 2 before MatLab application for Supplementary motor area (SMA).....	116
3.84	Image 103 for saccade trials 1, 4, and 6 of subject 2 after tracing of boundaries for Supplementary motor area (SMA).....	116
3.85	Image 103 for saccade trials 1, 4, and 6 of subject 2 after cropping the traced regions Supplementary motor area (SMA).....	117
3.86	Image 58 for vergence trials 2, 3, 5 and 7 of subject 2 before MatLab application for Brodmann area 17.....	118
3.87	Image 58 for vergence trials 2, 3, 5 and 7 of subject 2 after tracing of boundaries for Brodmann area 17.....	118
3.88	Image 58 for vergence trials 2, 3, 5 and 7 of subject 2 after cropping the traced regions for Brodmann area 17.....	119

LIST OF FIGURES
(Continued)

Figure		Page
3.89	Image 58 for vergence trials 2, 3, 5 and 7 of subject 2 before MatLab application for components of basal ganglia.....	119
3.90	Image 58 for vergence trials 2, 3, 5 and 7 of subject 2 after tracing of boundaries for components of basal ganglia.....	120
3.91	Image 58 for vergence trials 2, 3, 5 and 7 of subject 2 after cropping the traced regions for components of basal ganglia.....	120
3.92	Image 86 for vergence trials 2, 3, 5 and 7 of subject 2 before MatLab application for Brodmann area 9.....	121
3.93	Image 86 for vergence trials 2, 3, 5 and 7 of subject 2 after tracing of boundaries for Brodmann area 9.....	121
3.94	Image 86 for vergence trials 2, 3, 5 and 7 subject 2 after cropping the traced regions for Brodmann area 9.....	122
3.95	Image 103 for vergence trials 2, 3, 5 and 7 of subject 2 before MatLab application for Brodmann area 8.....	122
3.96	Image 103 for vergence trials 2, 3, 5 and 7 of subject 2 after tracing of boundaries for Brodmann area 8.....	123
3.97	Image 103 for vergence trials 2, 3, 5 and 7 of subject 2 after cropping the traced regions for Brodmann area 8.....	123
3.98	Image 103 for vergence trials 2, 3, 5 and 7 of subject 2 before MatLab application for Supplementary motor area (SMA).....	124
3.99	Image 103 for vergence trials 2, 3, 5 and 7 of subject 2 after tracing of boundaries for Supplementary motor area (SMA).....	124
3.100	Image 103 for vergence trials 2, 3, 5 and 7 of subject 2 after cropping the traced regions for Supplementary motor area (SMA).....	125

CHAPTER 1

INTRODUCTION

1.1 Objective

The first goal of this thesis is to investigate which areas are involved in the oculomotor learning of visual tasks using saccadic and vergence eye movements. Substantial background research had studied to hypothesis the relationship between the regions of activation and the task studied. The second aim is quantification of activated area.

1.2 Background Information

1.2.1. The Anatomy of the Eye

The early stages of the visual processing occur in the eye. The description of the anatomy of the eye is important for understanding how the components of the eye are involved in adjusting the light that reaches the photosensitive surface, fixating on near and far objects, keeping stable relationship between the focusing structure and the photosensitive surface, and recording the pattern of incoming light. The eye is formed by three main tissue layers which are named as sclera, uvea, and retina (Nolte, 2002, pp. 411).

The sclera is the outermost layer of the eye which is also known as the white of the eye. This layer is extended posteriorly functioning as a cover of the optic nerve. The limbus and the cornea are two sections that belong to the sclera. The limbus is a circular transition region situated between the cornea and the sclera. The cornea is avascular, transparent, and highly curved section which surrounds the anterior of the sclera. The

light that reaches to the eye from peripheral world is first admitted by the cornea (Nolte, 2002, pp. 411; Cassin and Solomon, 2007).

The uvea or uvea tract is the second tissue layer between the sclera and the retina. The structure of the eye encompasses blood vessels and nerves that travel within the wall of the eye beside the optic nerve. The choroid is a highly pigmented extent of the uvea where choroidal capillaries nourish retinal photoreceptors by blood, and the pigment of the choroid absorbs the light. The ciliary body, the iris, the suspensory ligament and the lens are other components of the uvea. The ciliary body adheres to the lens by connective tissue which is called as the zonule of Zinn and is responsible for accommodation, aqueous humor production, the production and maintenance of the lens zonules and waste management from these regions. The secretion of aqueous humor is the essential role of the ciliary body for supplying necessary nourishment to the lens and the cornea (Cassin and Solomon, 2007). Accommodation, how the eye focuses on object near or far, is achieved by the contraction and relaxation of the ciliary muscle. The lens, one of the components of the uvea, is involved in execution of accommodation function. The lens has elastic characteristics suspended by circular fibrous ligaments which are also called as the suspensory ligaments in the ciliary muscle. The lens is held by the suspensory ligaments by the inner pressure of the eye. The relaxation of the ciliary muscle causes the lenses to be flattened and results in fixation on farther objects. The contraction of the ciliary muscle increases tension on the lens where the lens curves outward and focuses on nearby objects (Cassin and Solomon, 2007; Nolte, 2002, pp. 411). The iris is located in front of the lens with a variable-sized and has a black opening in the center called the pupil. The function of the iris is to adjust the amount of light that enters through the

pupil. The rapid light adaptation starts within the iris and continues with slower mechanism that occurs on the photoreceptors (Goebel, Muckli, Kim, 2004, pp.1281).

The retina, the inner membrane of the eye, encompasses 120 million neurons. The outer nuclear layer, the outer plexiform layer, inner nuclear layer and ganglion cell layer are the five layers that form the structure of the retina. The transduction process occurs in the retina, and is described as encoding visual input into neuronal signals and obtaining information about the visual input that enters. The macula is a region on the retina and another area located in the center of the macula is named as fovea. The best vision occurs in the fovea because it has the highest density of photoreceptors. The fovea is the only area of the retina that neuronal and vascular circuitry parallel to each other which provides light a direct communication with the photoreceptors. Rods and cones are types of photoreceptors composed of the outer segment including the photosensitive pigment, an inner segment, a cell body, and a synaptic terminal (Goebel, Muckli, Kim, 2004, pp.1282). The first nuance starts with the location of rods and cones. The rods are situated in the periphery of the fovea and the cones are highly aggregated in the fovea. Rods are highly sensitive to the light and are used for night vision. Cones have low sensitivity to light hence are used primarily for day vision. Although cones have high temporal resolution with a quick response and short integration time, rods have low temporal resolution with a slow response and long integration time. Scattered light is highly perceived by rods and direct axial rays are quickly perceived by cones. Rods have more photo pigment and obtain more light where cones have opposite characteristics. The final observed difference occurs in amplification. The rods are involved in high amplification, whereas cones use lower amplification (Kandel, 2000, pp. 509).

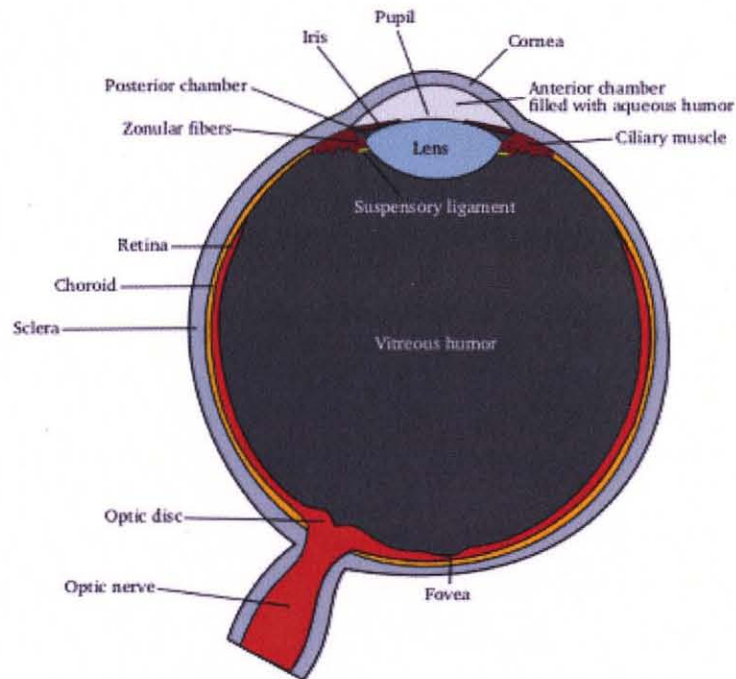


Figure 1.1 The structure of the eye (Wikimedia, 2007).

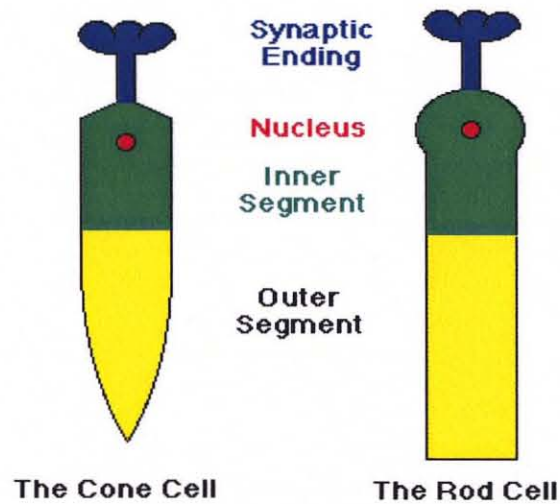


Figure 1.2 Rods and cons (Thinkquest, 2007).

1.2.1.1 The Early Stages of the Visual Pathway. When the light enters, it first penetrates through the cornea, and continues its way through the aqueous humor to the iris. According to the amount of light, the pupil constricts and enlarges adjusting to the lighting conditions. After adjustment of the pupil, the lens regulates the fixation between near and far objects by becoming flattened or tightened. Vitreous humor is a gelatinous substance which fills the space behind the lens and is responsible for conveying the light to the retina (Nolte, 2002, pp.412; Anatomy of the human eye, 2001). The projection of the visual input from the retina to the brain is accomplished by photoreceptors, bipolar cells, horizontal cells, amacrine cells, and ganglion cells (Goebel, Muckli, Kim, 2004, pp.1282). Photoreceptors convert the light into the electrochemical signals. Bipolar cells are involved in detecting contrast and edge. Horizontal cells are situated among photoreceptors, bipolar cells, and other cells. Horizontal cells allow better contrast to distinguish objects better. Amacrine cells are arranged perpendicular to the photoreceptors, bipolar and ganglion cells, located between bipolar and ganglion cells (Kandel, 2000, pp. 520; Ranpura, 2007; An eye in vision: Anatomy of the human eye, 2001; Horizontal cells, 2007; Nelson, 2007; The eye: Visual System, 2007). Ganglion cells are the last layer of the retina. The optic nerves, the optic chiasm and optic tracts are three structures which are formed by the axons of the ganglion cells. The function of the ganglion cells is to collect light and obtain information about color, form and motion features of the visual input and transfers the pre-processed image to the related centers in the brain (Nelson, 2007; Goebel, Muckli, Kim, 2004, pp.1285). The extracted information is carried to the regions in the brain via the optic nerve. The optic nerve is also called the blind spot because does not have any photoreceptors. The intersection of

fibers which are originated from retina form a zone known as optic chiasm (Kandel, 2000, pp. 525). The fibers that belong to the left half of the each retina continues through the right side of the brain, and, the fibers of the right half of the each retina divide to left side of the brain. This organization of the fibers results in comprehending right visual world by the left half of the brain, and comprehending of left visual world by the right half of the brain. The axons of all ganglion cells that belong to the retina elongate through the optic disc and constitute the bilateral optic nerves. The optic chiasm is a point where the bilateral optic nerves intersect and separate inversely. The bilateral optic tracts gather these nerves and project through three major subcortical regions which are named as the prectum, the superior colliculus, and the lateral geniculate nucleus. From these three subcortical regions, the visual input is transmitted to the striate (Brodmann's area 17/V1) and extrastriate areas (Brodmann's area 18/V2, Brodmann's area 19/V3) which are located in the occipital lobe (Kandel, 2000, pp. 526; Ranpura, 2007; An eye into Vision: Anatomy and eye, 2007; The eye: Visual System, 2007).

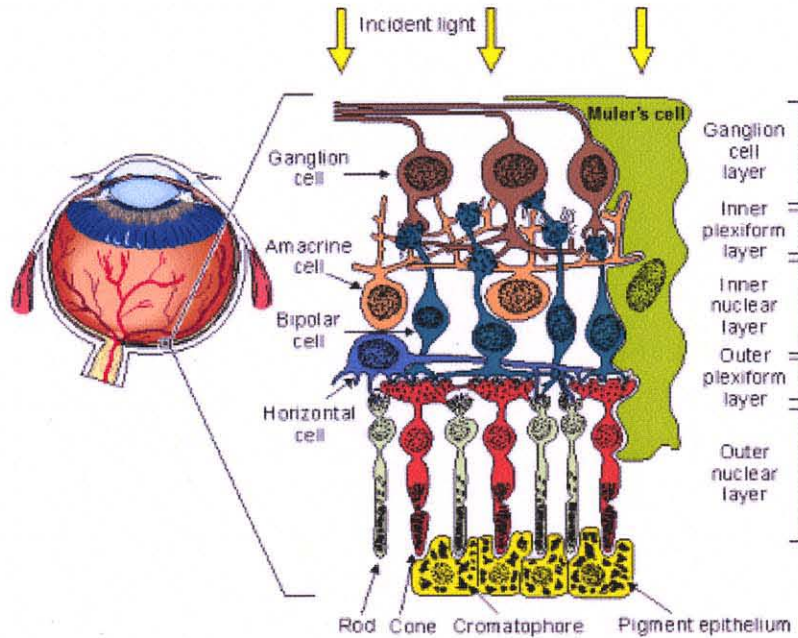


Figure 1.3 The types of cells that form the retina (Malmivvo and Plonsey, 1995).

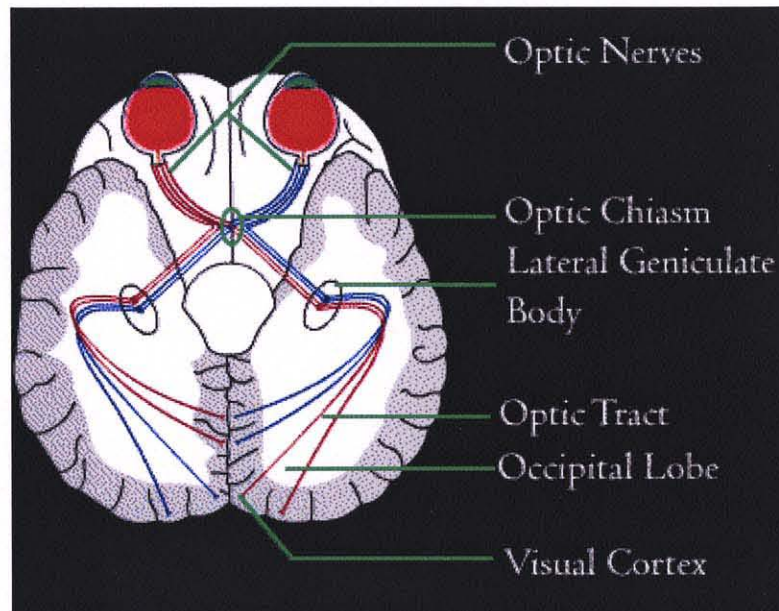


Figure 1.4 The visual pathway (Keenan, 2007).

1.2.1.2 The Extraocular Muscles of the Eye. The geometry of the eye and the extraocular muscles are important topics to understand how eye movements are generated based upon the rotation of the globe of the eye in the socket of the orbit. The eyes move in three axes which are named as horizontal, vertical, and torsional. Abduction, adduction, elevation, depression, intorsion, and extorsion are essential terms that are used to explain the movements of the eye. Abduction occurs when the eye moves away from the nose, whereas adduction is eye movement towards the nose. Elevation is described as the vertically upward movement of the eye, whereas depression occurs when the eye moves downward. The line of the sight does not change because of the torsional movements, but cause rotation of the eye around it. When intorsion is needed, the top of the cornea rotates toward the nose and when the extorsion is needed, the top of the cornea moves away from the nose (Kandel, 2000, pp. 786). There are six extraocular muscles which are called as the medial rectus, the lateral rectus, the superior rectus, the inferior rectus, the superior oblique, and the inferior oblique. The control of the horizontal position of each eye is provided by the medial and lateral rectus muscles. When the medial rectus adducts the eye, the lateral abducts it, so the lateral and medial recti have antagonistic effect on each other. The superior rectus is activated during elevation and the activation of the inferior rectus is needed for depression (Glimcher, 2003, pp. 874). The function of the superior oblique is intorsion, whereas, extorsion occurs when the inferior oblique muscle is activated (The oculomotor system: Anatomy and Physiology, 2007; Montgomery, 2007).

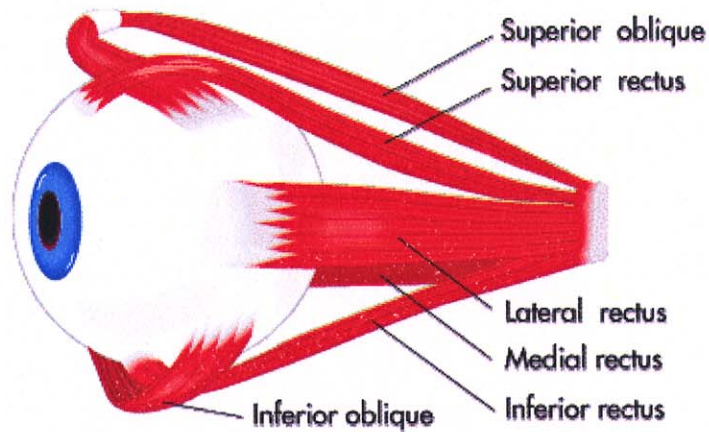


Figure 1.5 The extraocular muscles (Howstuffworks, 2007).

1.2.1.3 The Eye Movements. The harmonious relationship between head and eye movements provides the required fixation of the fovea on the visual stimuli which is called gaze (Kandel, 2000, pp. 796). The eye movements are accomplished by gaze mechanisms which are categorized as gaze-stabilization and gaze-shifting mechanism. Gaze-stabilization mechanism controls the oculo-motor movements with respect to the position of the head and can be divided as vestibulo-ocular systems and optokinetic systems. Gaze-shifting mechanisms are evolved to generate higher acuity and resolution characteristics for visual stimuli by utilizing the eye muscles effectively. Gaze-shifting mechanisms are separated into three groups which are called as the smooth pursuit system, the saccadic system, and the vergence system (Glimcher, 2003, pp. 874).

1.2.1.4 Gaze-Stabilization Mechanisms

Vestibulo-ocular Movements (vor)

This is a reflex type of movement that stabilizes the visual target on the fovea during the movements of the head by creating opposite motion according to the direction of the movement of the head which provides protection for image on the center of the visual field. For example, when the head turns right, the eyes move to the left. The VOR does not need any feedback which means it is operating even when the eyes are closed. The ratio of change in the eye angle to the change in the head angle during the head movement is called the gain of VOR and can not be greater than one. For providing more accurate and improved eye motions, the gain of the VOR is adjusted by motor learning and this process is named as VOR adaptation (Kandel, 2000, pp. 796; Straka and Dieringer, 2004).

Optokinetic Movements

The optokinetic movements are achieved under lower speeds when it is compared with vestibulo-ocular movements, because they depend on the photoreceptors. The photoreceptors are used for providing speed and direction of the motion and by shifting the fovea to the visual periphery (Glimcher, 2003, pp. 873).

1.2.1.5 Gaze-Shifting Mechanisms

Smooth Pursuit Eye Movements

Smooth pursuit system is activated when the visual target moves across a stationary background where this moving target is followed by the fovea. The smooth pursuit eye movements are created from the optokinetic system. The similarity between the smooth pursuit and the optokinetic systems is explained as the limitation on the velocity which is provided by the movements of the eye and the stimuli moving across the retina. The difference between these two systems is defined as the smooth pursuit system functions when there are movements of small targets, whereas the optokinetic system is activated for movements of the entire world (Glimcher, 2003, pp. 874). Smooth pursuit eye movements have two phases that can be categorized as initiation and maintenance. Initiation provides necessary information about the optical motion processing for tracking the target. Maintenance is the second phase which is concerned with updating and improving the internal, also mental representation of moving target. Initial acceleration, peak velocity, velocity at set time points, and finally latency are four parameters of the smooth pursuit eye movements. The change in the eye velocity is defined as initial acceleration. When smooth pursuit eye movements start, the characteristics of the target such as target speed and position are ignored in the 20 ms that occur. Target speed and position start to be more essential parameters for the next 80 ms which create noticeable effects on acceleration. The smooth pursuit eye movement can be evaluated as an open loop system for the initial 100 ms, because the delays in visual system provide no visual feedback. Optical feedback and other sources of information are used for closing the loop and enhancing performance after 100 ms. When the pursuit begins; the velocity firstly

reaches to a maximum, then decreases slowly and finally oscillates around the target velocity. The gain is computed by the ratio between the peak velocity and target velocity. Velocity at set time points is needed when the velocity at specific times is required corresponding to the appearance of the target or beginning of the track. The time from the appearance of target to the beginning of track is qualified as the latency (Knox, 2007).

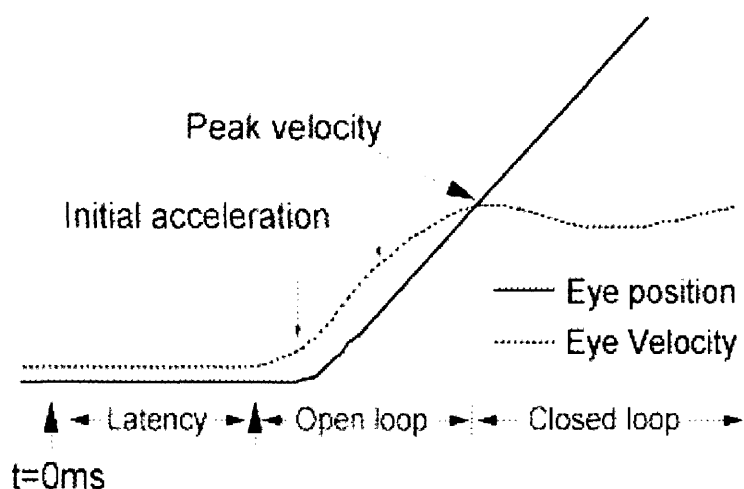


Figure 1.6 The parameters of the smooth pursuit movements (Knox, 2007).

The Saccadic oculo-motor Movements

The saccadic eye movements are the most well studied oculo-motor system and are defined as gaze-shifting responses of the eyes with a high velocity. The line of sight is approximately rotated $800^{\circ}/s$. The saccadic eye movements are fast and conjugate eye movements which can be horizontal and/or vertical where both eyes move to the same direction.

There are two purposes for the saccadic system; 1) to achieve a dynamic force pulse where high velocity to the eye is provided and 2) to generate an increase in the static holding force that is used for keeping the eye at its new orbital position. When both goals are accomplished successfully, the eye creates a saccadic movement. Visual, somatosensory or auditory stimuli are used for computing the rotation of the eye needed for alternating the line of the sight according to the location of the visual target for the saccadic system. The static and dynamic forces required for the preferred eye rotation depends upon the magnitude and direction of alteration in position of the eye which is also defined as motor error (Glimcher, 2003, pp. 882; Nolte, 2002, pp. 515-517). Amplitude, peak velocity, duration, and latency are four important parameters related to saccades. Amplitude is the magnitude of the saccadic system which is represented in degrees or minutes of arc. The accuracy of the saccadic eye movements is extracted from the amplitude which is named as gain. When the actual saccade amplitude is divided by the desired saccade amplitude, the ratio that is yielded by this division provides the gain. Gain that is smaller than one indicates that the saccade is too small or hypometric; on the other hand, gain that is greater than one implicate large or hypermetric saccadic condition. Peak velocity is the greatest velocity during execution of the saccade. Duration is the time interval at which the saccade is completed. The final parameter which is called the latency is described as the response of the visual system corresponding to the time which starts by the appearance of the target till beginning of the saccadic eye movement (Knox, 2007).

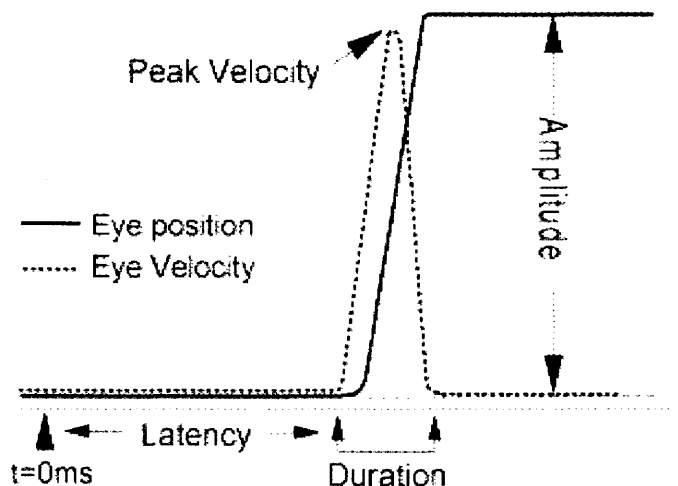


Figure 1.7 The representation of the parameters related to saccades (Knox, 2007).

The saccades can be categorized as reflexive visually guided saccades and volitional saccades. Reflexive visually-guided saccades are executed, when appearance of newly target is emerged while a person is looking at a precedent target. The overlap task is a technique that is used for creating reflexive visually-guided saccades under laboratory conditions. The overlap task is generated by providing a continually appearing target and a sudden peripheral target in which refixation is needed. The refixation process is achieved by disengagement of attention, substituting of attention from the fixation target to the new target, and the disengagement of fixation. Volitional saccades have four subdivisions which are called as predictive saccades, self-paced saccades, antisaccades (contralateral saccades), and memory-guided saccades. Predictive saccades are obtained when the location of the anticipated target stimuli is known but has not been visible yet. Self-paced saccades are applied between previously chosen targets. Antisaccades or contralateral saccades are produced when the position of appearing and the given direction are opposite to each other. Antisaccades are achieved depending on attention

and volitional effort in which reflexive saccades has to be suppressed (Sharpe, 1998). Memory-guided saccades are produced in which the subject fixates a central point at the beginning that can be defined as a signal needed for making voluntary eye movement, and then the person who is instructed to memorize the locations of a flashed target in the peripheral visual field, tries to remember the position of the target when the central fixation point is turned off (Deseilligny-Pierrot et al. 2002). Prosaccades is another group that can be listed down under volitional saccades which are explained as saccades that occurs when pointing direction and the location are congruent (Olk et al. 2006).

Vergence Eye Movements

Vergence oculo-motor movements provide binocular vision and fovea-like specializations. The angle that belongs to the lines of gaze of the two eyes is controlled to see a single visual target with both eyes. The disparity vergence system can be separated into two subdivisions which are called as convergence and divergence. When the visual stimulus moves closer to the eyes, foveal fixation is accomplished by incongruent movements of both eyes toward the nose which is named as convergence. The divergence occurs when the visual target moves farther away from the eyes, in which foveal fixation is obtained by inharmonious movements of both eyes away from the nose (Glimcher, 2003, pp. 889; Nolte, 2002, pp. 521). The essential purpose of the convergence and divergence is to reduce disparity which is defined as location difference that occurs between the back of the retina and the fovea where the visual input is projected. Disparity causes for a person to perceive the visual target as two so that subdivisions of the vergence system emerge to compensate disparity-related errors (Daftari et al. 2004). The

control of vergence systems is explained with a theory which is called as the Dual Mode Theory (Hung et al. 1986). The Dual Mode Theory indicated that the dynamic characteristics of the vergence eye movements encompass two components which are named as transient component and sustained component. The transient component is fast, pre-programmed and open-loop control process which is used for providing accurate fixation on the visual target by bringing the eyes to the right position. The sustained component is responsible for correcting errors that occurred in execution of the initial transient response which results in perceiving a single image and successful slow tracking of the moving targets for a person (Munoz et al. 1997).

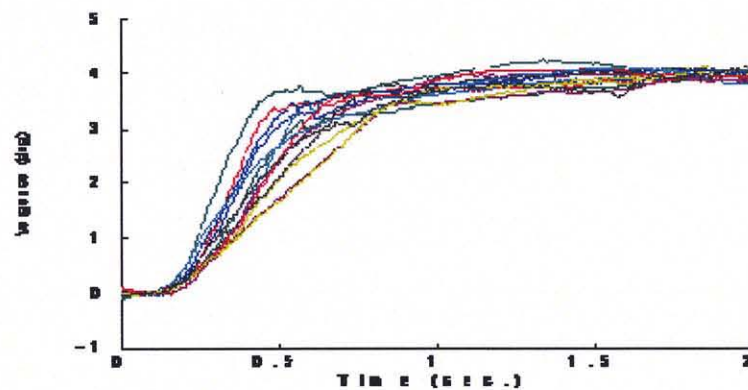


Figure 1.8 Example of vergence responses to 4 deg step changes.

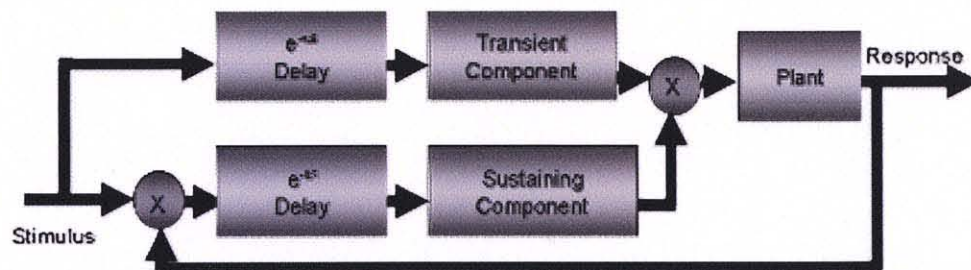


Figure 1.9 The model for representation of The Dual Mode Theory (Hung, et al. 1986).

1.2.1.6 Cerebral Control of Oculo-motor Movements. Eye movements are mediated by the extraocular eye muscles. The utilization of these muscles to obtain and control eye movements can be evaluated as just the appearing portion of the iceberg. When a profound assessment is done, it is observed that the eye movements are also the result of cognitive functions which are driven by the cortical regions of the brain. Each of the eye movements comprehend different cortical networks for preparing and triggering with respect to the type of oculo-motor movement. The coordination of cerebral cortex and subcortical regions which are involved in saccadic eye movements are well defined by investigators. Other oculo-motor systems like vergence need more research about which regions of the brain participate and correlate to each other to produce related eye movement and how the formed specific brain regions network processes for that oculo-motor movement.

The saccadic eye movements are generated by the brainstem which functions as a trigger for the muscles to achieve this oculo-motor movement. Pontine and mesencephalic regions which are components of brainstem drive dynamic signals for saccades and are controlled by the superior colliculus. The superior colliculus, a multilayered structure, is responsible for integrating visuomotor signals. The superficial layers, the intermediate layers, and the deep layers form the structure of the superior colliculus where each of these layers has diverse roles. Projection of the right and left visual world and visual input from the retina are obtained by the three superficial layers of the superior colliculus. The neurons in the superficial layers respond the visual stimuli. Oculo-motor movements create activation on the cells within two intermediate and deep layers of the superior colliculus. The intermediate layers of the rostral part of the superior

colliculus are activated during visual fixation and before execution of contralateral saccades (antisaccades) so that this section of the superior colliculus is named as “fixation zone”. Extrastriate (Brodmann’s area 18/V2; Brodmann’s area 19/V3), middle temporal (MT/V5), and parietal regions define cortical areas on the brain, are involved in transferring the visual information to the movement-related cells of the intermediate and deep layers, whereas the motor information is conveyed via the frontal eye field (Brodmann’s area 8) which is another region on the cerebral cortex of the brain (Kandel, 2000, pp. 792-793).

Beside the brainstem regions and the superior colliculus, the regions like the frontal eye field (FEF/Brodmann’s area 8) on the cerebral cortex are important for the saccadic system. The FEF, the supplementary eye field (SEF), and the parietal eye field (PEF) within the posterior parietal cortex are involved in programming and execution of saccades. Moreover, the FEF and the lateral intraparietal area of the posterior parietal cortex (portion of Brodmann’s area 7) are responsible for the control of the superior colliculus. The dorsolateral prefrontal cortex (DLPFC/Brodmann’s area 9), the pre-SEF, and the cingulate cortex are responsible for the programming of saccades (Milea et al. 2005).

The roles of the FEF, the SEF, the posterior parietal cortex, and DLPFC have to be well understood in the circuit of the saccadic system. The FEF has three different types of neurons which are called as visual neurons, movement-related neurons, and visuomovement neurons. The features of the visual neurons can be revealed as being highly responsive to visual input and not having projections to the superior colliculus. Movement-related neurons are activated before and during all saccades if the visual

inputs are the targets of saccades. Unlike visual neurons, these neurons have projections to the superior colliculus. Visuomotor neurons are responsive for both visual and movement-related activity and fire up best before execution of visually-guided saccades. There are two ways the FEF activates its influence on the superior colliculus. First, the movement-related neurons in this region affect same type of neurons of the intermediate layers which belong to the superior colliculus. Secondly, movement-related neurons of the similar layers trigger the neurons of the caudate nucleus which is a component of basal ganglia by applying excitatory synapses to suppress the substantia nigra which is a nucleus in the midbrain and creates obstacles in the generation of saccades. Consequently, this communication between neurons that is related to the two different regions results in inhibition of effects of substantia nigra on the saccadic system. The supplementary eye field (SEF) another region that has to be evaluated for the control of saccades, because it is more involved in cognitive side of the saccades which means neurons of this region are capable of producing saccades through just preferred portion of a target rather than an absolute saccade direction. The posterior parietal cortex (PPC) which includes Brodmann's areas 5 and 7 is responsible for supplying visual attention. Any impairment on the PPC causes latency in saccades and inaccuracy in targeting. The dorsolateral prefrontal cortex (Brodmann's area 9) functions as a memory region when the location of the target has to be remembered by the saccadic oculo-motor movements (Kandel, 2000, pp. 794).

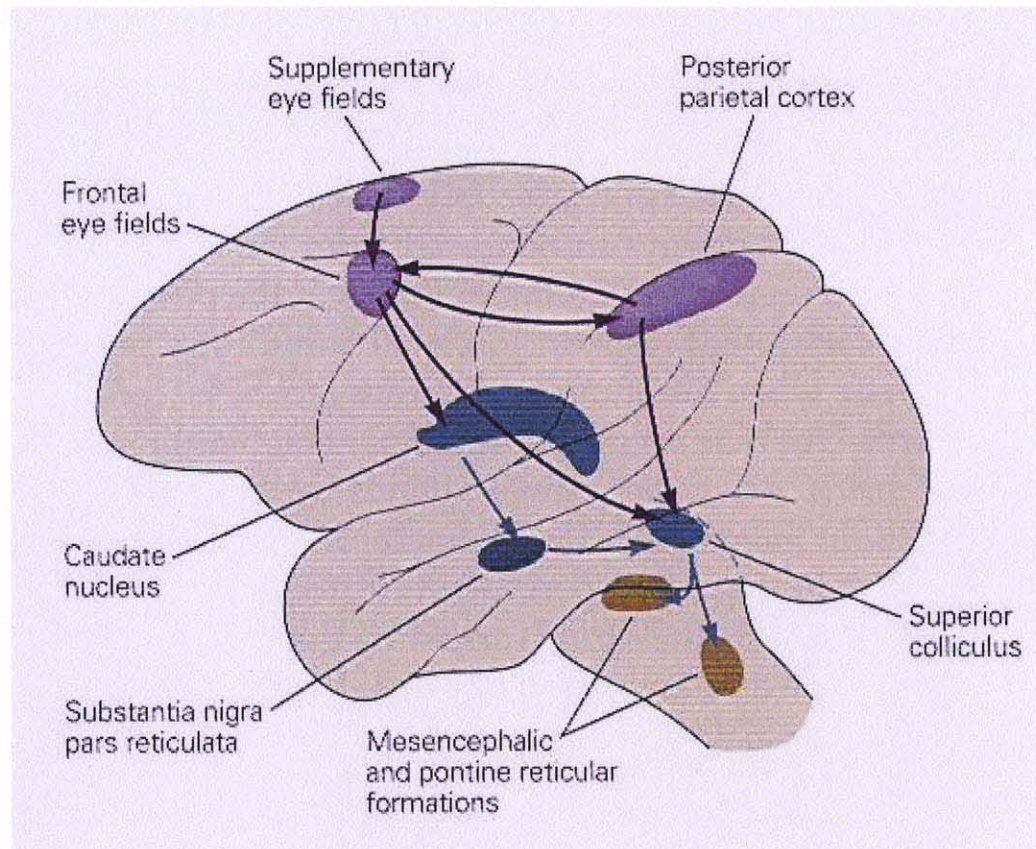
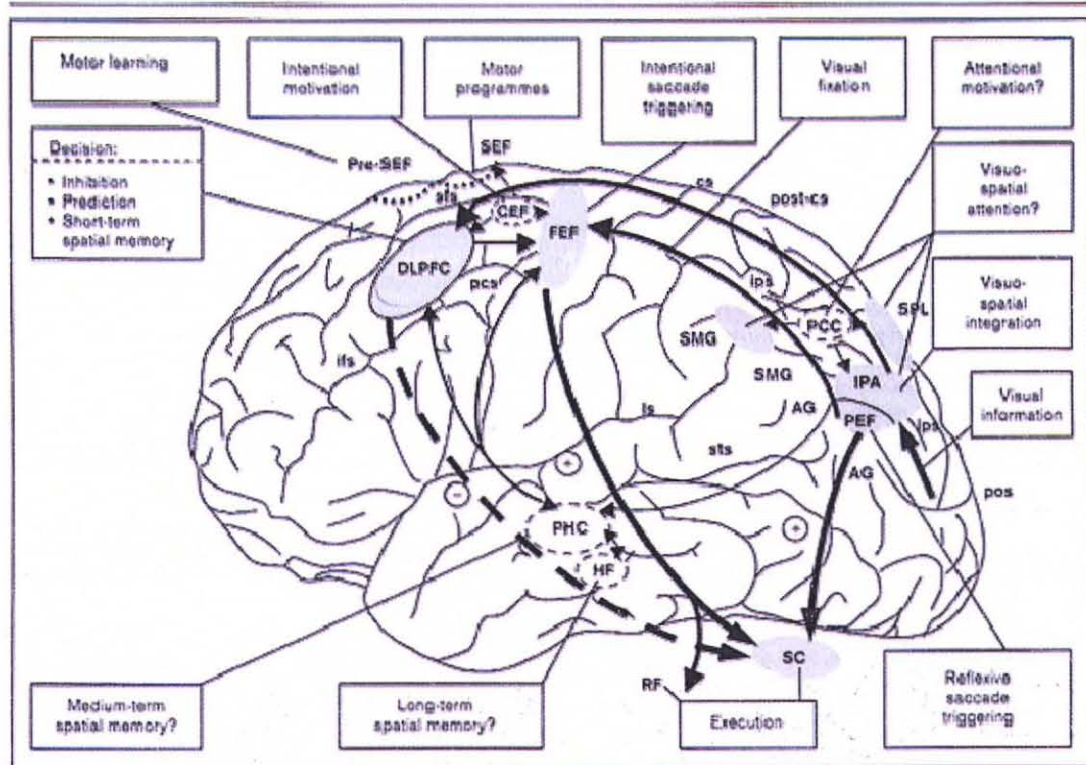


Figure 1.10 Cortical pathways for saccadic eye movements in the monkey (Kandel, 2000, pp. 793).



SEF, supplementary eye field; sfs, superior frontal sulcus; CEF, cingulate eye field; cs, central sulcus; DLPPFC, dorsolateral prefrontal cortex; pca, precentral sulcus; FEF, frontal eye field; ips, intraparietal sulcus; ifs, inferior frontal sulcus; SMG, supramarginal gyrus; PCC, posterior cingulate cortex; SPL, superior parietal lobule; IPA, intraparietal areas; ls, lateral sulcus; AG, angular gyrus; PEF, posterior eye field; sts, superior temporal sulcus; pos, parieto-occipital sulcus; PHG, parahippocampal cortex; HF, hippocampal formation; SC, superior colliculus; RF, reticular formations.

Figure 1.11 Essential regions and pathways for saccade control (Deseilligny-Pierrot et al. 2004).

1.2.2. The Human Brain

1.2.2.1 Lobes of Cerebral Cortex And Brodmann Areas.

The peripheral nervous system (PNS) and the central nervous system (CNS) are subdivisions of the nervous system (Nolte, 2002, p.1). The CNS itself is divided into the brain and the spinal cord (Nolte, 2002, p.1). The brain is composed of cerebral hemispheres where both of them include the cortex and basal ganglia (Swanson, 2003, p. 40-41). Both hemispheres of the brain are approximately similar to each other. The dorsal midline is divided by the deep interhemispheric (longitudinal) fissure (Swanson, 2003, p. 40-41). The gyri which are developed during embryogenesis are folds and separated by invaginations. These

invaginations are called as sulci and where deeper invaginations are named fissures (Swanson, 2003, pp. 40-41). The gyri and the sulcus of the two sides have different patterns. The large surface area of the cerebral cortex is accomplished by this folding. The anatomical landmarks of the human cerebral hemispheres are the central sulcus (sulcus of Rolando (Nolte, 2002, pp.57) and the lateral (Sylvian) fissure. The external surface of the cerebral cortex has four main lobes which are frontal, parietal, temporal, and occipital. Moreover, the retrosplenial, the hippocampal, the cingulate and the insular regions are subareas of the cerebral cortex (Garey, 2006, pp. 122-126).

The frontal lobe starts from anterior part of the brain and continues through the central sulcus. The frontal lobe and the temporal lobe are separated by the fissure of Sylvius (the lateral sulcus). The frontal lobe is connected to the cingulate sulcus on the medial surface. It is posteriorly elongated from the top of the central sulcus to the cingulate sulcus. The lateral surface of the frontal lobe includes four gyri. These four are named as the precentral, the superior, the middle and the inferior frontal gyri. The precentral gyrus precedes the central sulcus which is also parallel to the central sulcus and extends to the precentral sulcus. The superior, middle, and inferior frontal gyri are located parallel to each other and orthogonal to the precentral gyrus. Furthermore, the inferior frontal gyrus of the frontal lobe has three subdivisions which are named as the orbital part, the opercular part and the triangular part.

The remainder of the frontal lobe is known as the prefrontal cortex. The prefrontal cortex covers a very wide area on the frontal lobe with subdivisions which are laterally named as dorsal and ventral prefrontal cortex (Nolte, 2002, pp. 60; Miller and Wallis, 2003, pp. 1358). This anatomical structure increases the importance of the prefrontal

cortex in cognitive control. The prefrontal cortex is responsible for obtaining from and sending projections to forebrain systems which comprehends and processes information about the external world, motor system structures that produce voluntary movement, systems structures that consolidate long-term memories, and systems that processes information about affect and motivational states. It also encodes the locations of objects which are held in short-term memory (Colby and Olson, 2003, pp. 1245; Miller and Wallis, 2003, pp. 1359).

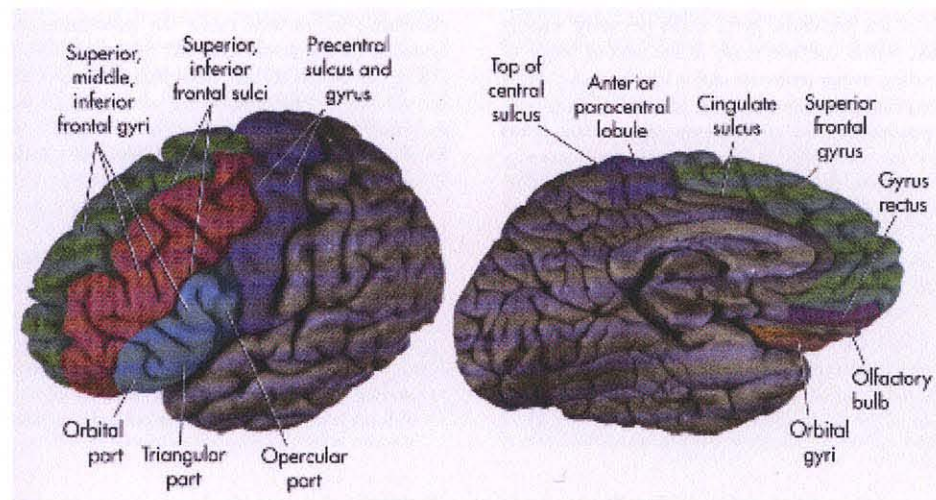


Figure 1.12 Lateral, medial, and inferior surfaces of the frontal lobe (Nolte, 2002, pp. 59).

The parietal lobe can laterally be separated into three regions; the postcentral gyrus, the superior and inferior parietal lobules. The postcentral gyrus is situated behind the central sulcus in a parallel way, and extends through the postcentral sulcus. The superior and inferior parietal lobules are divided by the intraparietal sulcus which is behind the postcentral sulcus and the occipital lobe. The supramarginal gyrus, which is a component of the inferior parietal lobule, covers the end of the lateral sulcus. The angular gyrus is another section of the inferior parietal lobule that spreads over the superior

temporal sulcus. The medial extension of the postcentral gyrus is linked to the medial surface of the parietal lobe which contains a region named the precuneus. The subparietal and calcarine sulci, the parietooccipital sulcus, and the marginal branch of the cingulate sulcus are boundaries of the precuneus. The paracentral lobule which partly belongs to the frontal and the parietal lobes is a name that is sometimes used to refer to the extensions of the precentral and postcentral gyri through the medial surface of the hemisphere (Colby and Olson, 2003, pp. 1230; Nolte, 2002, pp.60).

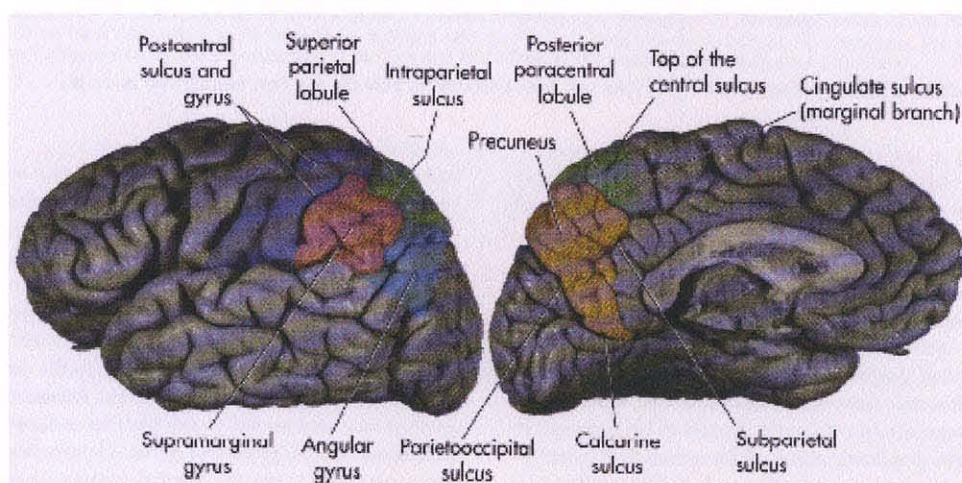


Figure 1.13 Lateral and medial surface of the parietal lobe (Nolte, 2002, pp. 60).

The temporal lobe laterally contains the superior, middle, and inferior temporal gyri. The superior layer of the temporal lobe elongates into the lateral sulcus and generates the temporal operculum. The inferior surface of the lobe includes the inferior temporal gyrus. The wide occipitotemporal (fusiform) gyrus which is partly linked to the occipital lobe and temporal lobe creates the rest of the inferior layer of the lobe.

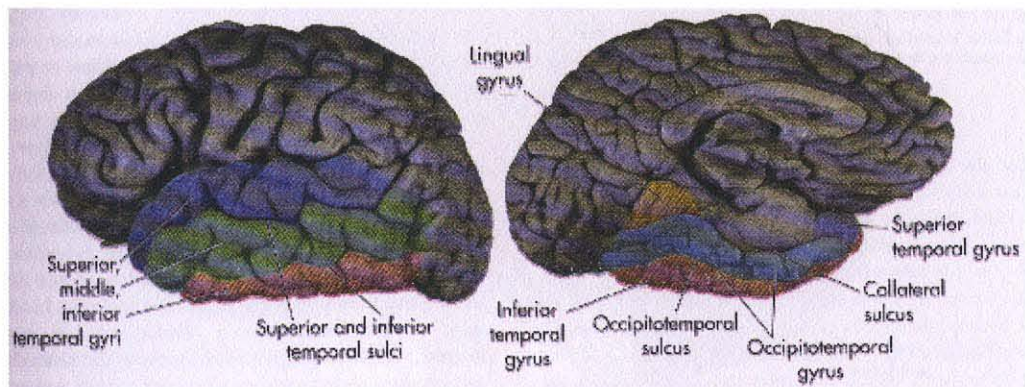


Figure 1.14 Lateral, medial, and inferior surfaces of the temporal lobe (Nolte, 2002, pp. 61)

The occipital lobe is situated in the posterior part of the brain. The lateral surface of the occipital lobe has lateral occipital gyri. The medial surface of the occipital lobe contains a region named as the cuneus which is placed between the parietooccipital and calcarine sulci. The gyrus which is named as the lingual gyrus is located below to the calcarine sulcus. The lingual gyrus extends through the parahippocampal gyrus and separated from the posterior section of the occipitotemporal gyrus by the collateral sulcus.

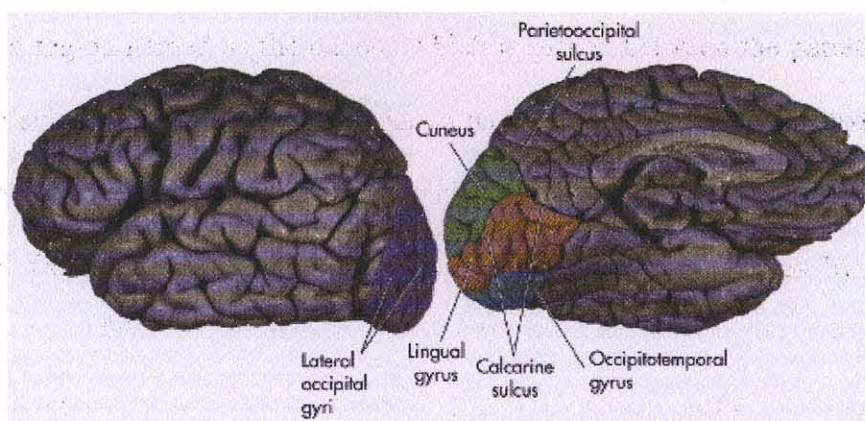


Figure 1.15 Lateral, medial and inferior surfaces of the occipital lobe (Nolte, 2002, pp. 62)

The functional organization of the cerebral hemisphere is done according to localization of the lobes (Swanson, 2003, pp. 40-41). The most famous map for defining cortical regionalization is created by Korbinian Brodmann. The purpose of this map is to reveal how the brain is organized and divided into the areas which are named as Brodmann's areas for accomplishing highly complex behaviors according to these specific and diverse regions on the cerebral cortex (Swanson, 2003, pp. 41; Kandel, 2000, pp. 12).

The frontal lobe of the brain is composed of areas 4, 6, 8, 9/46, 10, 11, 44, 45, 47, supplementary eye field (SEF) and supplementary motor area (SMA). Area 4 (MI) is known as the primary motor cortex lies through the precentral gyrus is involved in observation and execution of motor tasks (Kandel, 2000, pp. 671; Hari et al. 1998; Garey, 2006, pp. 10). The primary motor cortex has subdivisions which are named as area 4a (anterior) and 4p (posterior). The subareas of primary motor cortex show different neural activity. Separate regions within human primary motor cortex may have diverse motor channels that ensure parallel processing of motor information with different levels of attention related to conditions where attended and unattended actions simultaneously are needed. Moreover, differential anatomical connections are implicated. According to these findings, the subarea 4p has connections to the primary sensory cortex where neural activity can be adjusted by attention to action, while subarea 4a has connection to the premotor cortex where no neural activity modulation is seen in this subregion linked to attention to action. These findings reveal that differential neural mechanisms occur during attended and unattended action in human primary motor cortex which implicates that human primary motor cortex has cognitive function. According to

electrophysiological studies that is done on primates, direction of movement, motor sequences, and the serial order of movements is held in the memory by nonhuman primate's M1 neurons. These studies are also supported by magnetoencephalographical experiments on humans which explain the role of the M1 neurons in motor imagery and movement observation. In the light of these findings, the function of human primary motor cortex can not be restricted with a crude motor output which is reinforced by fMRI results and previous data found (Binkofski, 2002). Furthermore, the study mentioned above is supported by Jerome N. Sanes and his colleagues in which they proposed that motor cortical areas are not just involved motor functions; they are also responsible for learning and cognition processes. Investigations on MI neurons implicated that there is a relationship between MI and cognition functions. Some of these observations revealed that MI neurons are capable of holding premotor information for short periods which can be evaluated as an indication of elementary memory functions. Also, some studies suggest that MI is involved in higher-order motor functions which include movement direction, movement distance or movement goal. Other observations showed that during the delay period, the MI neuronal population vector changes its directional properties according to the visual motor mental rotation. It is also demonstrated that there is a relationship between MI neurons and the serial order within a short list of items. Moreover, MI circuits as called the MI networks are activated during the mental rehearsal of movements or motor imagery. Consequently, cognitive variables create activation in motor cortex where MI can be thought as one of the main component of a larger cortical network (Sanes and Donoghue, 2000).

Area 6 is called as the premotor cortex localized along the rest of the precentral gyrus together with adjacent sections of the superior and middle frontal gyri (Nolte, 2002, pp. 60). Area 6 is involved in motor functions and dynamic visuospatial imagery which is related to higher cognitive functions of mental representation, creating thinking, and planning complex actions, as well as contributing to the understanding of differences in mental ability. (Garey, 2006, pp. 10-11; Lamm et al. 2001; Dennis et al. 2001). Also, neurophysiological evidence claims that oculomotor and somatomotor space coding merges in the premotor cortex (Area 6) (Iacoboni et al. 1997). Furthermore, according to studies that are done by Rizzolatti and his colleagues, motor and cognitive functions like space perception, action understanding, and imitation is done by the ventral premotor cortex in both humans and monkeys (Rizzolatti et al. 2002).

Area 8 is known as Frontal Eye Fields (FEF). Anterior part of the precentral gyrus, the posterior part of the middle frontal gyrus, and the edges of the precentral sulcus are borders of the FEF. The FEF has noticeable contributions to the initiation of saccades (Nolte, 2002, pp. 517). The role of the Area 8 especially on preparation and triggering of purposive saccades is well understood in studies. According to investigations that are done by B. Gaymard and his colleagues it is shown that the FEF is also involved in short-term memorization of the parameters of the forthcoming memory-guided saccades which is encoded in oculocentric or retinocentric coordinates where eye orbit position is important. Another important result that is found in this study, the FEF seems not to have a function on inhibition of reflexive saccades (Gaymard et al. 1999). In addition to this study, one of the other investigation indicated that the FEF probably uses retinocentric reference system to control saccades. Moreover, craniotopic reference

system which is related to again position of the eye orbit can be utilized by the FEF. It is observed that when a person has a lesion on the area of the FEF, memory-guided saccades are disrupted, but saccade amplitude can be calculated with a retinocentric reference system (Deseilligny-Pierrot et al. 1993). Furthermore, another study that is done by Dan Milea and his colleagues indicated the importance of the FEF in saccades. In this investigation, it is mentioned that fMRI and electrical cortical stimulation studies demonstrate the FEF is responsible for producing fast and contralateral saccades. Also, this research pointed out several other studies' results where indicated the FEF has other subregions. fMRI studies and electrophysiological studies propose activation along the lateral part of the superior frontal gyrus and the adjacent portion of the central gyrus. For instance, one of the these recent fMRI studies shows the FEF for saccades was restricted in the upper portion of the anterior wall of the precentral sulcus, on the other hand, smooth pursuit movement was related to the region that was along the anterior wall, the fundus, and the deeper part of the posterior wall. According to last evaluations from studies, the FEF is responsible for intentional saccades which are caused by the subject's preference toward the objects or locations like intentional visually guided saccades, memory guides saccades, and predictive saccades, but not for reflexive saccades (Milea et al. 2005). Lastly, another function of the FEF is voluntary shifts of gaze (Miller and Wallis, 2003, pp. 1358).

Area 9/46 which is also known as the dorsolateral prefrontal cortex (DLPFC) comprehends one-third of the superior frontal gyrus. The region that is referred as Area 46 is partially or completely encircled by Area 9 (Petrides and Pandya, 2004, pp. 958-959). In one of the studies that are done by Dan Milea and his colleagues, it is mentioned

that lesion studies confirmed the location of the Area 9/46 as anterior to the FEF (area 8). In this study, the roles of the DLPFC are well defined and explained with new additions to the functions of the DLPFC. Decisional role in oculomotor behavior, combination of visual representation with knowledge, goals to produce an action, prediction, and occurrence of antisaccades are some of the known main functions of the DLPFC. The DLPFC provides control on inhibition of saccades through superior colliculus which is a large, rounded mass of gray matter in the top of the rostral midbrain. Moreover, the DLPFC expedites triggering of predictive saccades which is produced by the FEF (area 8). The other function of DLPFC is related to the short-term spatial and temporal working memory processes which are important for memory-guided saccades. Decision is another concept mentioned in this research. The interpretation and behavioral selection as a result of connection between sensory input and output is referred to as decision. In this study, the role of the DLPFC in decisional conditions is reinforced by other investigations that are related to event-related fMRI. Through this research two-sided activation is observed in the DLPFC when there is a directional decision to be taken. When executive requirement has to be processed, the level of activation increased in the DLPFC which reveals that another role of the DLPFC is to plan new actions where long-term storage of information is needed rather than short-term (Milea et al. 2005; Nolte, 2002, pp. 626). Pierrot Deseilligny has also reported how unilateral DLPFC lesion affects saccadic and smooth pursuit eye movements and compared results with the FEF lesions that are previously reported. According to his evaluations, the behavior of the FEF and DLPFC is different on the control of eye movement characteristics. The investigation demonstrated that the percentage of errors was increased bilaterally (both hemispheres) in an

antisaccade paradigm but the latency of correct saccades was normal for patients who have DLPFC lesions. A slight increase in latency occurred in memory-guided saccade of these patients but the opposite happened for the patients who have FEF lesions; they had effective bilateral increase in their latency. Visually guided saccades and smooth pursuit were normal on these subjects. However, for the subjects with FEF lesions, saccade latency increased bilaterally and the gain decreased contralaterally, in addition to these results, the gain also decreased in smooth pursuit. Furthermore, in predictive saccades the percentage of anticipatory saccades decreased in patients who have FEF and DLPFC lesions. All these findings supports that the DLPFC has crucial roles in deciding whether or not to inhibit a saccade, facilitating saccade triggering, keeping spatial information and making self-selection of direction for forthcoming intentional visually guided saccade. Additionally, the DLPFC shapes the temporal flow of information processing of the prefrontal cortex. On the other hand, the FEF is more involved in managing saccade physiology, controlling the activation of intentional saccades, the amplitude of contralateral saccades and has a role on visual fixation and smooth pursuit. Consequently, this investigation clarified that the patients with lesions on the DLPFC may have abnormalities on inhibiting of reflexive saccades, spatial working memory and adaptation of future behavior (Deseilligny-Pierrot et al. 2003).

Area 10 which is also referred as frontopolar area can be defined as the most anterior region of the frontal lobe that encompasses approximately one-fourth of the anterior portion of the superior frontal gyri and the middle frontal gyri, but it does not medially reach the cingulate sulcus (Garey, 2006, pp. 114; Brodmann area 10, 2007). According to research that is done by Katerina Semendeferi and her colleagues, the role

of the area 10 is higher cognitive functions like the undertaking of initiatives and the planning of future actions. Investigations referred in this paper implicate that higher-cognitive abilities that facilitate extraction of meaning from ongoing experiences, the organization of mental contents that control creative thinking and language, and the artistic expression and planning of future actions are damaged as a result of lesions in the prefrontal cortex including area 10 (Semendeferi et al. 2001). In another study, the function of the Area 10 is revealed as to be involved in prospective memory which is defined as remembering to do something in the future (Okuda et al. 1998).

Area 11, area praefrontalis, forms the rostroventral part of the frontal lobe on its orbital and medial surfaces covers most of the straight gyrus (defined as a convolution on the orbital surface of the frontal lobe and continues with the medial frontal gyrus on the medial surface) the rostral gyrus and the extreme anterior end of the superior frontal gyrus (Garey, 2006, pp. 114; Elliot, 2000). The limbic cortex which is also responsible for memory and emotion includes area 11 (Kandel, 2000, pp. 350-351). Planning, reasoning and decision making are some of the functions that area 11 is involved in (Brodmann area 11, 2007). Furthermore, according to studies that are done by M. Jueptner and his colleagues, medial prefrontal cortex including area 11 has interactions with the visual spatial network during the cue-induced internal generation of anticipatory attentional bias (Jueptner et al. 1996).

Area 44, the opercular area, is a clearly distinguishable and sharply restricted structural region which forms the opercular part of the inferior frontal gyrus. The inferior precentral sulcus posteriorly, the inferior frontal sulcus superiorly, and the ascending branches of Sylvian fissure are borders of area 44. Area 45, the triangular area, has

cytoarchitecturally similar features with area 44 which creates the triangular part of the inferior frontal gyrus. Area 47, the orbital area, has also same affinities with areas 44 and 45 where three of them create a subfrontal subregion (Garey, 2006, pp. 115). Area 44 and 45 approximately cover the cortical area of Broca in the lower frontal convolution. They have long connections to the area 10 and supplementary motor area (SMA) (Talairach and Tounoux, 1988). Investigations that are done by Masud Husain and his colleagues indicate that area 44 may be involved in directing attention in visual space. This study suggests that area 44 in the human right hemisphere may be involved in directing attention or planning movements to search contralateral space. In the left hemisphere, area 44 is responsible for planning and production of speech where this role of area 44 is supported by another research that is referred in the study of Masut Husain and his colleagues (Husain and Christopher, 1996; Smith and Jonides, 2003, pp.1380).

The role of area 45 and 47 is speculated to be involved in the interaction between short-term and long-term memory systems and executive processing (Mottaghy et al. 2002). Furthermore, Leslie G Ungerleider and her colleagues also mention another investigation through their research which points out activation of areas 45 and 47 in selective face and location matching respectively (Underleider et al. 1994).

The supplementary eye field (SEF) is a division of premotor cortex which is located on the medial surface of the superior frontal gyrus, anterior to the supplementary motor area in the upper part of the paracentral sulcus (Milea et al. 2005). The SEF has attentional and oculomotor functions. Activation on the neurons of the SEF is observed during the execution of saccadic eye movements. The two main features of the SEF which indicate its role in eye movement control occurs at a comparatively abstract level

form a separation between subcortical oculomotor centers and the SEF. First, in primate studies, it is observed that neurons of the SEF are activated while the primate is waiting to make an eye movement in the preferred direction, and also during the eye movement itself. Second, when the monkey is learning to create connection between arbitrary visual cues and particular directions of the eye movement, some of the SEF neurons are especially active. In addition to these characteristics, more investigations that are done on primates indicate that the SEF has a unique spatial selectivity where the monkey is trained to make eye movements to particular locations on an object. This finding demonstrates that neurons of the SEF encode the direction of the approaching eye movement in which object-centered reference frame is used (Colby and Olson, 2003, pp.1241-1243). All these results are supported by other studies and added new roles to the SEF. For instance, visually guided eye movements depend on perception, cognition and choice behavior which create neural activity in supplementary eye field (SEF). It is also known that the SEF is responsible for self-generated saccade production, conditional motor learning, object perception and behavior monitoring (Schall, 2001). Another study reveals that according to lesion studies, damage to the SEF does not affect reflexive saccades, but it causes alteration on a sequence of memory-guided saccades. Additionally, the SEF comprehends motor programs which include a combination of saccades and a body movement or a sequence of several successive saccades. fMRI studies also observed that voluntary saccades, visually-guided, or memory-guided and antisaccade tasks create activation in the SEF. Moreover, learning and starting of antisaccades can be controlled by distinct medial regions in the SEF area (Milea et al. 2005). According to another fMRI study that is done by Charles Pierrot-Deseilligny and

his colleagues, the SEF is active during memory-guided saccades, but not essential for performing single saccades. Some lesion investigations referred through this study implicate that learning and executing motor programs that contain several types of body movements and oculomotor movements like saccades or sequential successive saccades are achieved by the SEF (Deseilligny-Pierrot et al. 2002). Jun Tanji mentioned in his study that lesions in the SEF create problems for executing sequential saccades, especially when there is no visual guidance (Tanji, 2001). Lastly, the results that are found by lesion studies are also supported by another investigation that is done by Charles-Pierrot Deseilligny and his colleagues where the effects of the SEF lesions on vestibular signals to do appropriate saccadic oculomotor movements are discussed and compared with the FEF lesions. It is concluded that saccades which are done after vestibular stimulation are impaired for subjects who have the SEF lesions, not the FEF lesions (Deseilligny-Pierrot et al. 1993).

The supplementary motor area (SMA) which is anterior to the primary motor cortex and the medial extension of area 6 is situated on the medial surface of the hemisphere. The SMA is responsible for initiation of voluntary movements and also is one of the regions beside the presupplementary motor area that plays an important role in learning sequences of discrete movements (Nolte, 2002, pp. 60, pp., 542; Kandel, 2000, pp. 771). In addition to these characteristics, SMA lesions results in problems on executing a sequence of movements to an object which occurs without visual cues. Brain imaging studies including SMA, cingulate cortex, the lateral premotor cortex and the lateral prefrontal cortex showed that these regions are involved in sequential motor

performance. Furthermore, some other investigations implicated that the sequence-selective activity on SMA depends on memory-based information (Tanji, 2001).

The parietal lobe of the brain is composed of areas 1, 2, 3, 5, 7, 39 and 40. Area 1, intermediate postcentral area, which is between areas 2 and 3 separated from them with a narrow band that elongates approximately to the whole length of the top of the postcentral gyrus. Area 2, the caudal postcentral area, covers the posterior portion of the postcentral gyrus and anterior section of the postcentral sulcus. Area 3, rostral postcentral area, occupies the anterior extent of the postcentral gyrus and forms the posterior portion of the central sulcus along its whole length (Garey, 2006, pp. 109-110). Area 3 has two subdivisions named as 3a and 3b. Area 3b and 1 are together responsible for obtaining information from receptor in the skin, whereas area 3a and 2 perform cooperatively to receive information from muscles and joints (Kandel, 2000, pp. 452).

Moreover, these three regions form the primary somatosensory cortex which is involved in the initial cortical processing of tactile and proprioceptive information (Nolte, 2002, pp. 60). According to Tatsuya Mima and colleagues, it is demonstrated that the activation on the primary somatosensory cortex including secondary somatosensory cortex, are affected by attention. Through this research, effects of active and passive attention on primary and secondary somatosensory cortex are investigated (Mima et al., 1998). In another study, it is showed that somatosensory and motor functions connected with each other where information from somatosensory inputs is conveyed to the primary motor cortex via thalamus directly, and from other somatosensory cortical areas. Additionally, this study suggests that functioning of these areas is the indication of

sensorimotor information which creates precise and purposeful movements (Forss and Jousmäki, 1998).

Areas 5 and 7 form posterior parietal cortex (PPC) (Kaas, 2004, pp.1080). Areas 5 and 7 have contralateral connections to the areas 1 and 2. Also, area 5 where area 7 is connected to the area 5 has opposite- lateral relations to the area 4 (Talairach and Tounoux, 1988, pp.11). Somatosensory and visual functions as well as premotor planning are some of the known responsibilities of the PPC. Lesions on this region do not cause simple sensory impairments, but large injuries related to this region generate a different type of complex symptoms including the contralateral sensory neglect or inattention (Kaas, 2004, pp.1080)

Additionally, other studies that are done on this area implicate that the patients who have injuries on the PPC struggle with problems in the visual spatial perception. These patients are able to see objects, but they can not compare the size of the two objects or which of two objects is closer (Colby and Olson, 2003, pp. 1230). Furthermore, Dan Milea and his colleagues demonstrate that in their study, the parietal eye field (PEF) which is located in the PPC is involved in programming and execution of saccades. Moreover, the PEF in human beings which is referred as lateral intraparietal area (LIP) in primates is responsible for reflexive saccades (Milea et al. 2005). Pierrot-Deseilligny showed that visuospatial integration occurs in the PPC. Through this investigation, the role of the PEF on reflexive saccades is also supported (Deseilligny-Pierrot et al. 2005). When the function of this region is evaluated by transcranial magnetic stimulation research comparing the role of the PPC between primates and humans, it is observed that the PPC is active in visuospatial memorization for primates;

however, short-term spatial memorization occurs in human beings. Also, triggering of saccades by the PPC can be explained as a common characteristic for both species. In addition to all these, a transcranial magnetic stimulation study reveals three findings related to the functions of the PPC which can be listed according to this research as 1) during the brief initial visuospatial integration phase which is immediately after the stimulus presentation but before the memorization phase, the right PPC is activated with the roles of controlling accuracy of saccades and short-term spatial memory; 2) The left PPC is not highly active in the control of saccade accuracy which indicates and confirms the findings of previous studies that the role of the right cerebral hemisphere is defined as visuospatial functions; 3) the function of the FEF is triggering memory-guided saccades (MGSs) in which PPC may also have contributions. Although the control of short-term spatial memory is provided by DLPFC after a parietal visuospatial integration and before a triggering by the motor areas in humans, the PPC and the FEF has reciprocal connection to the DLPFC in monkeys (Deseilligny-Pierrot et al. 2002).

Also, multiple modalities for motor learning are accomplished by the PPC (Kandel, 2000, pp. 465). The information about the position of body parts to control movements can be obtained by the PPC because of the direct connections to the area 4 which can be concluded as the PPC is a higher order somatosensory area where proprioceptive information is analyzed (Hanakawa et al. 2002). Also, investigations that are done on monkeys indicated that multimodal sensory information is integrated on the PPC for object recognition and manipulation (Kalaska et al. 1997). In another animal study that is achieved by go/no go experiment, it is observed that when the animal has to give a decision related to apply action or not, neurons in area 5 are activated. Through

this research, it is also revealed that neural activities occur in area 5 for higher cognitive functions where attention is needed (Andersen et al. 1997)

Area 39, the angular area, including the angular gyrus as well, extends around the posterior end of the superior temporal sulcus where it is located caudal to it. Areas 19 and 37 which are located in the occipital and temporal lobes respectively are boundaries of the area 39 (Garey, 2006, pp.118, pp. 120). Area 39 is responsible for processing language, spatial orientation and semantic representation (Brodmann's area 39, 2007). It is also involved in semantic aphasia which causes not to produce and/or understand language (Brodmann area 39, 2007; Aphasia, 2007).

Area 40, the supramarginal area, is located at the posterior end of the Sylvian fissure and in the inferior lateral part of the parietal lobe. Moreover, supramarginal gyrus belongs to the area 40 (Brodmann area 40). Spatial orientation and semantic representation are functions in which area 40 is involved in (Brodmann's area 40, 2007) Beside these functions, one of the studies that are done by R.J.Perry and S.Zeki indicated that visual neglect condition occurs when patients have lesions on supramarginal gyrus (area 40). Through this study, event-related functional MRI is used to assess the function of the supramarginal gyrus for saccades and attention shifts. It is observed that lesions that comprehend right inferior lobule which contains supramarginal gyrus results in ignoring of left side of the world. Patients with this type of injury make very few saccades to their left world and do not recognize objects on this side of the space which is known as left visual "inattention" or "hemi-neglect". Covert attention shifts is another term used in this paper which are planned but never applied saccades and also can be also called as premotor theory of attention. It is hypothesized that saccades and covert

attention shifts are promoted by different ways but they have spatially overlapping mechanisms. Shifts in spatial attention are distributed asymmetrically through supramarginal gyrus including anterior cingulate (areas 24 and 32). Consequently, significant asymmetrical condition appeared during this research according to evaluation of responses where the right supramarginal gyrus provided high activation, on the other hand, the left supramarginal gyrus contained no activation in which the same situation weakly observed in saccades (Perry and Zeki, 2000).

The temporal lobe and the hippocampal region of the brain are composed of areas 20, 21, 22, 27, 28, 34, 35, 36, 37, 38, 41 and 42. Area 20, inferior temporal area, includes the inferior temporal gyrus. Areas 37 and 38 are borders of the area 20 (Garey, 2006, pp. 120). Investigations that are done on primates showed that inferior temporal (IT) cortex is involved in higher-order visual representation of objects and functions as a storehouse of visual-long term memory (Miyashita and Hayashi, 2000). In addition to this, the inferior temporal (IT) cortex is an essential component of the ventral stream of visual processing. fMRI studies demonstrated that neurons in this region are activated not just in object-feature recognition, but also during spatial localization of visual stimuli (Bushara et al. 1999). Moreover, this region is involved in producing the visual deficits. According to studies that are done on primate those with bilateral IT cortex lesions experienced difficulty in learning to distinguish between different visual patterns or objects and in obtaining previously acquired visual discriminations (Rodman, Pessoa, Ungerlieder 2003, pp.1204).

Area 21 which is known as the middle temporal area (MT)/V5, first defined by functional and anatomical studies were done on nonhuman primates. PET and fMRI studies indicated a similar region in the human brain located on the tempora-parieto-occipital junction whose response properties are same with nonhuman primates. This region is also referred as human MT/V5 with similar functional characteristics when it is compared with macaque MT but with a different anatomical location (Hampson et al. 2004). The MT/V5 in monkeys functions as a motion processing region because the cells in this area directionally and the shape or the color of the moving stimulus can create a significant change in the activity of these cells. Motion of spots or bars of light are visual cues where MT/V5 responds by detecting contrast in luminance. Moreover, some cells in MT/V5 are also responsive to moving forms which are not defined differences in luminance but well characterized with differences in color or texture. Under these conditions, cells are not selective for color itself; they detect motion by responding to an edge defined by color (Kandel, 2000, pp. 553). In addition to all these, brain imaging investigations supported the roles of MT/V5 by observing activation on the cells of this area for moving stimuli, stationary stimuli inducing motion, apparent motion and motion imagery. Also, it is demonstrated that MT/V5 is the first region of the dorsal processing stream and involved in adjusting the visual control of skilled action (Grézes and Decety, 2002). According to another investigation, because the MT/V5 is located in the anterolateral part of the occipital lobe, neurons in this area exhibit a sharp preference for direction and speed of visual stimuli (Riecansky, 2004). Furthermore, Matthew C. Hagen and his colleagues referred in their study the perception of visual motion as another

function corresponding to MT/V5 (Hagen et al. 2002). Lastly, another study shows that neurons of MT/V5 are affected by the eye position signal (Melcher and Morrone, 2003).

Area 22, the superior temporal area, is situated in the mid-portion of the superior temporal convolution and encircles the auditory area (Talairach and Tounoux, 1988, pp. 22; Garey, 2006, pp. 121). The function of the area 22 alters according to being on the left or right hemisphere. On the left side of the brain, area 22 is involved in generation and understanding of individual words. On the right side of the brain, this area detects the difference between melody, pitch, and sound intensity (Brodmann area 22, 2007). The roles of area 22 in both hemispheres are supported by other studies which are referred in the study of Ralf A. W. Galuske and his colleagues (Galuske et al., 2000) Additionally, one of the PET investigation that is done by T.J Anderson and his colleagues indicated that area 22 is also involved in remembered saccades (Anderson et al., 1994) Moreover, Wernicke's area where language comprehension occurs is located in the area 22 (Zilles, 2004, pp. 1028; Nolte, 2002, pp. 61).

Areas 28 and 34 are two regions which are referred as the entorhinal area and the dorsal entorhinal area (Garey, 2006, pp. 125-126). The entorhinal cortex which is the one of the components of the medial temporal lobe is formed by the areas 28 and 34. According to studies that are done on the entorhinal cortex (areas 28/34) and the perirhinal cortex (areas 35/36), it is showed that these regions have complex roles in object perception and memory. Neurons in the entorhinal, perirhinal and prefrontal cortices are involved in object and/or place-specific delay activity. Additionally, object-selective and place selective information is carried by the visual response and the delay activity of the entorhinal neurons (Káldy and Sigala, 2004). The investigation done by

Joelle Crane implicated that the right entorhinal cortex and the junction of the right entorhinal and parahippocampal cortices are activated when the condition of retrieving locations was subtracted from that of retrieving object locations and when recognition of object location was compared with a baseline condition where object-place associations were minimized. Furthermore, two other investigations that are done on primates report that lesions on the hippocampus or the entorhinal, perirhinal, and parahippocampal cortices cause problems of memory for object-place associations and for location information when more than one location had to be remembered (Crane and Milner, 2005). Another study mentions that all anterior-posterior levels of the entorhinal cortex are responsible for processing visuospatial information because of the projection patterns of this region. For instance, information about an object from the ventral stream is transmitted to entorhinal cortex via the perirhinal cortex, which projects primarily to anterior and the lateral portions of the entorhinal cortex, on the other hand, visuospatial information which comes from the dorsal stream pathway projects via the parahippocampal cortex. Consequently, roles of the entorhinal cells on carrying and obtaining sensory information about objects and spatial locations, and retaining this information in short-term memory are also discussed in this research (Suzuki et al. 1997).

Areas 35 and 36 are two regions in the cerebral cortex which form the perirhinal cortex. Area 35, the perirhinal area, belongs to the hippocampal region and area 36, the entorhinal area, is located in the temporal region (Garey, 2006, pp. 120, pp. 126). The entorhinal area 28 medially and the entorhinal area 36 (H) laterally are borders of the area 35 (Brodmann area 35, 2007). Area 36 is encircled laterally and caudally by the inferior

temporal area 20, medially by the perirhinal area 35 and rostrally by the temporopolar area 38 (H) (Brodmann area 36, 2007). The crucial role of the perirhinal cortex is to obtain information about objects. According to event-related fMRI study that is done by Andy C. H. Lee, it is observed that the perirhinal cortex is not just responsible for object and spatial memory; it is also involved in short-term visual working memory or higher order perception. Pihlajamäki and his colleagues, who are referred through the study mentioned above, demonstrated via fMRI research activation of the perirhinal cortex occurs for conditions where short-term memory or even the higher order perception of objects and spatial scenes are needed. Another study from Tyler and colleagues suggest that because the perirhinal cortex is capable of profound discriminations among objects, it may also stand for an indicative role in a larger network of conceptual representation in the brain (Lee et al. 2006). Beside these functions, the investigation that is done by J. S. Holdstock signifies that the perirhinal cortex is also involved in declarative memory which is a type of memory corresponding to the facts and events. In another study, which is mentioned in the research done by J. S. Holdstock reveals that familiarity-based recognition memory is another function of the perirhinal cortex. It is also proposed that any perceptual role of the perirhinal cortex can be separated from its role in recognition memory (Holdstock, 2005). Consequently, the roles of the perirhinal cortex in cognitive functions can be briefly listed as first, it is related to recognition memory in an automatic fashion; second, it may have contributions to the perception as well as memory; third it detects objects by associating together the different sensory features of an object; and lastly, it associates objects with other objects and with abstractions (Murray and Barry, 2001).

Area 37, occipitotemporal area, is situated between the temporal, parietal, and occipital lobes. Area 37 encompasses laterally the posterior parts of the middle and inferior temporal gyri and the anterior parts of the middle and inferior occipital gyri (Zilles, 2004, pp.1030; Garey, 2006, pp. 120). Additionally, fusiform gyrus contains parts of area 37, because in a study which is done by Lee Ryan and his research group, fusiform gyrus is expressed as area 37 (Ryan et al. 2001). Previous imaging studies which is referred in the investigation of Fulvia Castelli and his colleagues indicated that the medial prefrontal cortex, temporoparietal junction (superior temporal sulcus), basal temporal regions (fusiform gyrus and temporal poles adjacent to the amygdala), and extrastriate cortex (occipital gyrus) are involved in self-monitoring, perception of biological motion, attribution of mental states using verbal stimuli or visual depictions of the human form (Castelli et al. 2000). Furthermore, A. Martinez and his colleagues demonstrated that the primary visual cortex which is involved in spatial attention recruits higher visual areas including the occipitotemporal ventral stream to provide preferential access to limited-capacity stages of feature analysis and pattern recognition. It is also mentioned that enhanced processing of the visual target information for pattern and object recognition is accomplished by ventral areas including posterior fusiform gyrus (Martínez et al. 1999)

Area 38, the temporopolar area, is located the most anterior part of the temporal lobe. Areas 20, 21 and 22 caudally and area 36 medially are neighbors of this region (Garey, 2006, pp. 120-121). Area 38 has contributions to networks in the amygdala and orbital prefrontal cortex where personal and social behavior, emotion, and decision making functions are executed (Brodmann's area 38, 2007). Furthermore, according to

the investigation that is done by Lucia M. Vaina and her colleagues, it is observed that area 38 is one of the regions involved in the biological motion recognition and face gender discrimination (Vaina et al. 2001).

Area 41, the medial (anterior) transverse temporal area, form the primary auditory cortex and surrounded caudolaterally by the secondary auditory area 42 which is also known as the lateral (posterior) transverse temporal area (Garey, 2006, pp. 122; Zilles, 2004, pp. 1026). The main known function of areas 41 and 42 is to process auditory information (Brodmann's area 41, 2007; Brodmann's area 42, 2007). In addition to this main role, Uri Werner-Reiss and his colleagues claimed that activity of the primary auditory cortex is affected by eye position in primates. Their study indicated that neurons of area 41 are responsive to complex interactions between stimulus position and eye position which results in eventual convergence of auditory and visual information. Also, it is declared that the interaction between the visual and auditory pathways is more complicated and distributed in primates (Reiss-Werner et al. 2003). The functional magnetic resonance imaging (fMRI) study that is done by James Lewis and his research group discussed how and where the communication between the visual and auditory motion systems occurs about the movements of objects. It is concluded that during visual and auditory motion processing tasks a number of common cortical regions and pathways are engaged in different ways related to the stimuli presented and the nature of the auditory or visual task (W. Lewis et al. 2000). Another fMRI investigation showed that the primary and secondary auditory cortices are highly involved in the selective attention where change in activity occurs on these regions when attention is needed to accomplish tasks (Jancke et al. 1999).

Areas 23, 24, 25, 31, 32, and 33 belong to the cingulate cortex. The cingulate cortex has two subdivisions which are the posterior cingulate cortex (PCC) and the anterior cingulate cortex (ACC). The posterior cingulate cortex is composed of area 23 which is known as the ventral posterior cingulate area and area 31 which is named as the dorsal posterior cingulate area (Garey, 2006, pp. 123; Deseilligny-Pierrot et al. 2004). The functional magnetic resonance imaging results, which are referred in the study of Charles-Pierrot Deseilligny, indicated that the control of externally guided eye movements and attentional mechanisms are accomplished by the posterior cingulate cortex. One of the fMRI study mentioned in this research claimed that the PCC is involved in reflexive saccades, but not in intentional saccades. Furthermore, it is concluded that the PCC can be considered as a control region for externally-triggered eye movements like the reflexive saccades and smooth pursuit. Also, two other reported fMRI investigations proposed that a forthcoming shift of visual attention occurs after indication of informative cue which results in activation in the PCC for purely attentional paradigms (Pierrot-Deseilligny et al. 2004). Beside these findings, R.J. Maddock and his colleagues suggested that another role of the PCC is memory retrieval (Maddock et al. 2001).

Area 24, the ventral anterior cingulate area, and area 32, the dorsal anterior cingulate area, form the anterior cingulate cortex (ACC) and participates in intentional saccade control. The ACC encompasses the cingulate eye field (CEF) which is involved in preparing the imminent intentional eye movements (Deseilligny-Pierrot et al. 2004). The study that is done by Angus W. MacDonald demonstrated that the anterior cingulate cortex is highly active in complicated tasks like solving difficult problems, overcoming

habitual responses and providing feedback of errors for an ongoing behaviour (MacDonald, 2000). In the research of Charles-Pierrot Deseilligny and his colleagues, it is observed that when visuoculomotor model is formed, the selection of visuospatial information starts with short-term memorization by the DLPFC (areas 9/46) and continues with the anterior cingulate cortex. It is also revealed that the anterior cingulate cortex has active roles in memorization and is involved in motivation which is a preparation level of intentional movements including memory-guided saccades. Additionally, the anatomical and functional locations of the ACC are convenient to take a role in visuospatial information selection. Thus, because the ACC is between the memory areas and motor areas, it is capable of obtaining afferences from the DLPFC and the medial temporal region and projecting to the primary motor cortex (area 4) and the frontal eye fields (area 8) (Deseilligny-Pierrot et al. 2002).

Area 25 is known as the subgenual area or subcallosal gyrus which is located below the corpus callosum defined as the gray matter in medial prefrontal cortex (Garey, 2006, pp. 124; Douglas Bremner et al. 2002). Area 25 is involved in executing personal and social behavior, emotion, and decision making (Brodmann's area 25, 2007). According to one of the studies that are done on primates, it is observed that neurons of the subgenual cingulate cortex (area 25) are highly active when the primates fell asleep. Moreover, in this study, it is mentioned that this region in humans is active when disengagement from tasks and to induced sadness occur where this activity is evaluated as passive or resting behavior (Rolls et al. 2003).

Area 33, the pregenual area, is one of the components of the ventral region of the anterior cingulate cortex (Garey, 2006, pp. 124; Phillips et al. 2003). Area 33 is involved in emotion and cognitive processing (Brodmann's area 33, 2007). Robert Rogers and his research group indicated that this area has a decisional role (Rogers et al. 2004). In another study, it is claimed that activation on the pregenual anterior cingulate and medial prefrontal cortex is observed during action selection and outcome processing stages of decision making which is an indication of evaluative role these regions (Paulus et al. 2005)

Areas 29 and 30 belong to the retrosplenial region (Garey, 2006, pp. 125). Area 29, the granular retrolimbic area, and is responsible for mental navigation from the memory of a previously learned route in a real environment. This area also participates in spatial memory with a comprehension of self generated eye or locomotor movements (Alain, 1997). Area 30 is defined as the agranular retrolimbic area (Garey, 2006, pp. 125). According to one of the studies on primates it is suggested that area 30 may have contributions to the working memory because of the connections it has to other thalamic regions (Morris et al. 1999).

The insular region is composed of area 13. In a study by Shulin Chen and her colleagues this area is named the insula. In this research, depending on voxel-based morphology, bilateral activation on the insula is observed for posttraumatic stress disorder conditions. fMRI studies, which are referred in this paper, indicated that area 13 is activated in memory processes, word-encoding tasks, retrieval tasks and paradigms where negative emotions like fear and disgust occurs. Also, another study, which is mentioned in this research, reported connections between the insula and the prefrontal

cortex (orbital cortex, medial prefrontal cortex), the limbic system (amygdala) and the temporal pole (Shulin et al. 2005).

The occipital lobe is composed of areas 17, 18 and 19. Area 17, the striate area, is also known as the primary visual cortex. Area 17 extends through the calcarine sulcus including the cuneus and the lingual gyrus depending on the degree of the invagination of the calcarine sulcus (Garey, 2006, pp. 117; Zilles, 2004, pp. 1030). Area 18, the occipital area, surrounds the striate area laterally and medially. It elongates anteriorly through the lateral (superior) occipital sulcus and covers the most anterior parts of the calcarine sulcus (Garey, 2006, pp. 118). Area 19, the preoccipital area, encircles area 18, then area 17. Area 19 anteriorly encompasses the interoccipital and parieto-occipital sulci (Garey, 2006, pp. 118). The visual association cortex is formed by areas 18 and 19. The inputs that come from the lateral geniculate nucleus are transmitted to the primary visual cortex for initial processing. For instance, the primary visual cortex combine input from two eyes and begins analyzing depth. Then, this information is projected to the various subareas of visual association cortex in which parameters like motion and color are profoundly analyzed. Any type of impairment on the primary visual cortex cause approximate or complete loss of conscious awareness of visual stimuli (Nolte, 2002, pp. 540).

Moreover, fMRI studies, which are referred in the research of Susan M. Courtney and Leslie G. Ungerleider, indicated that complex cognitive tasks like working memory, selective attention, and imagery result in change of activity on visual processing areas (Courtney and Ungerleider, 1997).

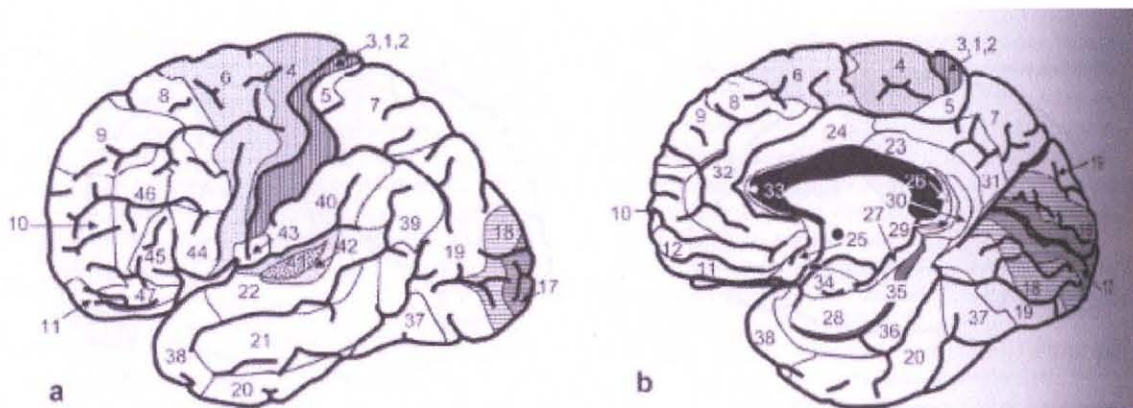


Figure 1.16 Areal map of the human cerebral cortex a) lateral b) medial views (Zilles, 2004, p. 1040).

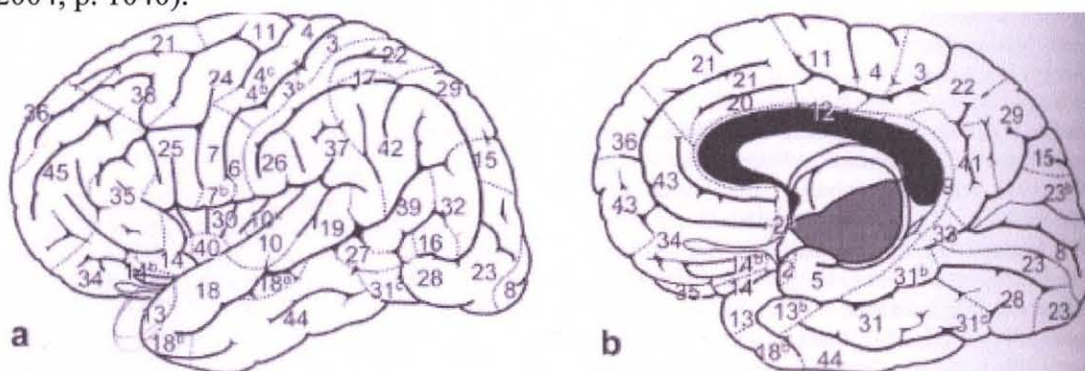


Figure 1.17 Areal map of the myelogenetic areas in the human cerebral cortex a)lateral b) medial views (Zilles, 2004, p. 1040).

1.2.2.2 Subcortical Regions of The Human Brain. The cortical motor systems obtain output information via the thalamus with two large subcortical motor systems which are basal ganglia and cerebellum (Mink, 2003, pp. 815). Accumulation of gray matter within cerebrum is referred as basal ganglia including caudate nucleus, putamen, globus pallidus, amygdala, claustrum, and thalamus. Although amygdale, claustrum, and thalamus are mentioned as components of basal ganglia, these regions belong to other systems or different pathways. For example, the amygdala is part of the limbic system, the thalamus is part of the multitude of different pathways and the function of the claustrum has not understood. In basal ganglia, the caudate nucleus and putamen form the

striatum. Additionally, the putamen and globus pallidus constitute the lenticular or lentiform nucleus. The globus pallidus has two subdivisions which are named as internal and external (or medial and lateral) globus pallidus. The caudate nucleus is separated into head, body, and tail sections. The orbital surface of the frontal lobe has a region in which the head of the caudate is followed by the anterior part of the putamen and called as the nucleus accumbens. The nucleus accumbens form another separate structure which is referred as the ventral striatum (Nolte, 2002, pp. 464-468).

The topographic relationship between the cerebral cortex and the striatum is the main reason for separation of functionally different circuits in basal ganglia which have somatomotor, oculomotor, cognitive, and limbic connections (Mink, 2003, pp. 818).

The function of the putamen is to obtain most of the input information from motor and somatosensory areas of the cerebral cortex and transmits via the globus pallidus and the thalamus to the motor, premotor and supplementary motor areas. When the small group of neurons on the putamen is fired, discrete movements are produced; however, particular movements or positions cause activation on individual neurons of the putamen. All these findings indicate that the putamen is responsible for motor functions of the basal ganglia. The role of the caudate differs from the putamen which receives information from association areas of cerebral cortex and conveys via the globus pallidus and thalamus to the prefrontal areas. The neurons of the caudate response motor functions rarely; on the other hand, they are responsive to the cognitive functions (Nolte, 2002, pp. 470).

The study that is done by Richard B. Ivry and Rebecca MC Spencer suggested that the basal ganglia is responsible for decision processes where this structure behaves

like a threshold mechanism. Additionally, one of the fMRI studies, which are referred in this paper, reveal that the cognitive functions of the basal ganglia encompasses timing, error prediction, and the coordination of attentional set. During an fMRI study, activation on the basal ganglia is observed for task order predictability which is evaluated as a reflection of error prediction role (Ivry and Spencer, 2004; Dreher and Grafman, 2002). Beside all these results, recent studies on trained animals and humans, which are mentioned in the research of Okihide Hikosaka and his colleagues, propose that the basal ganglia is involved in both initiation and suppression of saccades in complex behavioral contexts. According to Okihide Hikosaka and his research group, because the basal ganglia obtains information by memory and expectation, this region is also involved in memory-guided saccades which can be concluded that the impairment of the basal ganglia causes a preferential deficit in memory guided saccades. Furthermore, when sustained eye fixation is needed such as before a goal directed saccade, activation on this area is observed (Hikosaka et al., 2000).

The known functions of the cerebellum are sequencing of multiple movements, coordinating, and combining movements into single actions. The brain-imaging investigations on humans also indicated an existence of activation on cerebellum during learning sequential movements. On the other hand, the studies that are done monkeys showed no activation in the cerebellum during learning sequential movements. Moreover, some other recent findings from experiments that are done on monkeys corresponding to understand the function of the cerebellar structures reveal that development of motor skill which is required for exerting visuospatial control and production of spatial trajectories is processed by these cerebellar structures (Tanji, 2001). Furthermore, flocculus and vermis,

components of cerebellum, are involved in slow and fast eye movements. The flocculus which mostly comprehends slow eye movements, also responsible for alternating the gain of the vestibuloocular reflex related to changes affecting the optics of the eye. Opposite to flocculus, vermis which is involved in fast eye movements, known as a region where adjustment of the timing of muscle contractions during saccades occurs. Furthermore, any impairment on this component of the cerebellum causes dysmetric saccades (Nolte, 2002, pp. 522).

The investigations, which are referred in the research of Ulrich Ettinger and his colleagues, revealed that the role of the cerebellar vermis is also to provide saccadic accuracy. Also, Ulrich Ettinger and his colleagues observed an increase in neural activity on vermis of the cerebellum during their research (Ettinger et al. 2002). The importance of the cerebellar vermis in saccadic eye movements is additionally supported by another study done by Laurent Petit and his research group (Petit et al. 1996). Furthermore, Jeremy D. Schmahmann and Janet C. Sherman mentioned that lesions on the posterior and vermis sections of the cerebellum results in impairment of executive functions such as planning, set-shifting, verbal fluency, abstract reasoning and working memory; problems with spatial cognition including visual-spatial organization and memory; personality change with blunting of affect or disinhibited and inappropriate behavior; and lastly language deficits (Schmahmann and Sherman, 1998). M Takagi and his colleagues demonstrated that lesions for the cerebellar vermis in primate inhibited the ability to perform prism adaptation which is a form of motor learning (Takagi et al. 2003).

1.2.3. Functional Magnetic Resonance Imaging (fMRI)

The brain is composed of 70 percent of water like other tissues in the body. Water molecules contain hydrogen atoms which give magnetic characteristics to the structure of the brain. The hydrogen atoms that belong to the water molecules of the brain can be considered as small magnetic dipoles. When a very strong magnetic field is applied to the brain, these small magnetic dipoles of the brain change their orientations according to the way of executed magnetic field. A short pulse of radio-frequency energy is used to disturb this alignment to make them return back to the original position with a purpose of obtaining a signal from the energy they give off (Parry and Matthews, 2007). The spinning and magnetic field of nuclei of these tiny magnetic dipoles yield the absorption and re-emission of the electromagnetic energy which form the fundamentals nuclear magnetic resonance (NMR). Nuclear Magnetic Resonance is one of the components of functional magnetic resonance (fMRI). The other component of fMRI is Magnetic Resonance Imaging (MRI) which is defined as a technology for producing NMR signal by utilizing a variety of operator-controlled electromagnetic fields related to specific point in space.

Protons are positively charged atoms of the hydrogen molecules which continuously precessing around an axis. Spinning feature of these atoms generate intrinsic orientation and also a net magnetic moment depending on the axis of the spin. The order of protons are randomly aligned which results in having no main field ($B_0=0$) and no induced field ($M_0=0$) for a person when there is no external magnetic field applied. When a person enters an environment which is surrounded by high magnetic field where the main magnet (B_0) is larger than zero, the protons start rotation parallel to

the direction of the external applied main magnetic field. The components which are aligned according to the direction of B_0 are the longitudinal components of the protons of hydrogen atoms which are referred to as T_1 . The alignment of protons supplies not efficient orientation with respect to the direction of B_0 and the phase difference between the longitudinal and the transverse components of each protons results in low quality of signal production in which detection of the signal is not possible. The role of the radio-frequency (RF) pulse generates an adequate signal. When a radio frequency (RF) pulse is executed for a short period of time, 90 degree phase rotation occurs for the all protons of hydrogen atoms where the net induced magnetic field (M_0) and the main magnetic field (B_0) is perpendicular to each other. This perpendicular adjustment between the components of M_0 and B_0 creates a current because of the wires that surround the person which results in a detectable signal.

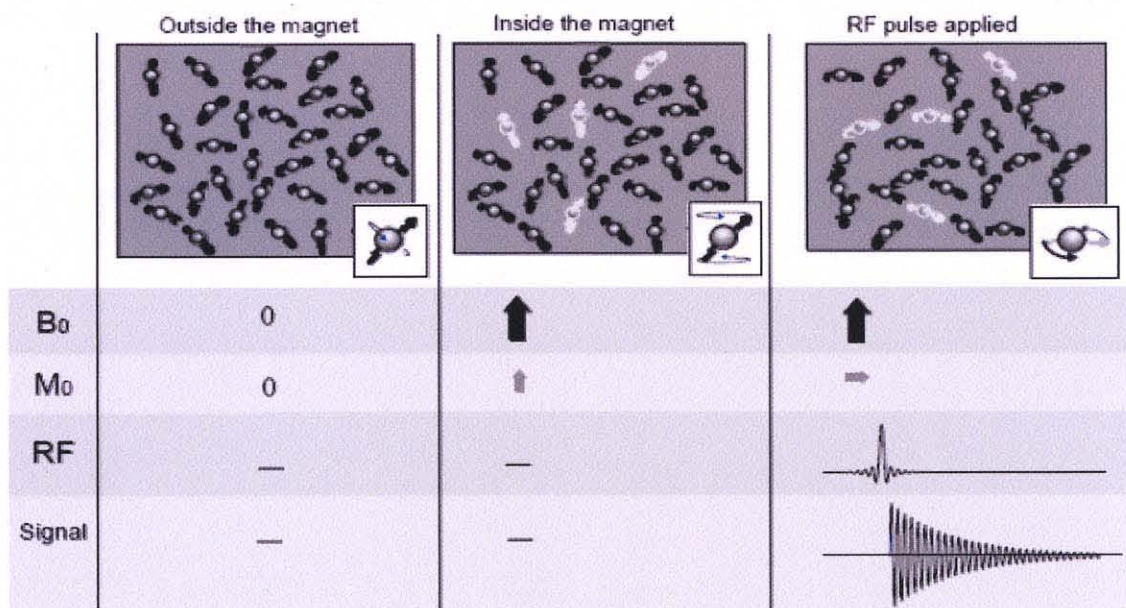


Figure 1.18 The orientation of protons relative to without RF pulse and with RF pulse (Savoy, 2007).

The raw signal exponentially decays and the time constant of this decay is called “ T_2^* ”. The tendency of returning back to the original position with the direction of magnetic field applied by the main magnet and effects of interactions with nearby water molecules and other biological tissues whose frequency are slightly different are reasons that lie under signal loss with respect to time. The spin-spin components of transverse relaxation are a term used for defining interactions between magnetic fields of adjacent nuclei. The spin-spin transverse relaxation and T_1 longitudinal component constitute the exponential decay rate “ T_2 ” under uniform magnetic field conditions. The “ T_2^* ” parameter is also named as free induction decay of the NMR signal, because there is no external influence on the protons of the hydrogen atoms to re-align them back to the original random orientation. The non-uniform magnetic fields are applied at different times and orientations to observe the NMR signals emerging from the diverse points in the three-dimensional volume. Pulse sequence is an important description used for defining application of multiple RF- pulses and multiple gradients. Selection of slices for the brain, the volume elements (voxels) detected for imaging within a slice, the evaluation of the produced signals appeared from physiological features such as arterial blood flow or the concentration of deoxyhemoglobin in venous blood flow form the structure of pulse sequence diagram. Pulse sequences use more than one RF-pulse for generation of NMR signals for a single plane and sometimes utilize data from one single RF-pulse for an entire plane which is called as Echo-planar Imaging. Echo-planar imaging is rapid but requires expensive hardware and is also sensitive imaging artifacts and distortions (Savoy 2007).

Another important parameter to create an image is the “Contrast”. The contrast is provided generally by the neural activity. The source of contrast in the image is the modulation of NMR signal. The exogenous and endogenous contrasts are types of contrasts that are used to obtain an image. The exogenous contrasts are chemical substances which are applicable to the human-beings. These chemicals can be injected into the blood stream of the person where magnetic field is disturbed and increase blood perfusion provides detection. The endogenous contrasts are mostly preferred and which make fMRI noninvasive. The endogenous contrasts are earned from naturally occurring molecules in the blood, like deoxyhemoglobin. When neurons of the brain are activated, there is an increase in oxygen usage. The increment in the blood flow is much greater than the increase in the oxygen level which results in augmentation of oxygenated hemoglobin in the venous part of the circulatory system. The addition of enhanced amount of oxygenated hemoglobin and raise in blood flow cause reduction in the occurring concentration of the deoxygenated hemoglobin on the venous side of the capillaries. The deoxygenated hemoglobin causes distortion in the local magnetic field because it is a paramagnetic molecule which is not bound by oxygen molecules and shows magnetic features. The decrement of deoxyhemoglobin supplies more uniform local magnetic field and keeps protons of the hydrogen atoms in phase longer times which yields strong NMR signal. This event is called as the Blood Oxygen Level Dependent (BOLD) effect. This is the main contrast for many fMRI investigations (Savoy, 2007).

Blood Flow	↑↑↑
O ₂ Utilization	↑
Blood O ₂ Level	↑↑
Deoxy-Hemoglobin Level	↓↓
Distortions to B ₀	↓↓
Phase dispersal of M	↓↓
Effective Decay Rate (1/T ₂ [*])	↓↓
T ₂ [*] -weighted Signal	↑↑

Figure 1.19 The hemodynamics of the blood with its changing characteristics depending on neural activation (Noll, 2001).

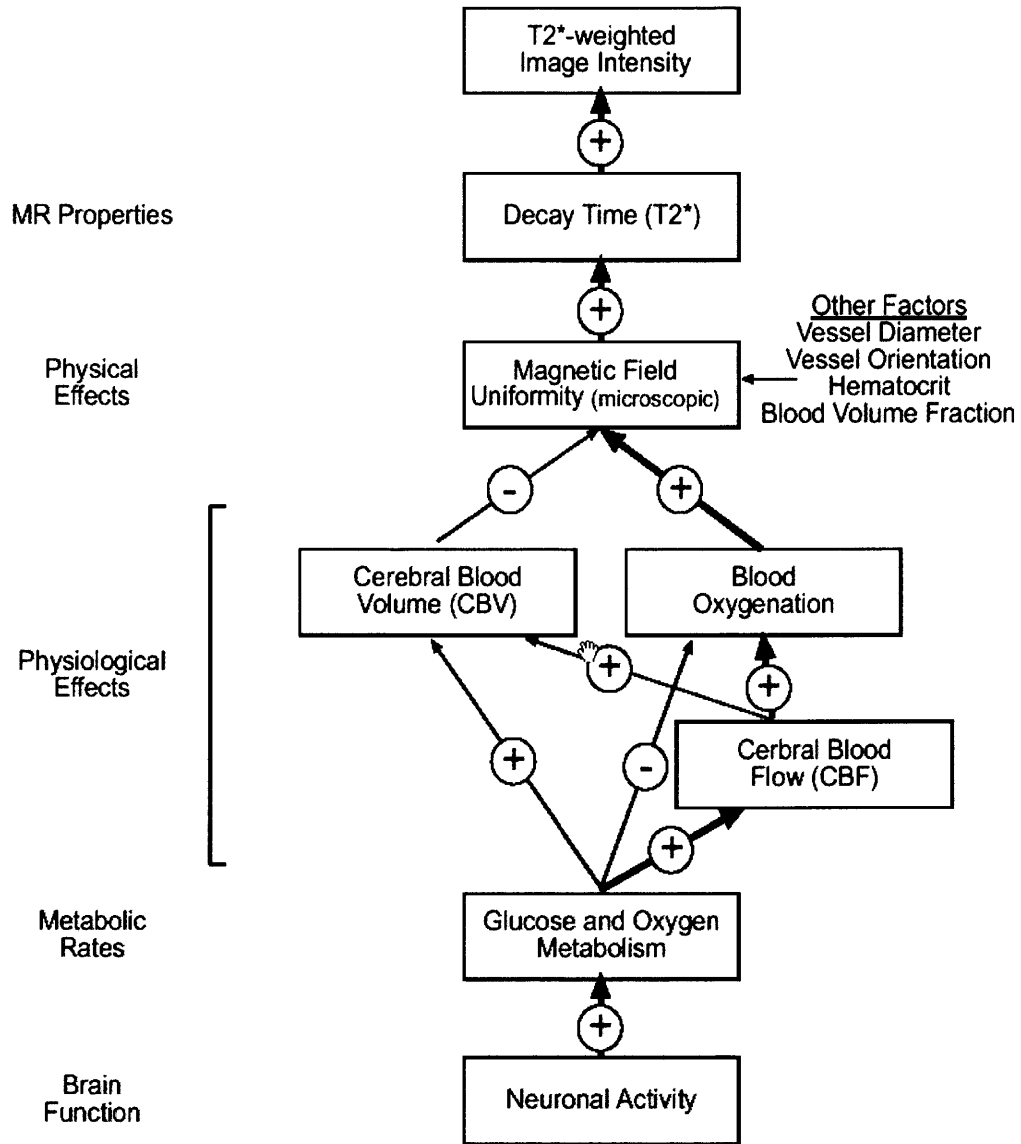


Figure 1.20 The formation of BOLD signal (Noll, 2001).

The discovery of the BOLD effect is done by Ogawa and his colleagues (1990). They claimed that the appearance of the blood vessels in relaxation time ($T2^*$) depends on oxygenation level. During their study, they scanned anesthetized rodents to observe blood oxygenation where the amount of oxygen level was changed. In trials of their experiment, rodents first inhaled 100 percent of oxygen and they found the lines of blood vessels were not clear because the hemoglobin in the blood was highly oxygenated which made the hemoglobin diamagnetic means not appearing in the magnetic field. When the rodents breathed normal air which contain 21 percent of oxygen or when they reduced the oxygen level zero percent, it is observed that the lines of the blood vessels are clear. Furthermore, Ogawa and his colleagues confirmed their study by using test tubes with oxygenated blood or deoxygenated blood into saline-filled container. The spin echo image of oxygenated blood appeared as homogenous black circles, whereas the spin echo image of the deoxygenated blood was distorted because of the their paramagnetic characteristic which caused inhomogeneity on the induced field while changing the resonance frequency of the water molecules (Huettel, Song, & McCarthy, 2004, pp. 160-161).

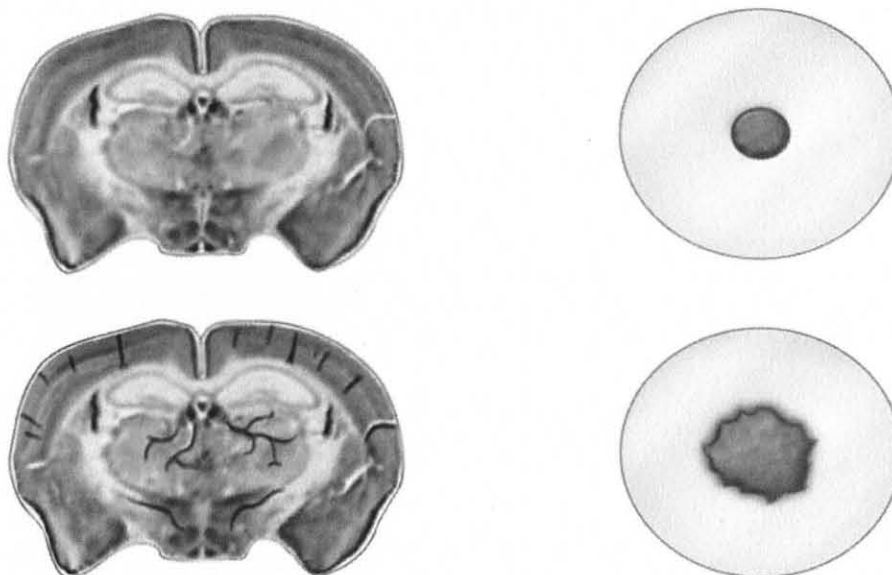


Figure 1.21 Start of Blood Oxygenation Level Dependent (BOLD) Imaging (Huettel et al. 2004).

One of the other significant evidence about fMRI technique is also provided by Kwong and his colleagues. During this investigation, they observed changes in hemodynamic responses for different tasks and showed this activation with a box car protocol where signal intensity versus time parameters were used.

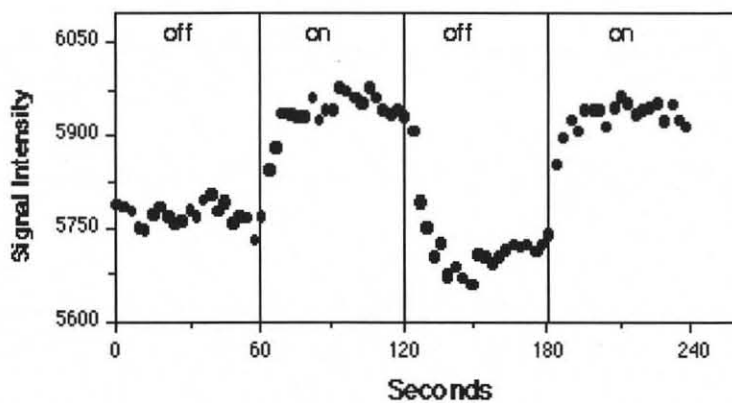


Figure 1.22 Brain activity occurred under application of visual task and darkness (Kwong et al. 1992).

Moreover, they mapped primary primary visual cortex activation (V1) during visual stimulation which is shown below.

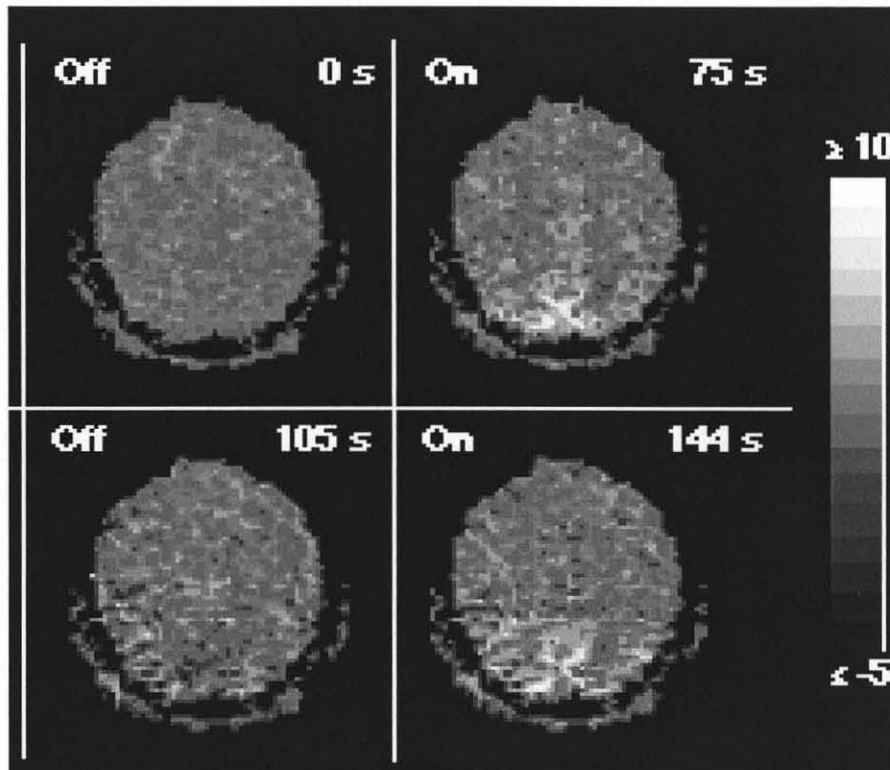


Figure 1.23 Activation on primary visual cortex (Kwong et al. 1992).

As seen from this stimulation, alterations in blood dynamics occurred when the images provided to subjects as a visual target where primary visual cortex activation on the occipital lobe appeared. Conversely, under during complete darkness, the neuronal activity in this region decreased (Kwong et al. 1992).

CHAPTER 2

METHODOLOGY

Eight volunteers participated in this study. Each of them has normal binocular vision which is assessed by using the Randot Stereo Test and there are no reported neurological disorders for these subjects. Before execution of experimental trials, the participants attended simulation of the trials in the Vision and Neural Engineering Laboratory by using mock head coil with a mirror and ISCAN monitor to record their eye movements. ISCAN monitor provided corneal reflection pupil differential using infrared light and the software is used for tracking of corneal reflection and pupil. All the components of the ISCAN monitor and its stand are MRI compatible because they do not contain ferrous materials.

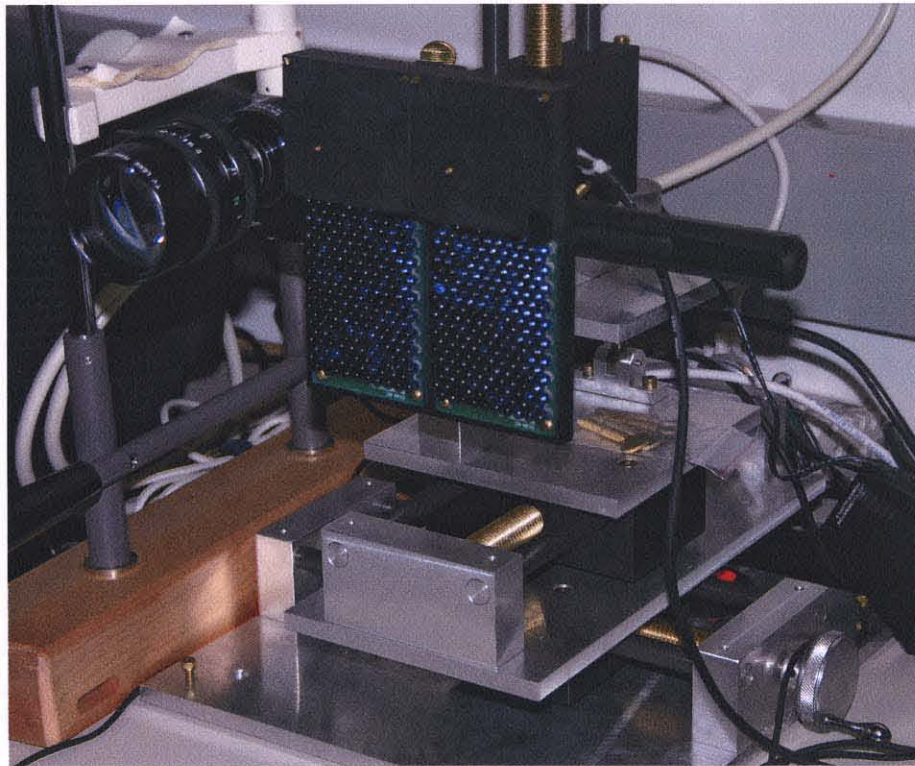


Figure 2.1 MRI compatible ISCAN monitor stand

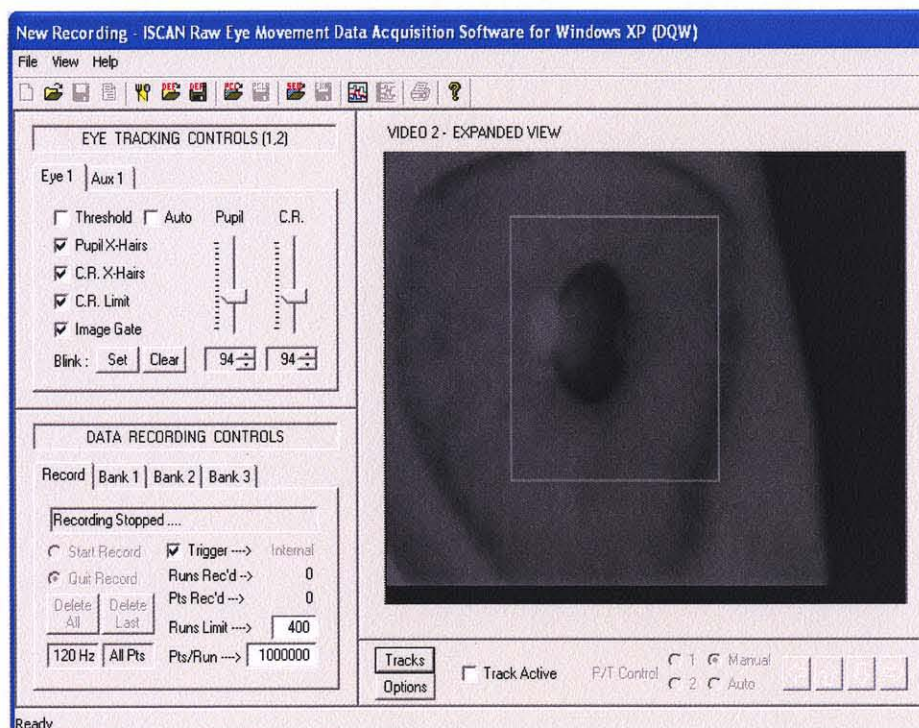


Figure 2.2 ISCAN software was used for recording eye movements

A custom MATLAB software program was used to create the visual stimulus. There were two types of stimulus; one of them was used to achieve saccadic eye movements and the other stimulus provided vergence eye movements which were stimulated by red and green glasses.

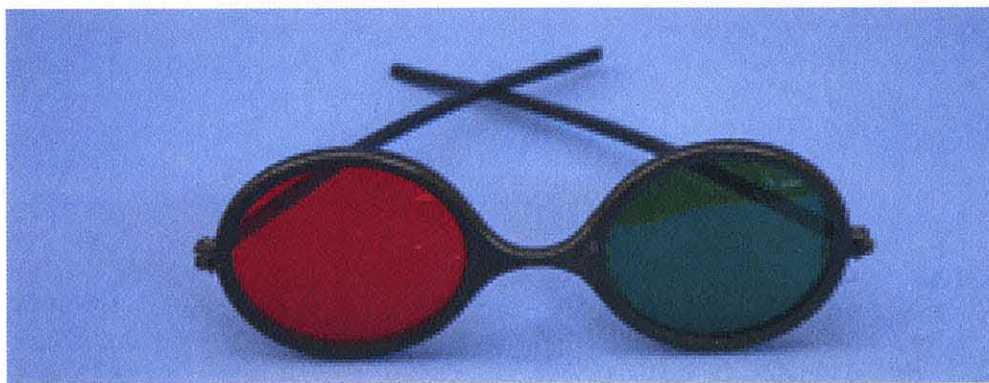


Figure 2.3 Red and green glasses for subjects to achieve vergence eye movements

Data were collected on a 3T Siemens magnetron. Before the functional imaging process, high resolution axial and sagittal anatomical scans were collected. The MRI parameters for functional imaging were TR 553, TE is 9.1, and FOV is 220. For our stimulus, 3 cycles of "off / on" predictable versus non predictable were collected where predictable was 20 seconds and non predictable was 20 seconds or 40 sec / cycle for a total of 120 seconds or 2 minutes. A total of 32 images of the brain were collected which were 5 mm thick with a spatial resolution of 3 mm x 3 mm for pixel resolution within each slice. An MPRAGE sequence contained 150 images of brain, with a spatial resolution of 1mm³ which is needed for Talairach transformation. Talairach transformation was calculated by using @auto_tlrc command which provided the coordinates of the activated parts of the brain using AFNI (Analysis of Functional Neural Imaging). The functional activation was determined by calculating the correlation between functional images. Talairach transformation could result in errors of up to 1cm. Tailarach transformation was also performed so that the subjects' data could be averaged to determine the areas of activation in common between the subjects.

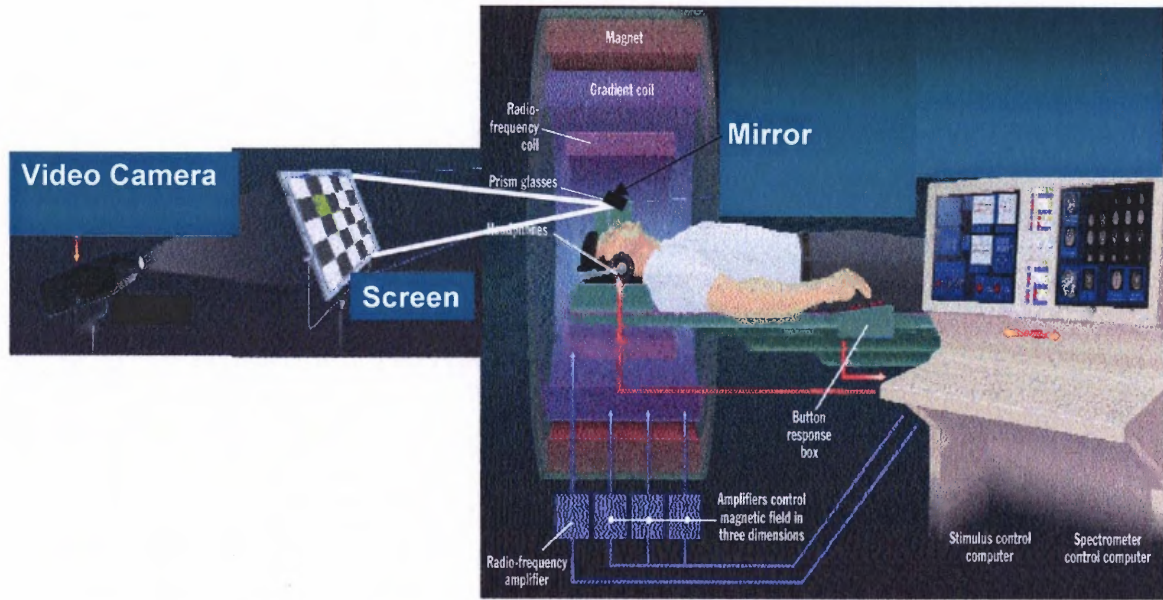


Figure 2.4 Visual display in magnet (Culham, 2007).

The first section of the experiment started with application of saccadic eye movements. The green line was our object to follow. There were two conditions predictable and non predictable for this green line. The green line got larger and smaller. The location of the large green line could be guessed by subjects. For example, there were two directions that green line can go; left and right, when it continued to go these directions, because the subject was getting used to task, he/she was able to predict where the large green line's target destination would be. For the smaller green line, the location and direction of the small green line could not be predicted. It moved randomly without any target destination. The subject just had to smoothly follow small green line wherever it appeared.

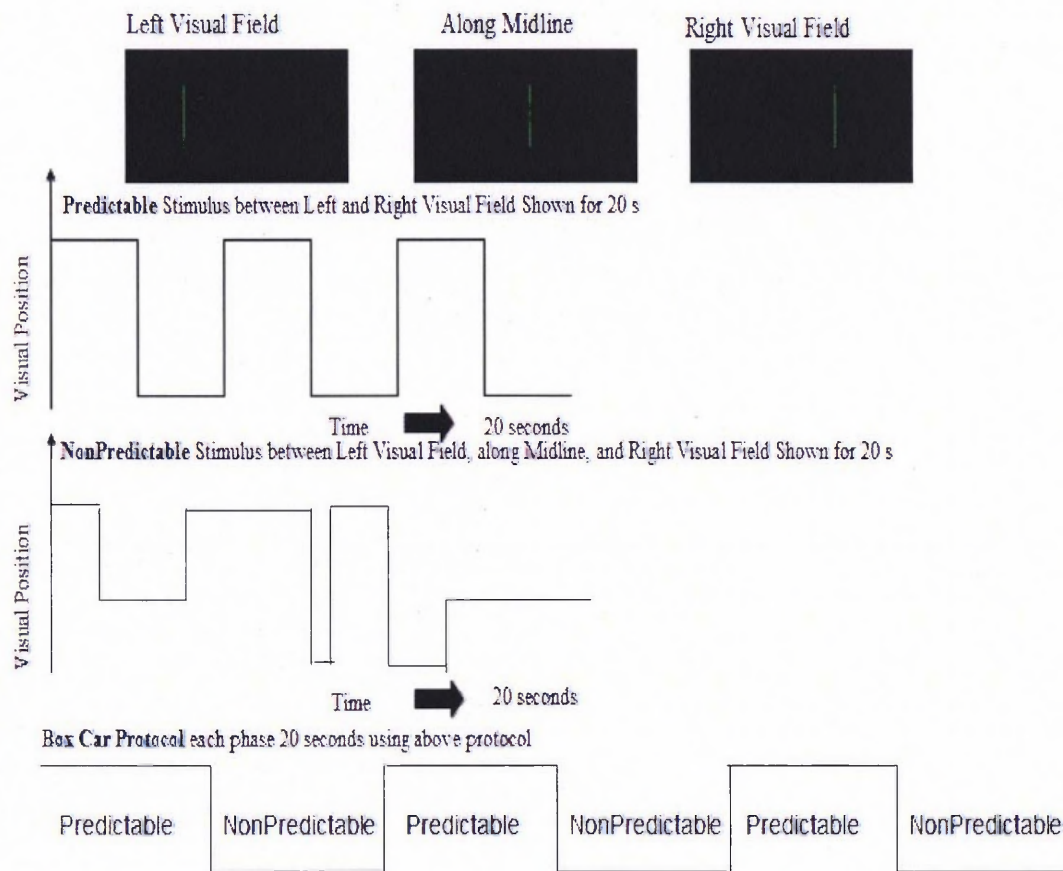


Figure 2.5 Representation of saccadic visual stimuli depending on Box Car Protocol

The second section of the experiment was corresponding to the vergence oculo-motor movements. There were two lines; green and red; one of them was on the left, the other was on the right side of the screen. Through this part of the study, these lines were fusing and getting separated. The aim of the subject was to combine or fuse separated green and red line and was to see these combined lines as one. Moreover, the subject's second aim was to predict where the target location of the large lines was. Smaller lines moved randomly through different target destinations and the subject had to just follow the smaller lines without predicting the target location.

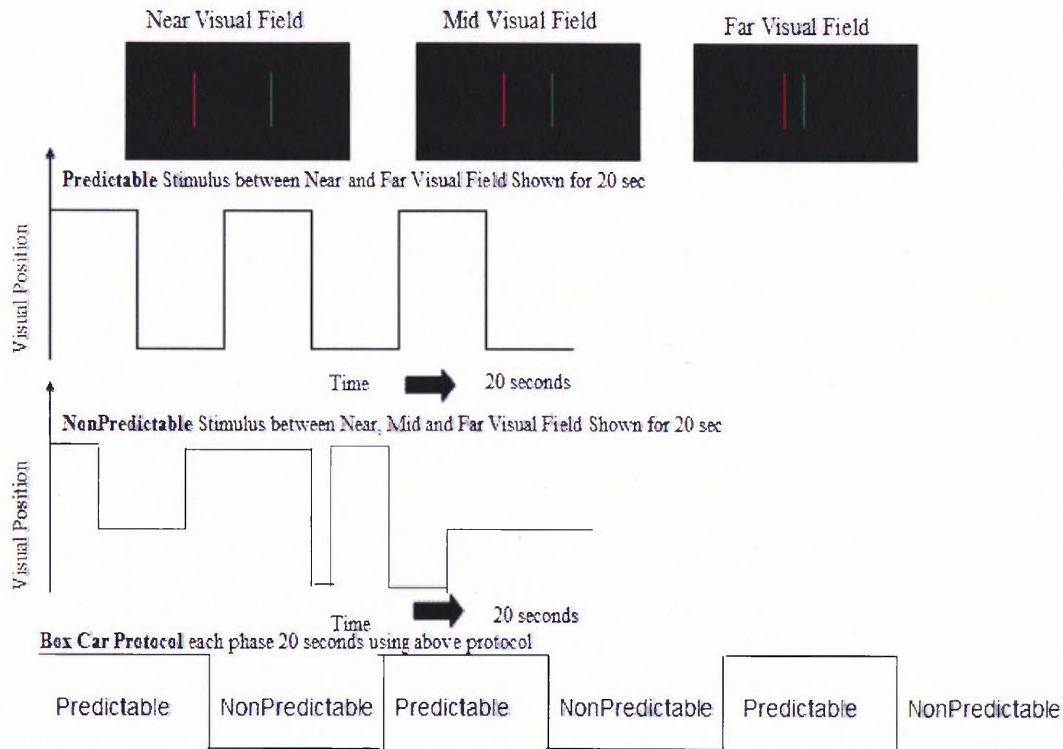


Figure 2.6 Representation of stimuli for vergence eye movements depending on Box Car Protocol

The data after completion of experimental sequences of eight subjects were analyzed by using AFNI (Analysis of Functional NeuroImages). This software program was executed on raw data for visualization of activation in regions of the brain. Processing of the data was done by using some command sequences which can be seen in Appendix 9. Reading of the images was accomplished by to3d command which also can be evaluated as registration of the images. Talairach transformation as mentioned before was provided by application of @auto_tlrc command line which can be seen in Appendix 9. This command line detected activated regions while defining the location of the activation with its coordinates. The threshold in this study was 0.0515. This value was determined according to statistical parameter 'p'. The p value was set to be less than 0.001 which provided the threshold mentioned above. The reason behind this statistical

value is to be consistent the values used in other fMRI investigations. The ideal model curve can be evaluated as have a correlation to the fMRI signal with an R value between zero and one. Zero represents no correlation and one represents perfect correlation. In this study, the threshold was 0.0515, a p value of less than 0.001. If the threshold was decreased, the number of activated pixels was a lower threshold corresponds to a lower 'R' value and vice versa. After all processes, the average of eight subjects was done. For this step firstly, saccade one trials for all eight subjects were added and divided by eight to get the average. The same application was executed for other trials. Then, each averaged trial for eight subjects were added and divided by three to observe the mean of the all saccadic trials.

The similar process was also used for vergence trials for eight subjects. The summation of average saccade data and average vergence data which can be assessed as "AND" gate supplied observation of all common areas for both eye movements. The subtraction of the areas common in saccades and vergence from the average saccade data which can be called as an "OR" gate of Boolean algebra provided observation of areas activated only in saccadic eye movements. The reverse application was done for vergence where again data of areas in common for saccades and vergence were taken and subtracted this time from the average of vergence trials.

CHAPTER 3

RESULTS

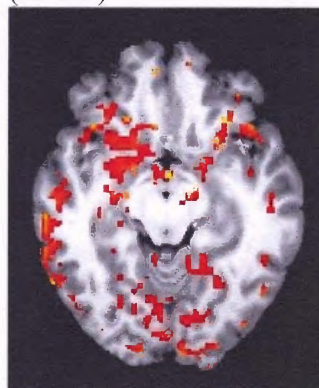
3.1. Regions of Activation for Subject 2 and Average of Eight Healthy Control Subjects

The regions that were activated after image processing are shown in between Figures 3.1 and 3.29. Figures from 3.1 to 3.19 represent the data from subject two. Subject 2 provided good observable activation. These figures contains observed activation areas for each saccadic and vergence trials. Figures from 3.20 to 3.29 implicate the data corresponding to the average of eight subjects. Furthermore, these include activated areas from the average of eight subjects. The threshold for both of them was calculated considering the statistical parameter “p value” in which the p value less than 0.001 ($p < 0.001$).

SUBJECT 2
Threshold: 0.0515
IMAGE#55

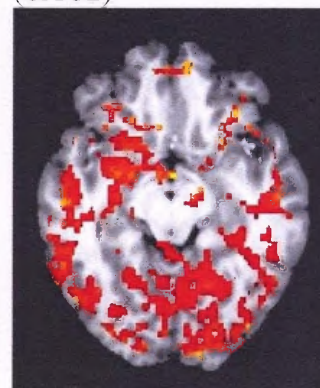
OBSERVED
ACTIVATED AREAS
This observation on
areas is done for
observing clearly
activation on BA 28, BA
34, BA 35, and BA
36.

TRIAL1
(SAC1)



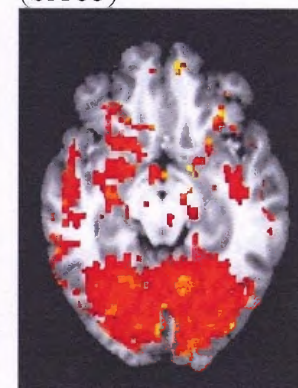
yelda7im55_sac1.jpg

TRIAL4
(SAC2)



yelda7im55_sac2.jpg

TRIAL6
(SAC3)

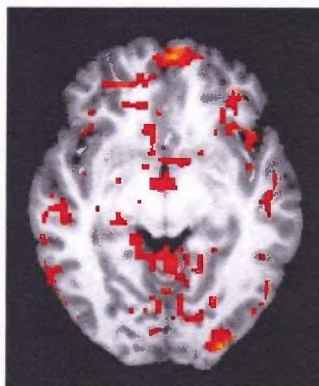


yelda7im55_sac3.jpg

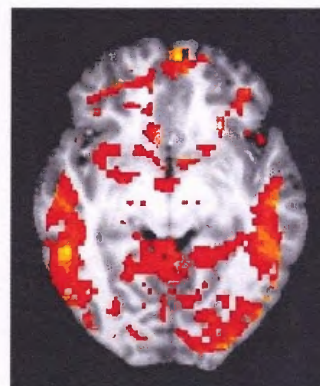
Figure 3.1 Image 55 for Saccade trials 1,4, and 6

IMAGE#58

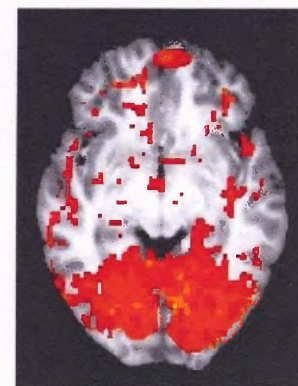
BA 10, BA 11, BA 13,
BA 17, BA 18, BA 19,
BA 20, BA 21, BA 22,
BA 24, BA 25, BA 27,
BA 28, BA 30, BA 32,
BA 34, BA 35, BA 36,
BA 37, BA 38, BA 47
Caudate
Putamen
Globus pallidus



yelda7im58_sac1.jpg



yelda7im58_sac2.jpg

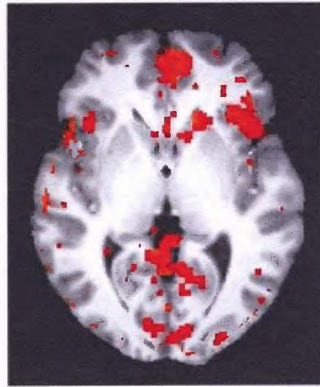


yelda7im58_sac3.jpg

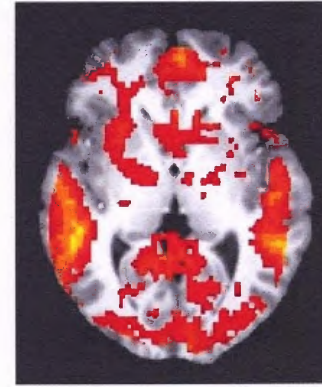
Figure 3.2 Image 58 for Saccade trials 1,4, and 6

IMAGE#67

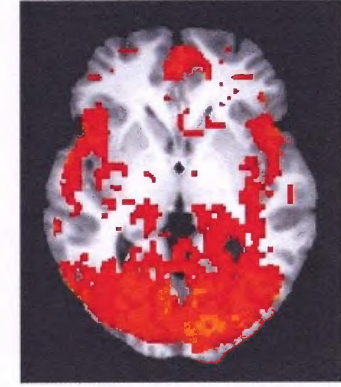
This image is for observation of activation on BA 27.



yelda7im67_sac1ba27.jpg



yelda7im67_sac2ba27.jpg



yelda7im67_sac3ba27.jpg

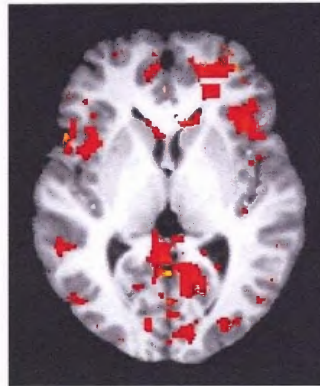
Figure 3.3 Image 67 for Saccade trials 1,4, and 6

IMAGE#70

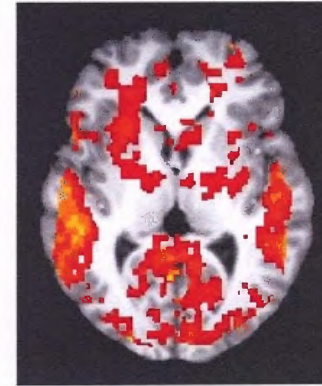
BA 6, BA 10, BA 13, BA 17, BA 18, BA 19, BA 21, BA 22, BA 24, BA 25, BA 27, BA 29, BA 30, BA 32, BA 37, BA 39, BA 41, BA 44, BA 45, BA 46, BA 47
Caudate
Putamen
Pulvinar

P.S

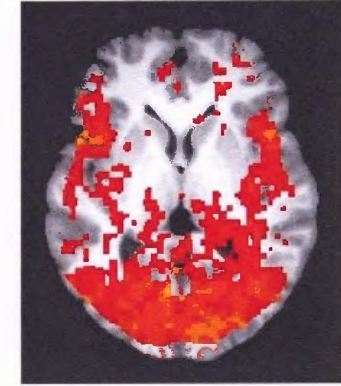
1-Activation on BA 42, BA 43, and globus pallidus is observed in saccade 2 and saccade 3 trials.



yelda7im70_sac1.jpg



yelda7im70_sac2.jpg

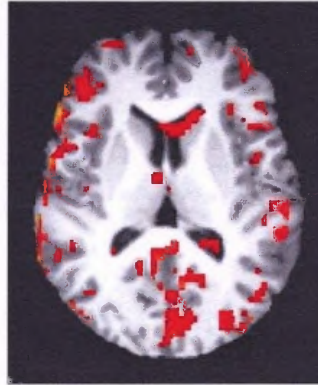


yelda7im70_sac3.jpg

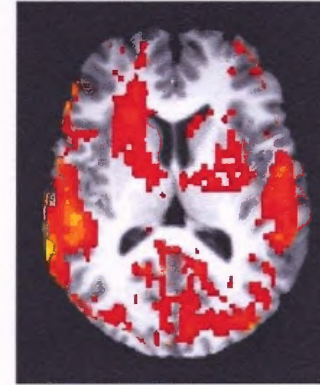
Figure 3.4 Image 70 for Saccade trials 1,4, and 6

IMAGE#76

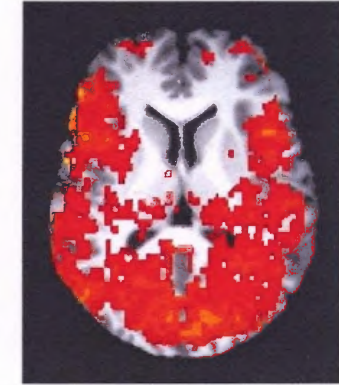
This observation on areas is done for observing clearly activation on BA 41, BA 42, and BA 43.



yelda7im76_sac1.jpg



yelda7im76_sac2.jpg



yelda7im76_sac3.jpg

Figure 3.5 Image 76 for Saccade trials 1,4, and 6

IMAGE#77

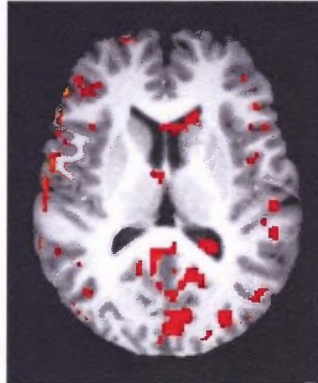
1-Image#77 is for observation of activation on BA 33 for saccade 1 trial.

IMAGE#80

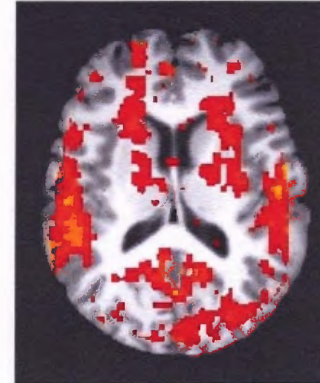
2-Image#80 is for observation of activation on BA 33 for saccade 2 trial.

IMAGE#97

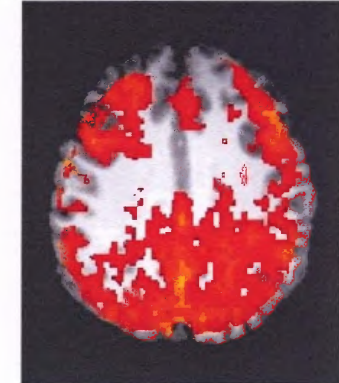
3-Image#97 is for observation of activation on BA 33 for saccade 3 trial.



yelda7im77_sac1ba33.jpg



yelda7im80_sac1ba33.jpg



yelda7im97_sac1ba33.jpg

Figure 3.6 Image 77, 80, and 97 for Saccade trials 1, 4, and 6, respectively

IMAGE#86

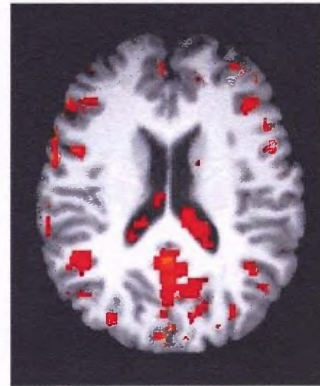
BA 1, BA 2, BA 3, BA 4, BA 6, BA 9, BA 10, BA 13, BA 17, BA 18, BA 19, BA 22, BA 23, BA 29, BA 30, BA 31, BA 32, BA 39, BA 40, BA 41, BA 42, BA 43, BA 44, BA 45, BA 46

Pulvinar

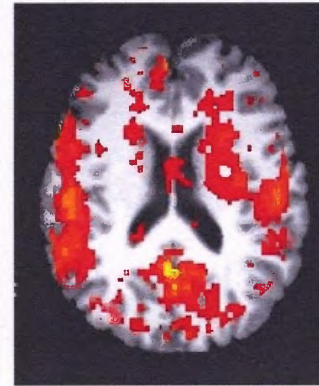
P.S

1- Activation on BA 33 is observed in saccade 3 trial.

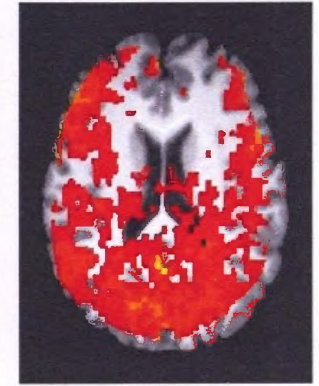
2-Activation on BA 24 is observed in saccade 2 and saccade 3 trials.



yelda7im86_sac1.jpg



yelda7im86_sac2.jpg

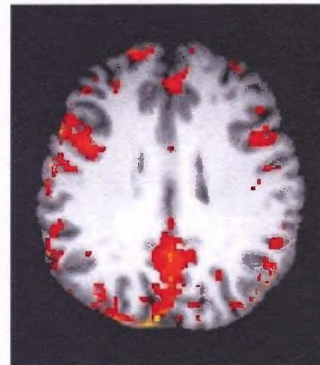


yelda7im86_sac3.jpg

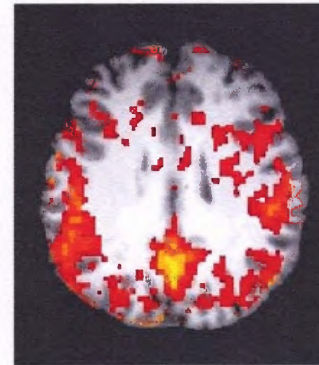
Figure 3.7 Image 86 for Saccade trials 1,4, and 6

IMAGE#95

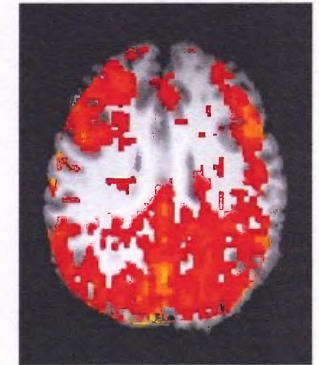
This observation on areas is done for observing clearly activation on BA 1, BA 2, BA 3, and BA 4.



yelda7im95_sac1.jpg



yelda7im95_sac2.jpg

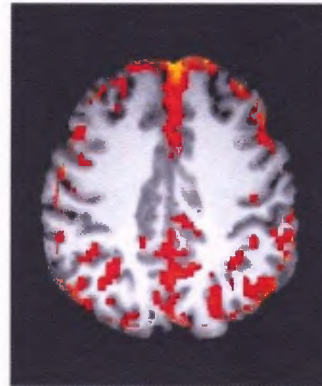


yelda7im95_sac3.jpg

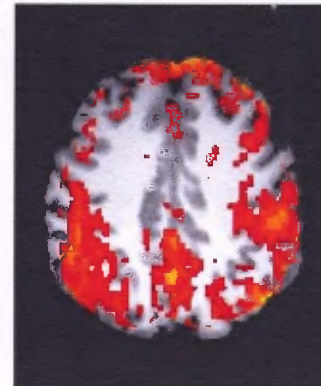
Figure 3.8 Image 95 for Saccade trials 1,4, and 6

IMAGE#103

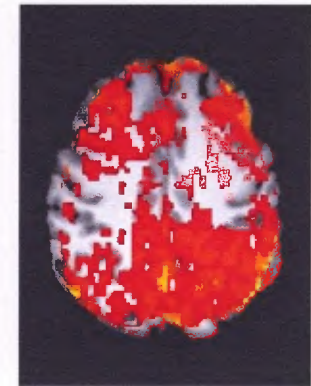
BA 1, BA 2, BA 3, BA 4, BA 6, BA 7, BA 8, BA 9, BA 19, BA 23, BA 24, BA 31, BA 32, BA 39, BA 40
SMA



yelda7im103_sac1.jpg



yelda7im103_sac2.jpg



yelda7im103_sac3.jpg

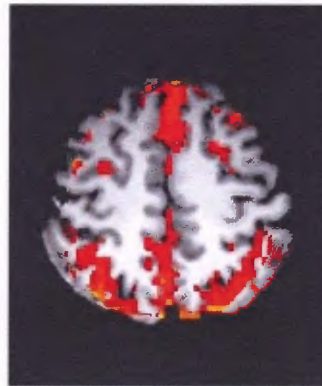
Figure 3.9 Image 103 for Saccade trials 1,4, and 6

IMAGE#114

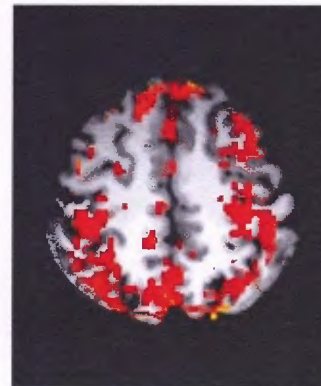
BA 3, BA 4, BA 5, BA 6, BA 7, BA 8, BA 19, BA 24, BA 31, BA 32, BA 39, BA 40
SMA

P.S

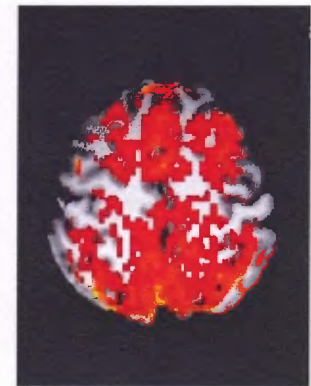
1-Activation on BA 1 and BA 2 is observed in saccade 2 and saccade 3 trials.



yelda7im114_sac1.jpg



yelda7im114_sac2.jpg



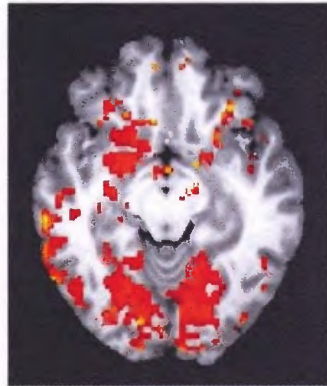
yelda7im114_sac3.jpg

Figure 3.10 Image 114 for Saccade trials 1,4, and 6

OBSERVED
ACTIVATED
AREAS

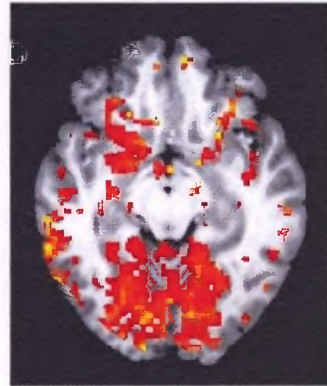
This observation on areas is done for observing clearly activation on BA 28, BA 34, BA 35, and BA 36.

TRIAL2
(VERG1)



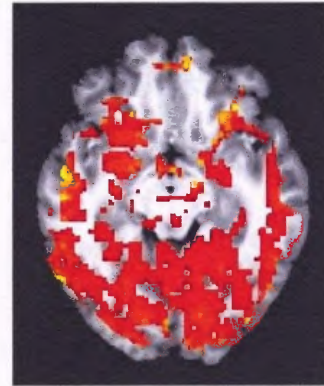
yelda7im55_verg1.jpg

TRIAL3
(VERG2)



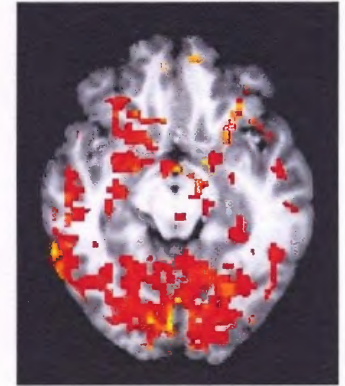
yelda7im55_verg2.jpg

TRIAL5
(VERG3)



yelda7im55_verg3.jpg

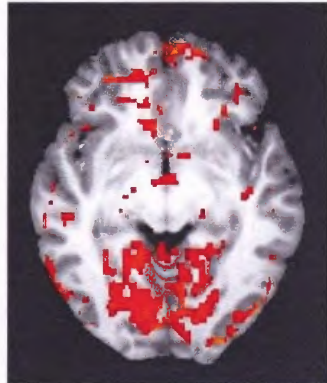
TRIAL7
(VERG4)



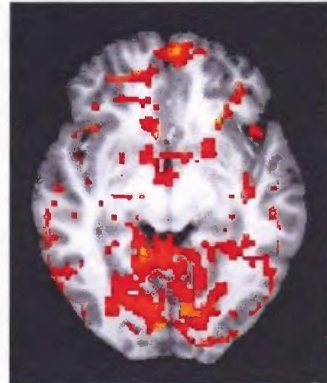
yelda7im55_verg4.jpg

Figure 3.11 Image 55 for Vergence trials 2, 3, 5, and 7

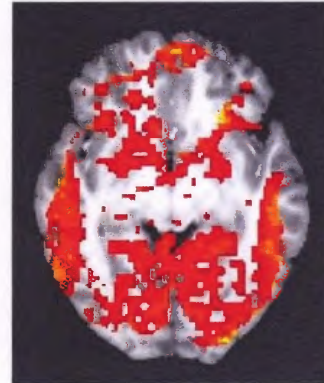
BA 10, BA 11, BA 13, BA 17, BA 18, BA 19, BA 20, BA 21, BA 22, BA 24, BA 25, BA 28, BA 30, BA 32, BA 34, BA 35, BA 36, BA 37, BA 38, BA 47
Caudate
Putamen
Globus pallidus



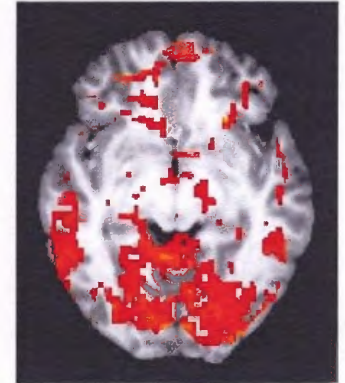
yelda7im58_verg1.jpg



yelda7im58_verg2.jpg



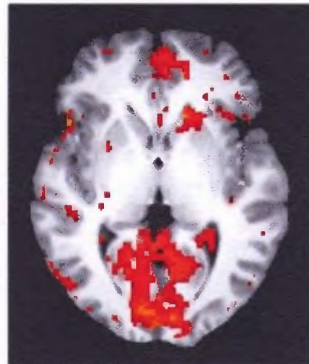
yelda7im58_verg3.jpg



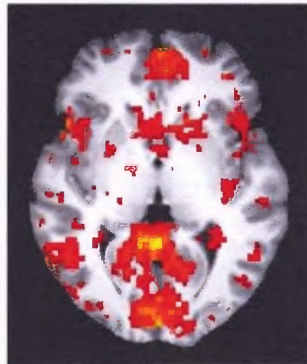
yelda7im58_verg4.jpg

Figure 3.12 Image 58 for Vergence trials 2, 3, 5, and 7

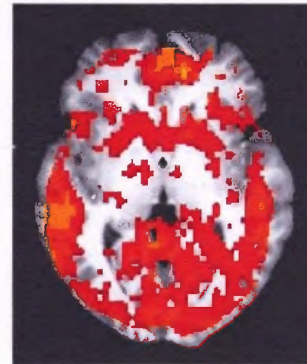
This image is for observation of activation on BA 27.



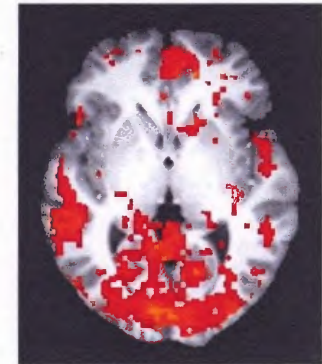
yelda7im67_verg1ba27.jpg



yelda7im67_verg2ba27.jpg



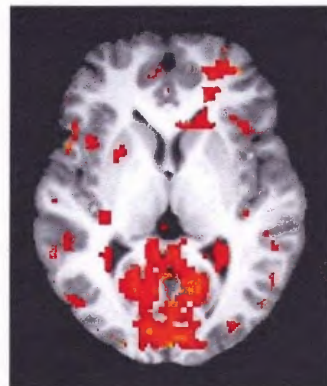
yelda7im67_verg3ba27.jpg



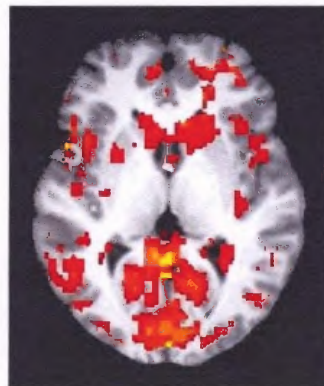
yelda7im67_verg4ba27.jpg

Figure 3.13 Image 67 for Vergence trials 2, 3, 5, and 7

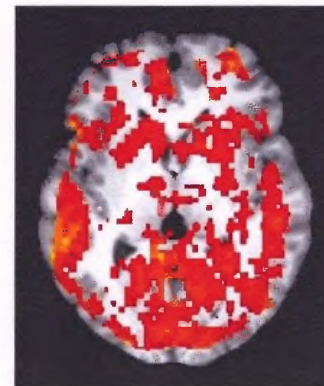
BA 10, BA 13, BA 17, BA 18, BA 19, BA 21, BA 22, BA 24, BA 25, BA 27, BA 29, BA 30, BA 32, BA 37, BA 39, BA 41, BA 44, BA 45, BA 46, BA 47
Caudate, Putamen
Globus pallidus
Pulvinar



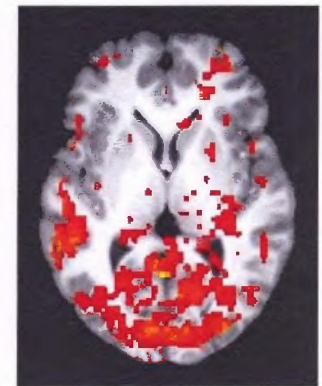
yelda7im70_verg1.jpg



yelda7im70_verg2.jpg



yelda7im70_verg3.jpg



yelda7im70_verg4.jpg

P.S

1-Activation on BA 6 and BA 43 is observed in vergence 2, vergence 3, and vergence 4 trials.

2-Activation on BA 42 is observed in vergence 1, vergence 3, and vergence 4 trials.

Figure 3.14 Image 70 for Vergence trials 2, 3, 5, and 7

This observation on areas is done for observing clearly activation on BA 41, BA 42, and BA 43.

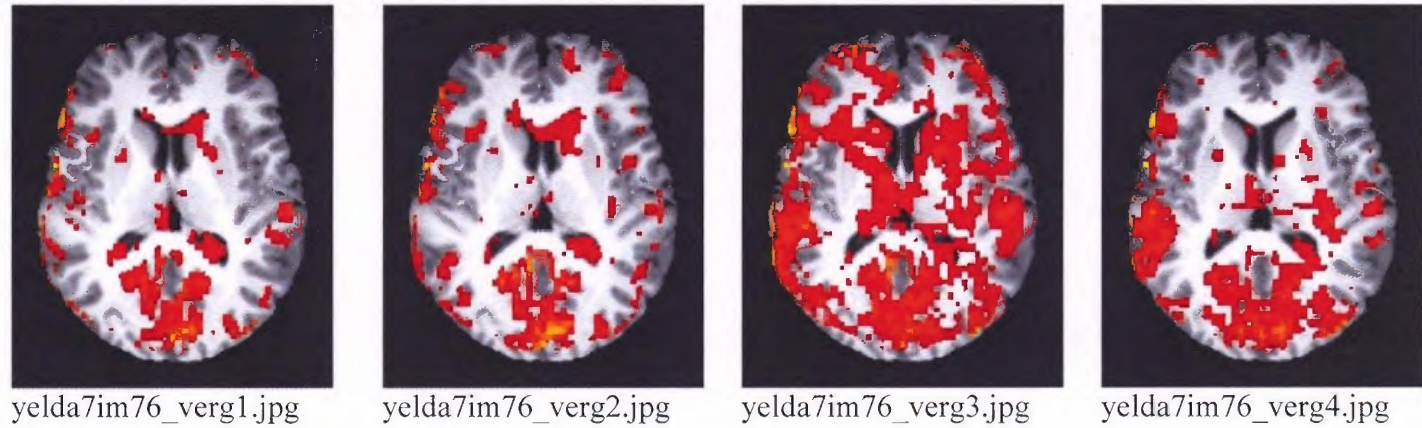


Figure 3.15 Image 76 for Vergence trials 2, 3, 5, and 7

1-Image#80 is for observation of activation on BA 33 for vergence 1, vergence 2, and vergence 3 trials.
 2-Image#84 is for observation of activation on BA 33 for vergence 4 trial.

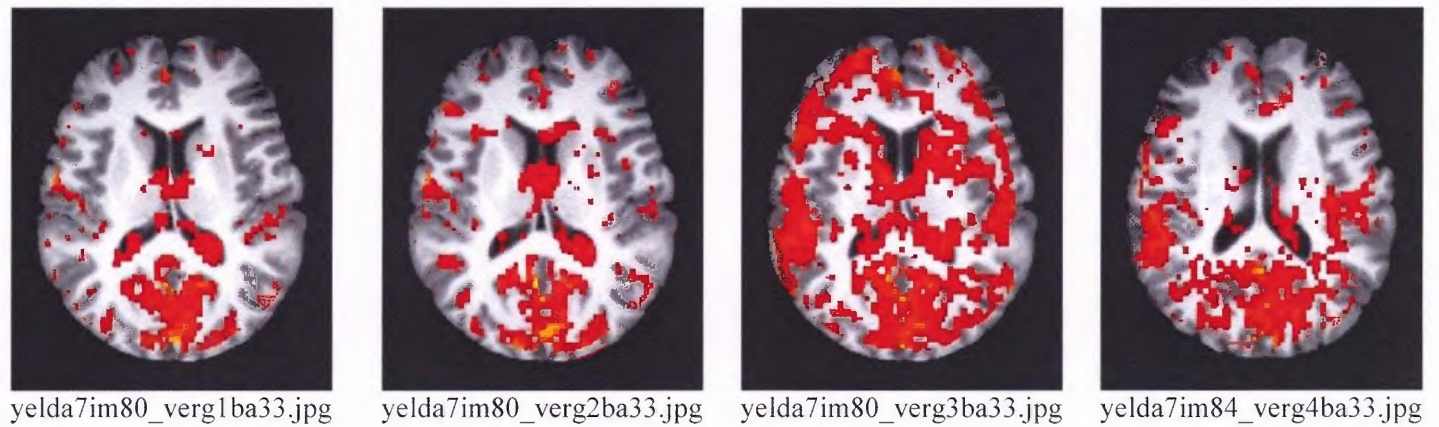
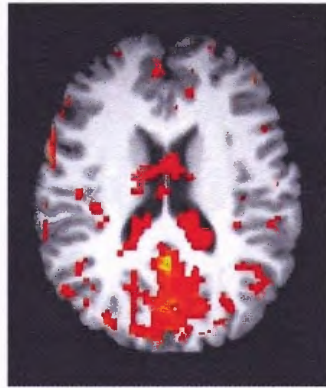
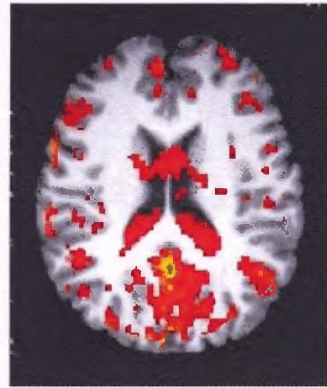


Figure 3.16 Image 80 for Vergence trials 2, 3, 5, and 7

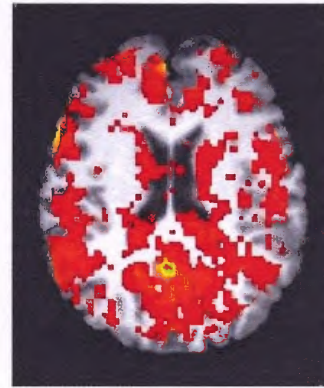
BA 1, BA 2, BA 3,
 BA 4, BA 6, BA 9,
 BA 10, BA 13, BA
 17, BA 18, BA 19,
 BA 22, BA 23, BA
 24, BA 29, BA 30,
 BA 31, BA 33,
 BA 32, BA 39, BA
 40, BA 41, BA 42,
 BA 43, BA 44, BA
 45, BA 46
 Pulvinar



yelda7im86_verg1.jpg



yelda7im86_verg2.jpg



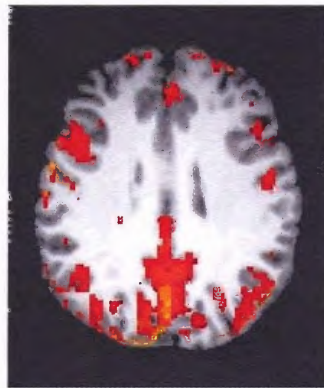
yelda7im86_verg3.jpg



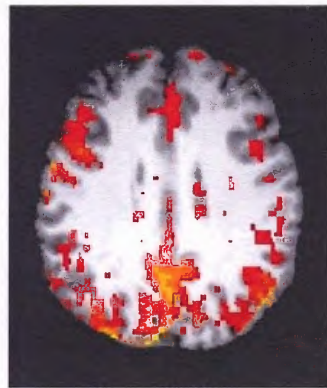
yelda7im86_verg4.jpg

Figure 3.17 Image 86 for Vergence trials 2, 3, 5, and 7

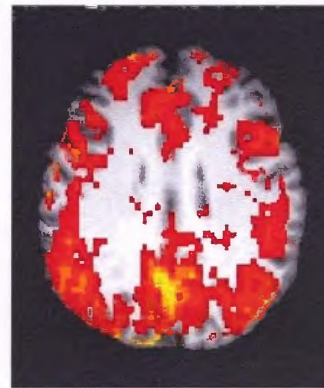
This observation
 on areas is done
 for observing
 clearly activation
 on BA 1, BA 2,
 BA 3, and BA 4.



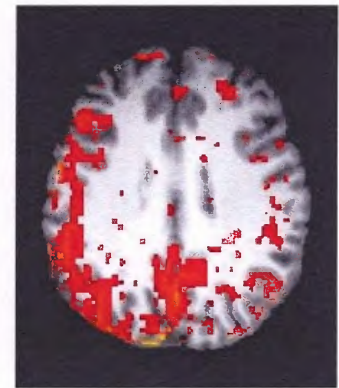
yelda7im95_verg1.jpg



yelda7im95_verg2.jpg



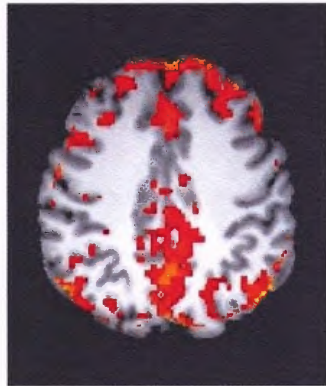
yelda7im95_verg3.jpg



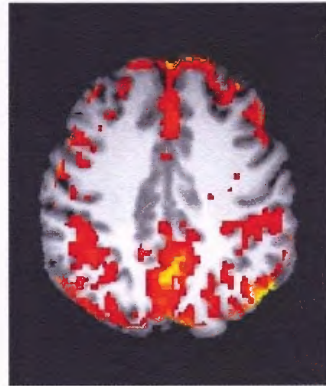
yelda7im95_verg4.jpg

Figure 3.18 Image 95 for vergence trials 2, 3, 5, and 7

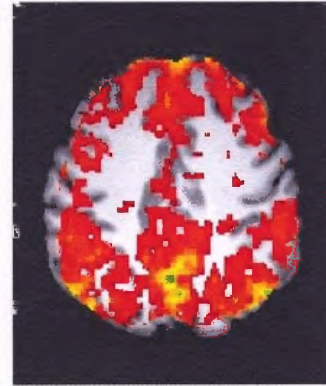
BA 1, BA 2, BA 3, BA 4, BA 6, BA 7, BA 8, BA 9, BA 19, BA 23, BA 24, BA 31, BA 32, BA 39, BA 40, SMA



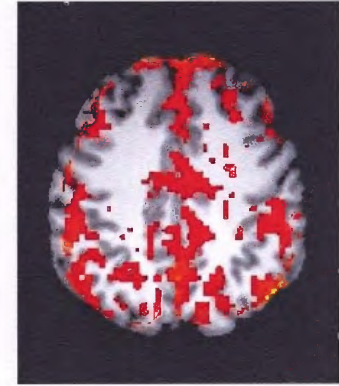
yelda7im103_verg1.jpg



yelda7im103_verg2.jpg



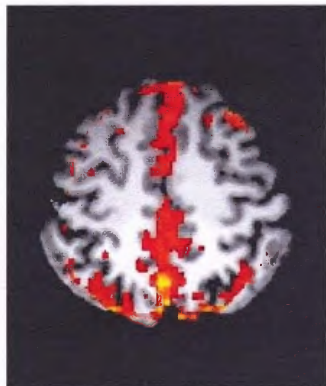
yelda7im103_verg3.jpg



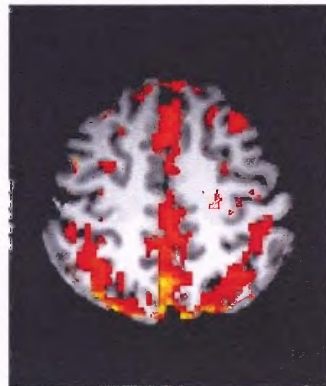
yelda7im103_verg4.jpg

Figure 3.19 Image 103 for vergence trials 2, 3, 5, and 7

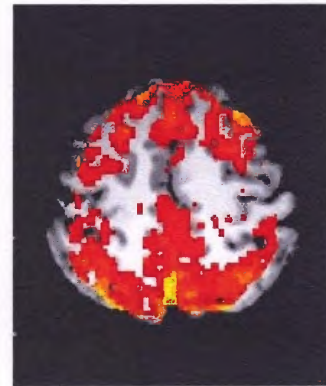
BA 1, BA 2, BA 3, BA 4, BA 5, BA 6, BA 7, BA 8, BA 24, BA 31, BA 32, BA 39, BA 40, SMA



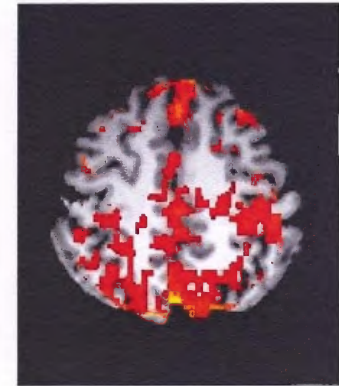
yelda7im114_verg1.jpg



yelda7im114_verg2.jpg



yelda7im114_verg3.jpg



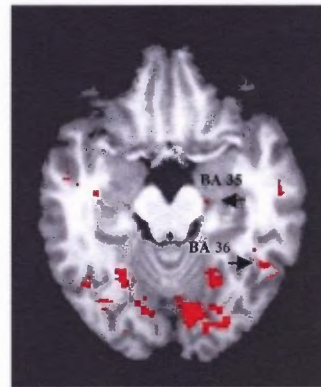
yelda7im114_verg4.jpg

Figure 3.20 Image 114 for Vergence trials 2, 3, 5, and 7

Average of eight subjects
 Threshold: 0.0515
 IMAGE # 50

OBSERVED ACTIVATED AREAS FOR SACCADES
 BA 35 and BA 36 (This image is chosen for clear observation of BA 35 and BA 36)

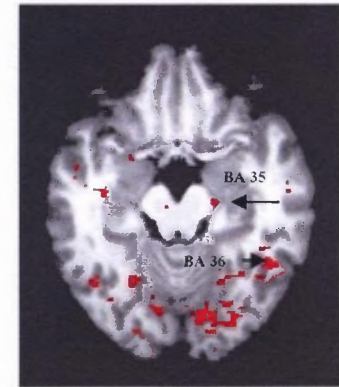
IMAGES FOR SACCADES



avge8_totalsacim50.jpg

OBSERVED ACTIVATED AREAS FOR VERGENCE
 BA 35 and BA 36 (This image is chosen for clear observation of BA 35 and BA 36)

IMAGES FOR VERGENCE

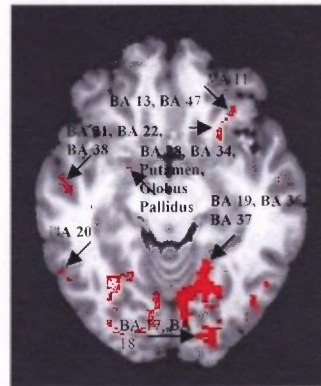


avge8_totalsacim50.jpg

Figure 3.21 Image 50 for averaged data from eight subjects

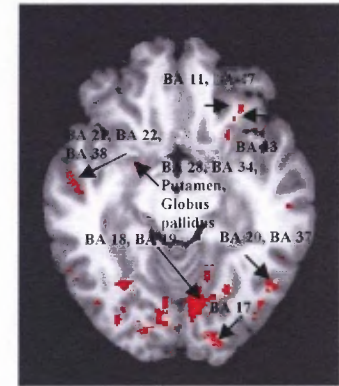
IMAGE#55

BA 11, BA 13, BA 17,
 BA 18, BA 19, BA 20,
 BA 21, BA 22, BA 28,
 BA 34, BA 36, BA 37,
 BA 38, BA 47
 Putamen
 Globus pallidus



avge8_totalsacim55.jpg

BA 11, BA 13, BA 17,
 BA 18, BA 19, BA 20,
 BA 21, BA 22, BA 28,
 BA 34, BA 37, BA 38,
 BA 47
 Putamen
 Globus pallidus

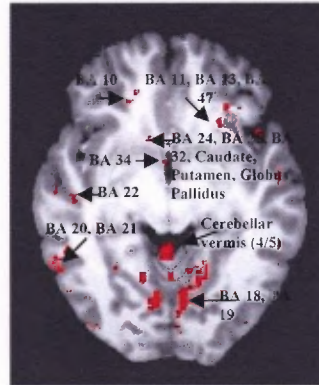


avge8_totalvergim55.jpg

Figure 3.22 Image 55 for averaged data from eight subjects

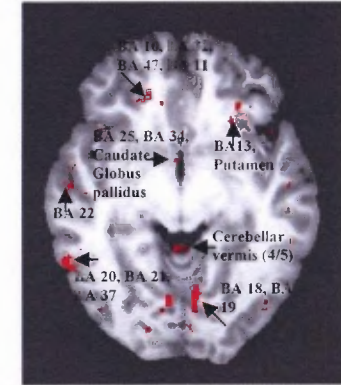
IMAGE#58

BA 10, BA 11, BA 13,
BA 18, BA 19, BA 20,
BA 21, BA 22, BA 25,
BA 32, BA 34, BA 37,
BA 47
Caudate
Putamen
Globus Pallidus
Cerebellar vermis(4/5)



avge8_totalsacim58.jpg

BA 10, BA 11, BA 13,
BA 18, BA 19, BA 20,
BA 21, BA 22, BA 25,
BA 32, BA 34, BA 37,
BA 47
Caudate
Putamen
Globus Pallidus
Cerebellar vermis(4/5)

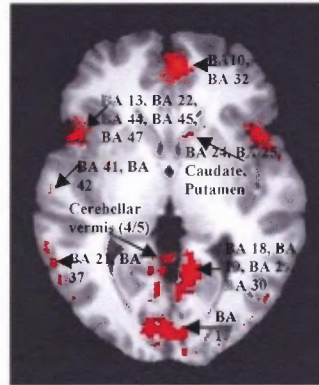


avge8_totalvergim58.jpg

Figure 3.23 Image 58 for averaged data from eight subjects

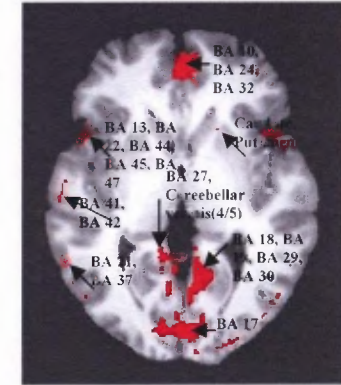
IMAGE#67

BA 10, BA 13, BA 17,
BA 18, BA 19, BA 21,
BA 22, BA 24, BA 25,
BA 29, BA 30, BA 32,
BA 37, BA 41, BA 42,
BA 44, BA 45, BA 47
Caudate
Putamen
Cerebellar vermis (4/5)



avge8_totalsacim67.jpg

BA 10, BA 13, BA 17,
BA 18, BA 19, BA 21,
BA 22, BA 24, BA 27,
BA 29, BA 30, BA 32,
BA 37, BA 41, BA 42,
BA 44, BA 45, BA 47
Caudate
Putamen
Cerebellar vermis (4/5)

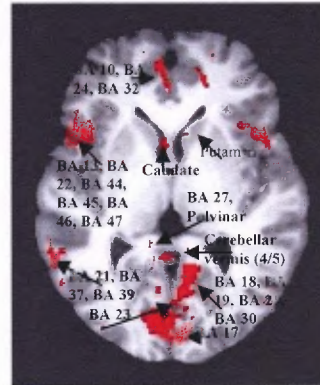


avge8_totalvergim67.jpg

Figure 3.24 Image 67 for averaged data from eight subjects

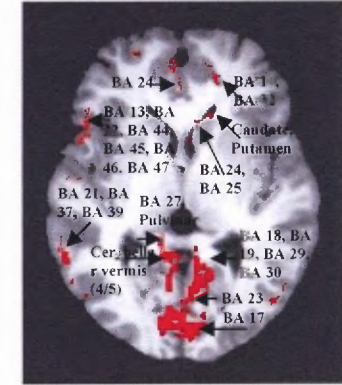
IMAGE#70

BA 10, BA 13, BA 17,
BA 18, BA 19, BA 21,
BA 22, BA 23, BA 24,
BA 27, BA 29, BA 30,
BA 32, BA 37, BA 39,
BA 44, BA 45, BA 46,
BA 47
Caudate
Putamen
Cerebellar vermis (4/5)
Pulvinar



avge8_totalsacim70.jpg

BA 10, BA 13, BA 17,
BA 18, BA 19, BA 21,
BA 22, BA 23, BA 25,
BA 27, BA 29, BA 30,
BA 32, BA 37, BA 39,
BA 44, BA 45, BA 46,
BA 47
Caudate
Putamen
Cerebellar vermis (4/5)
Pulvinar

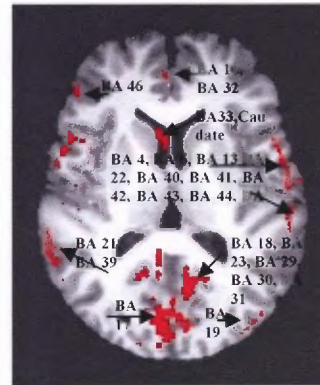


avge8_totalvergim70.jpg

Figure 3.25 Image 70 for averaged data from eight subjects

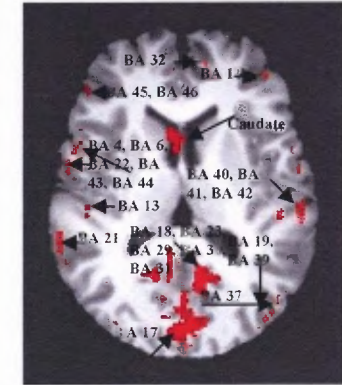
IMAGE#76

BA 4, BA 6, BA 10, BA
13, BA 17, BA 18, BA
19, BA 21, BA 22, BA
23, BA 29, BA 30, BA
31, BA 32, BA 33, BA
39, BA 40, BA 41, BA
42, BA 43, BA 44, BA
45, BA 46
Caudate



avge8_totalsacim76.jpg

BA 4, BA 6, BA 10, BA
13, BA 17, BA 18, BA
19, BA 21, BA 22, BA
23, BA 29, BA 30, BA
31, BA 37, BA 39, BA
40, BA 41, BA 42, BA
43, BA 44, BA 45, BA
46
Caudate

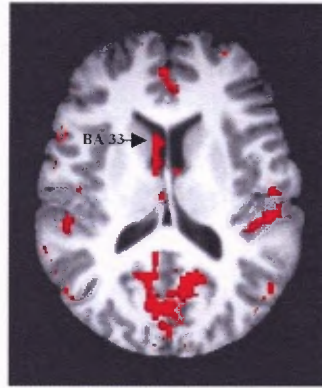


avge8_totalvergim76.jpg

Figure 3.26 Image 76 for averaged data from eight subjects

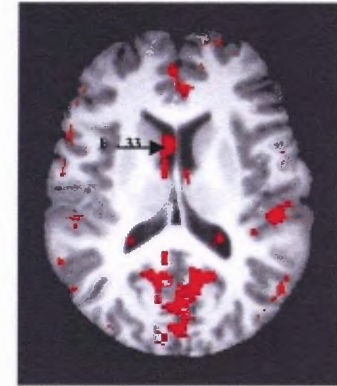
IMAGE#80

BA 33 (This image is chosen for clear observation of BA 33).



avge8_totalsacim80.jpg

BA 33 (This image is chosen for clear observation of BA 33).

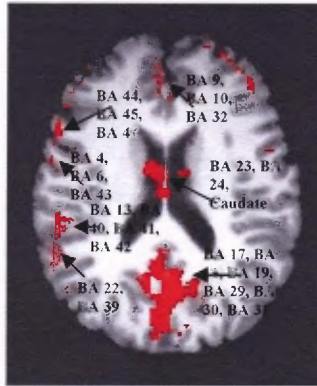


avge8_totalvergim80.jpg

Figure 3.27 Image 80 for averaged data from eight subjects

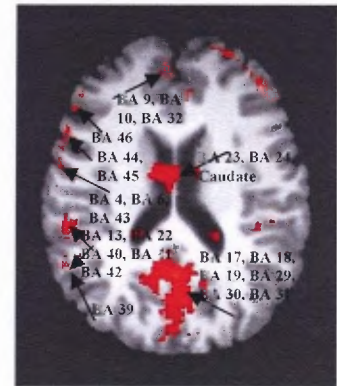
IMAGE#86

BA 6, BA 9, BA 10, BA 13, BA 17, BA 18, BA 19, BA 22, BA 23, BA 24, BA 29, BA 30, BA 31, BA 32, BA 39, BA 40, BA 41, BA 42, BA 43, BA 44, BA 45, BA 46
Caudate



avge8_totalsacim86.jpg

BA 6, BA 9, BA 10, BA 13, BA 17, BA 18, BA 19, BA 22, BA 23, BA 24, BA 29, BA 30, BA 31, BA 32, BA 39, BA 40, BA 41, BA 42, BA 43, BA 44, BA 45, BA 46
Caudate

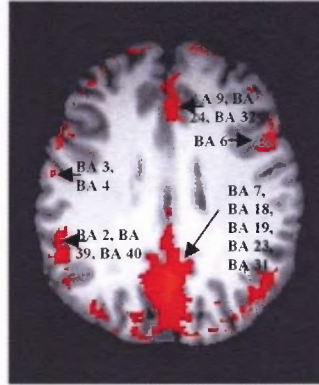


avge8_totalvergim86.jpg

Figure 3.28 Image 86 for averaged data from eight subjects

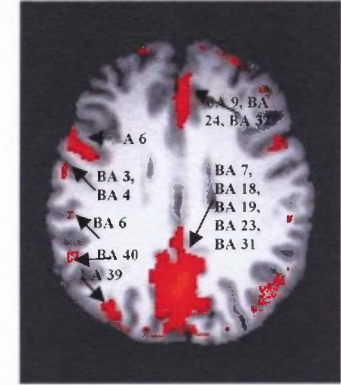
IMAGE#95

BA 2, BA 3, BA 4, BA 6, BA 7, BA 9, BA 18, BA 19, BA 23, BA 24, BA 31, BA 32, BA 39, BA 40



avge8_totalsacim95.jpg

BA 2, BA 3, BA 4, BA 6, BA 7, BA 9, BA 18, BA 19, BA 23, BA 24, BA 31, BA 32, BA 39, BA 40

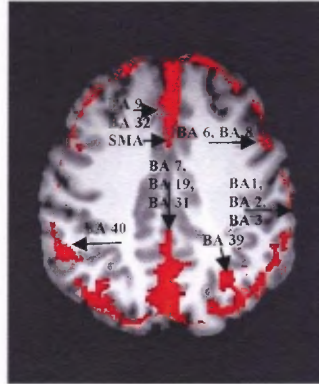


avge8_totalvergim95.jpg

Figure 3.29 Image 95 for averaged data from eight subjects

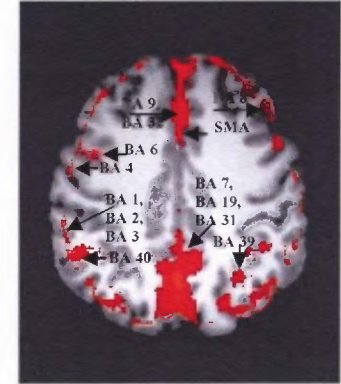
IMAGE#103

BA 1, BA 2, BA 3, BA 4, BA 6, BA 7, BA 8, BA 9, BA 19, BA 24, BA 31, BA 32, BA 39, BA 40
SMA (supplementary motor area)



avge8_totalsacim103.jpg

BA 1, BA 2, BA 3, BA 4, BA 6, BA 7, BA 8, BA 9, BA 19, BA 24, BA 31, BA 32, BA 39, BA 40
SMA (supplementary motor area)

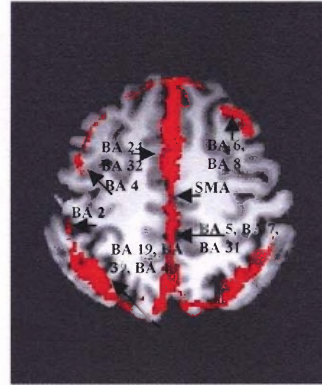


avge8_totalverg103.jpg

Figure 3.30 Image 103 for averaged data from eight subjects

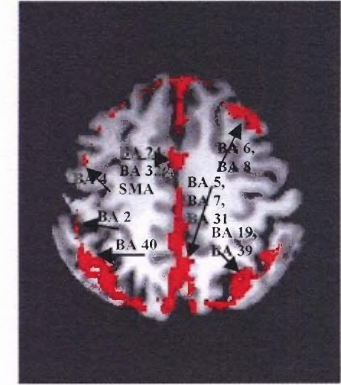
IMAGE#114

BA 2, BA 4, BA 5, BA 6, BA 7, BA 8, BA 19, BA 24, BA 31, BA 32, BA 39, BA 40
SMA (supplementary motor area)



avge8_totalsacim114.jpg

BA 2, BA 4, BA 5, BA 6, BA 7, BA 8, BA 19, BA 24, BA 31, BA 32, BA 39, BA 40
SMA (supplementary motor area)



avge8_totalvergim114.jpg

Figure 3.31 Image 114 for averaged data from eight subjects

3.2 Boolean Comparison of Commonality and Differences between Saccades and Vergence

Another purpose of this research is to observe common and different regions for saccades and vergence. Figure 3.32 show areas in common to vergence and saccades where “AND” gate is used to provide this result.

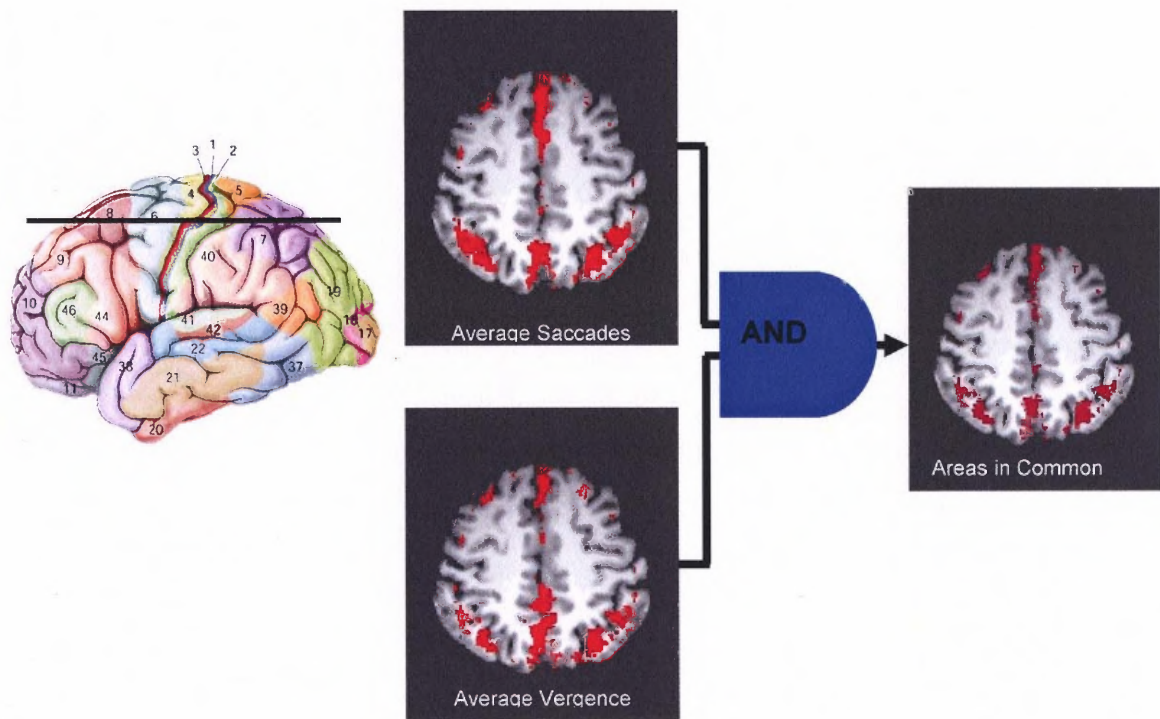


Figure 3.32 Areas in Common to Vergence and Saccades

Activation of areas that activated solely during the saccades or vergence experiment by using “OR” gate. Figure 3.33 indicate the activated regions for saccades only. It is observed that the frontal eye field (FEF) and Brodmann area 7 showed approximately no activation for saccade experiment.

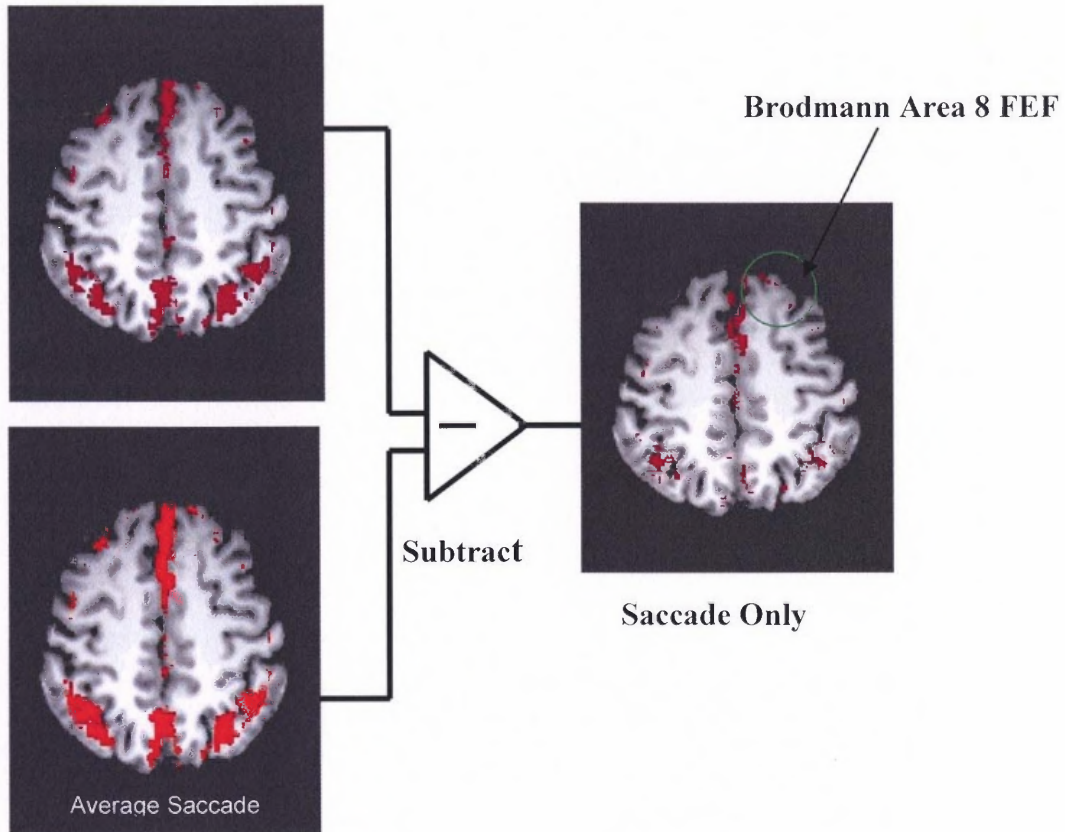


Figure 3.33 Areas activation in Saccade Experiment but NOT Vergence Experiment

Observation of activated regions for only vergence was again supplied by using “OR” gate. In vergence only, it is observed that the frontal eye field (FEF) and Brodmann area 7 was fired up for vergence experiment which is shown in Figure 3.34.

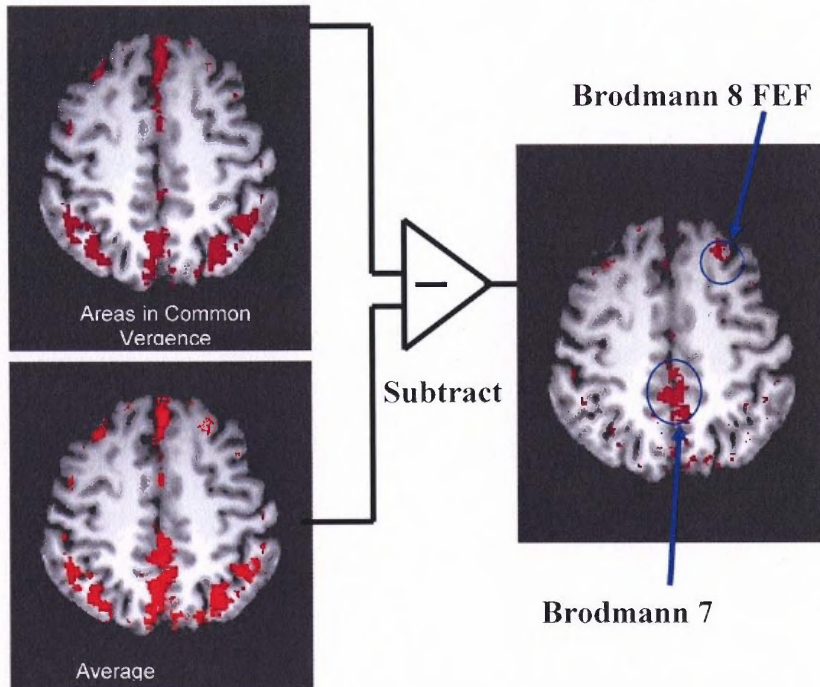


Figure 3.34 Areas activation in Vergence Experiment but NOT Saccade Experiment

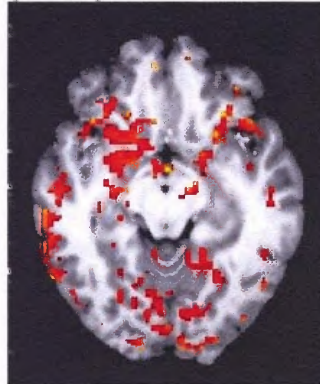
3.3 Oculomotor Learning

Another important result corresponding to this investigation is observation of oculomotor learning. The subjects two and seven who are best participants indicated learning activity among each experimental trials for saccades and vergence. The subject 2 implicated his learning process by increase in blood flow area. The borders of Dorsolateral prefrontal cortex (DLPFC), frontal eye field (FEF), and cerebellar vermis (4/5) regions especially enlarged for subject two which is shown between Figures 3.35 to 3.54. The subject 7 showed his learning indication by increasing the intensity of activity especially in cerebellar vermis (4/5) which is shown between Figures 3.55 to 3.70.

OBSERVED ACTIVATED AREAS

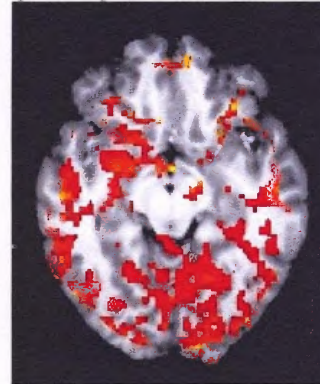
This observation on areas is done for observing clearly activation on BA 28, BA 34, BA 35, and BA 36.

TRIAL1 (SAC1)



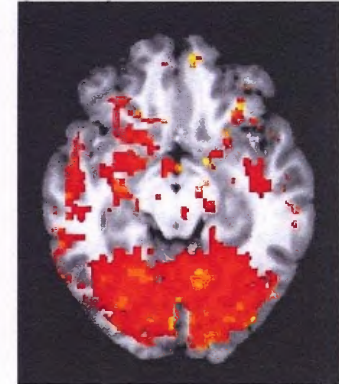
yelda7im55_sac1.jpg

TRIAL4 (SAC2)



yelda7im55_sac2.jpg

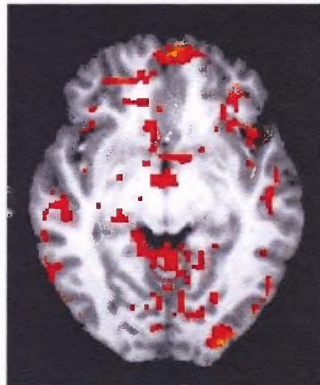
TRIAL6 (SAC3)



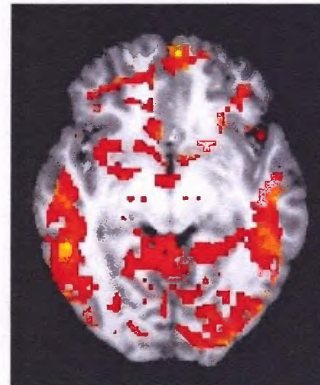
yelda7im55_sac3.jpg

Figure 3.35 Image 55 for saccade trials 1, 4, and 6 of subject 2 for observing growing of regions

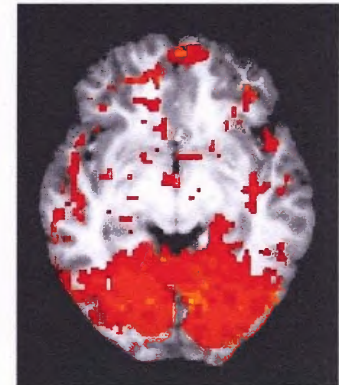
BA 10, BA 11, BA 13, BA 17,
 BA 18, BA 19, BA 20, BA 21,
 BA 22, BA 24, BA 25, BA 27,
 BA 28, BA 30, BA 32, BA 34,
 BA 35, BA 36, BA 37, BA 38,
 BA 47
 Caudate
 Putamen
 Globus pallidus



yelda7im58_sac1.jpg



yelda7im58_sac2.jpg



yelda7im58_sac3.jpg

Figure 3.36 Image 58 for saccade trials 1, 4, and 6 of subject 2 for observing growing of regions

This image is for observation of activation on BA 27.

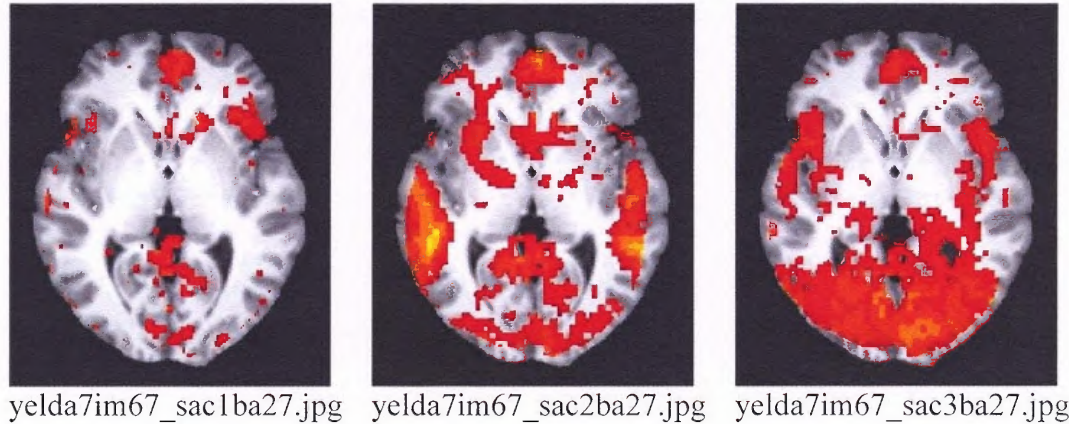


Figure 3.37 Image 67 for saccade trials 1, 4, and 6 of subject 2 for observing growing of regions

BA 6, BA 10, BA 13, BA 17, BA 18, BA 19, BA 21, BA 22, BA 24, BA 25, BA 27, BA 29, BA 30, BA 32, BA 37, BA 39, BA 41, BA 44, BA 45, BA 46, BA 47
Caudate
Putamen
Pulvinar
P.S

1-Activation on BA 42, BA 43, and globus pallidus is observed in saccade 2 and saccade 3 trials.

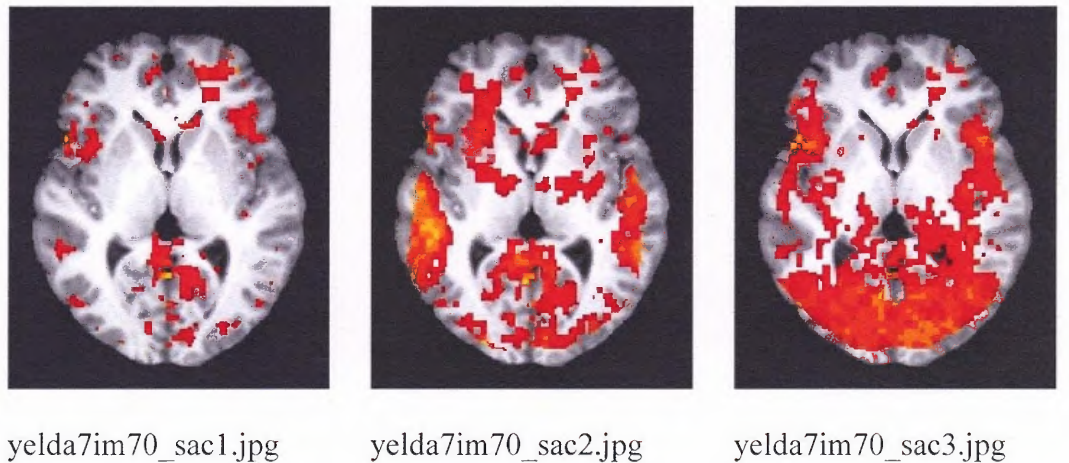


Figure 3.38 Image 70 for saccade trials 1, 4, and 6 of subject 2 for observing growing of regions

This observation on areas is done for observing clearly activation on BA 41, BA 42, and BA 43.

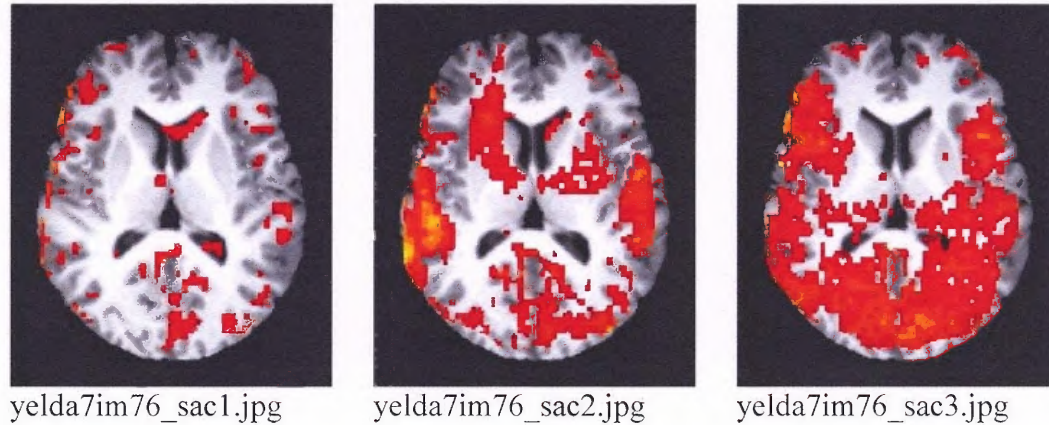


Figure 3.39 Image 76 for saccade trials 1, 4, and 6 of subject 2 for observing growing of regions

1-Image#77 is for observation of activation on BA 33 for saccade 1 trial.
2-Image#80 is for observation of activation on BA 33 for saccade 2 trial.
3-Image#97 is for observation of activation on BA 33 for saccade 3 trial.

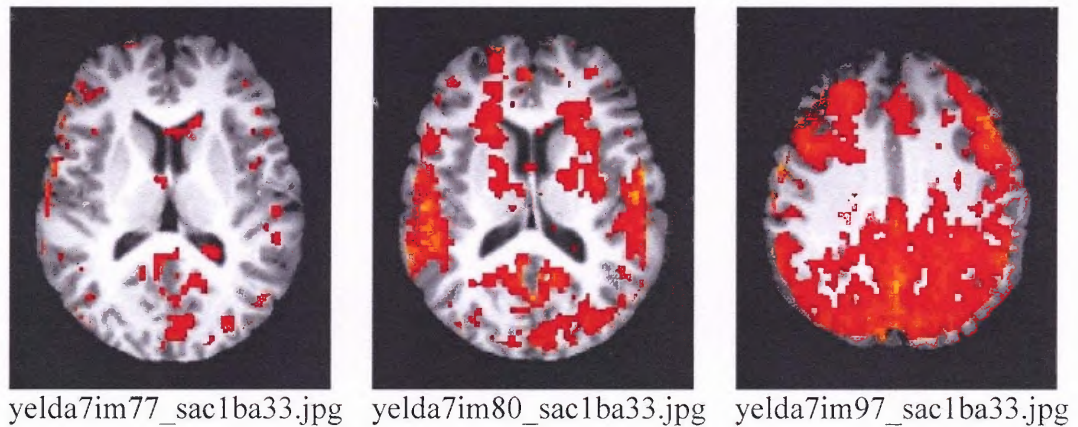


Figure 3.40 Image 77 for saccade trials 1, 4, and 6 of subject 2 for observing growing of regions

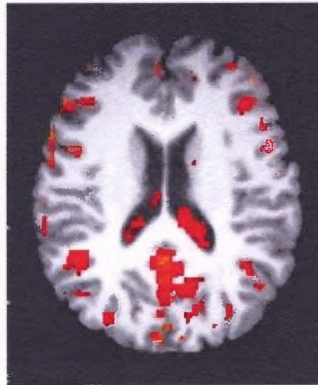
BA 1, BA 2, BA 3, BA 4, BA 6,
 BA 9, BA 10, BA 13, BA 17, BA
 18, BA 19, BA 22, BA 23, BA
 29, BA 30, BA 31, BA 32, BA
 39, BA 40, BA 41, BA 42, BA
 43, BA 44, BA 45, BA 46

Pulvinar

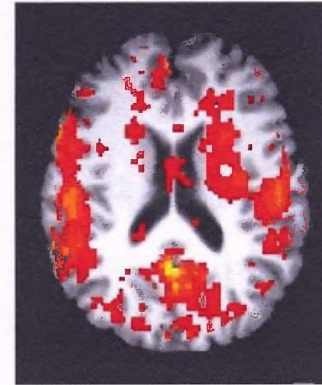
P.S

1- Activation on BA 33 is
 observed in saccade 3 trial.

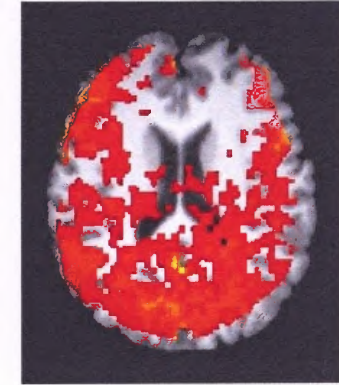
2-Activation on BA 24 is
 observed in saccade 2 and saccade
 3 trials.



yelda7im86_sac1.jpg



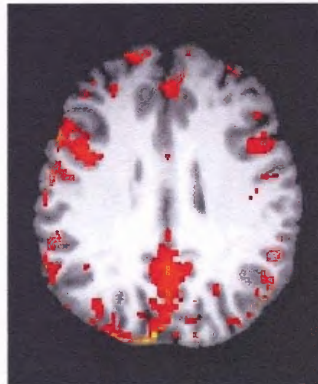
yelda7im86_sac2.jpg



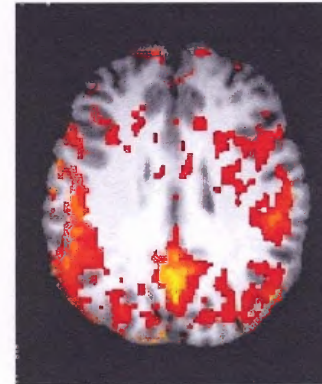
yelda7im86_sac3.jpg

Figure 3.41 Image 86 for saccade trials 1, 4, and 6 of subject 2 for observing growing of regions

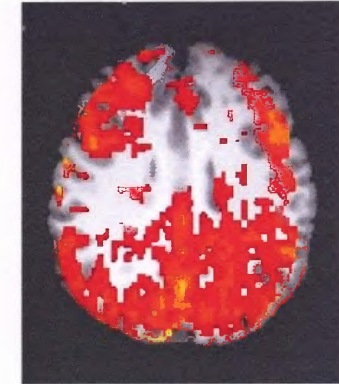
This observation on areas is done
 for observing clearly activation on
 BA 1, BA 2, BA 3, and BA 4.



yelda7im95_sac1.jpg



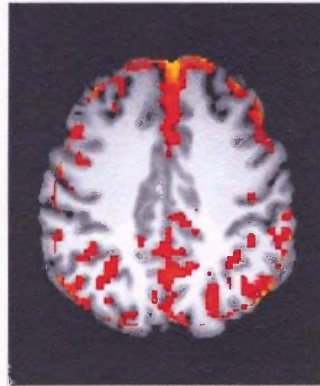
yelda7im95_sac2.jpg



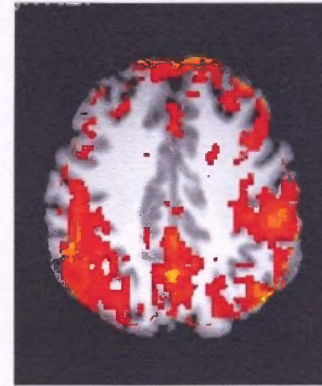
yelda7im95_sac3.jpg

Figure 3.42 Image 95 for saccade trials 1, 4, and 6 of subject 2 for observing growing of regions

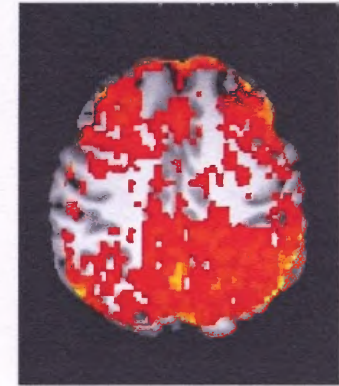
BA 1, BA 2, BA 3, BA 4, BA 6,
 BA 7, BA 8, BA 9, BA 19, BA 23
 BA 24, BA 31, BA 32, BA 39,
 BA 40
 SMA



yelda7im103_sac1.jpg



yelda7im103_sac2.jpg



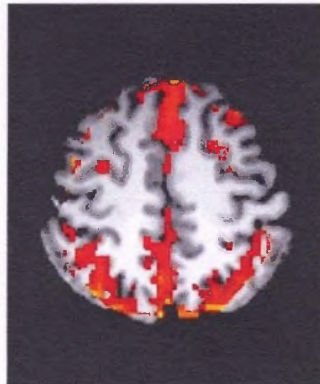
yelda7im103_sac3.jpg

Figure 3.43 Image 103 for saccade trials 1, 4, and 6 of subject 2 for observing growing of regions

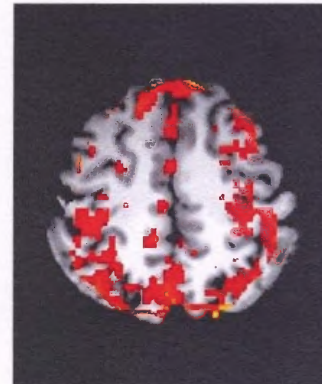
BA 3, BA 4, BA 5, BA 6, BA 7,
 BA 8, BA 19, BA 24, BA 31, BA
 32, BA 39, BA 40
 SMA

P.S

1-Activation on BA 1 and BA 2 is
 observed in saccade 2 and saccade
 3 trials.



yelda7im114_sac1.jpg



yelda7im114_sac2.jpg



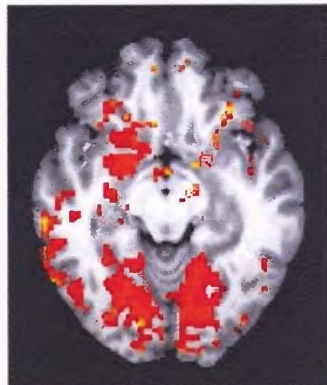
yelda7im114_sac3.jpg

Figure 3.44 Image 114 for saccade trials 1, 4, and 6 of subject 2 for observing growing of regions

OBSERVED
ACTIVATED
AREAS

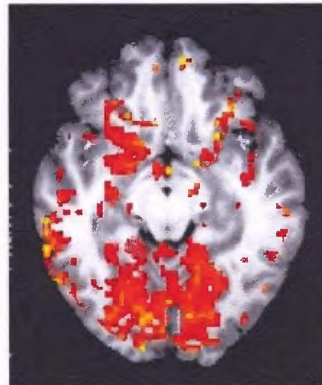
This observation on areas is done for observing clearly activation on BA 28, BA 34, BA 35, and BA 36.

TRIAL2
(VERG1)



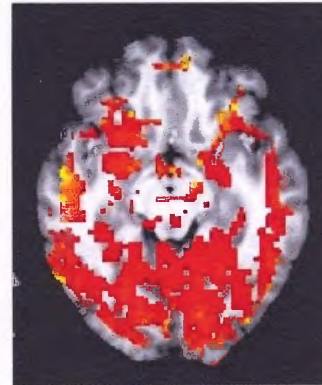
yelda7im55_verg1.jpg

TRIAL3
(VERG2)



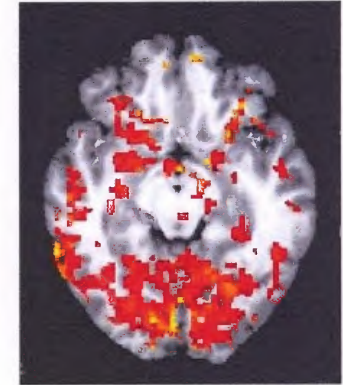
yelda7im55_verg2.jpg

TRIAL5
(VERG3)



yelda7im55_verg3.jpg

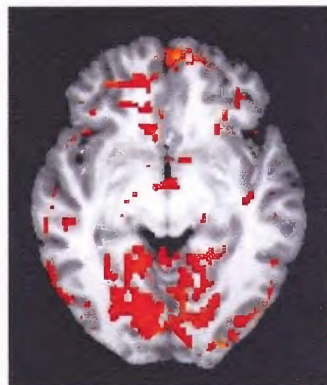
TRIAL7
(VERG4)



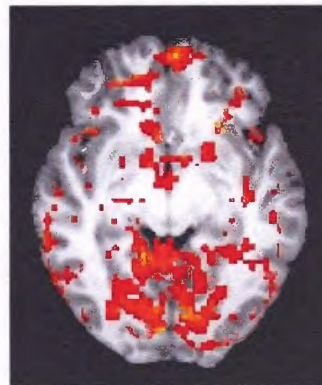
yelda7im55_verg4.jpg

Figure 3.45 Image 55 for vergence trials 2, 3, 5 and 7 of subject 2 for observing growing of regions

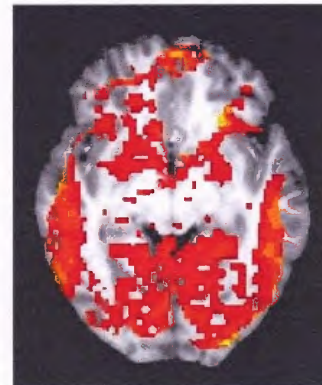
BA 10, BA 11,
BA 13, BA 17,
BA 18, BA 19,
BA 20, BA 21,
BA 22, BA 24,
BA 25, BA 28,
BA 30, BA 32,
BA 34, BA 35,
BA 36, BA 37,
BA 38, BA 47
Caudate,
Putamen, Globus
pallidus



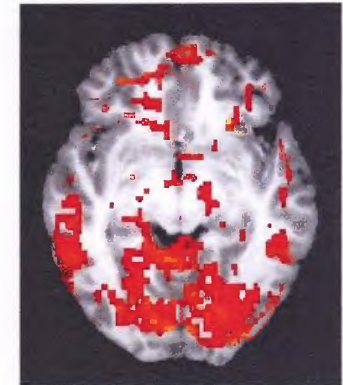
yelda7im58_verg1.jpg



yelda7im58_verg2.jpg



yelda7im58_verg3.jpg



yelda7im58_verg4.jpg

Figure 3.46 Image 58 for vergence trials 2, 3, 5 and 7 of subject 2 for observing growing of regions

This image is for observation of activation on BA 27.

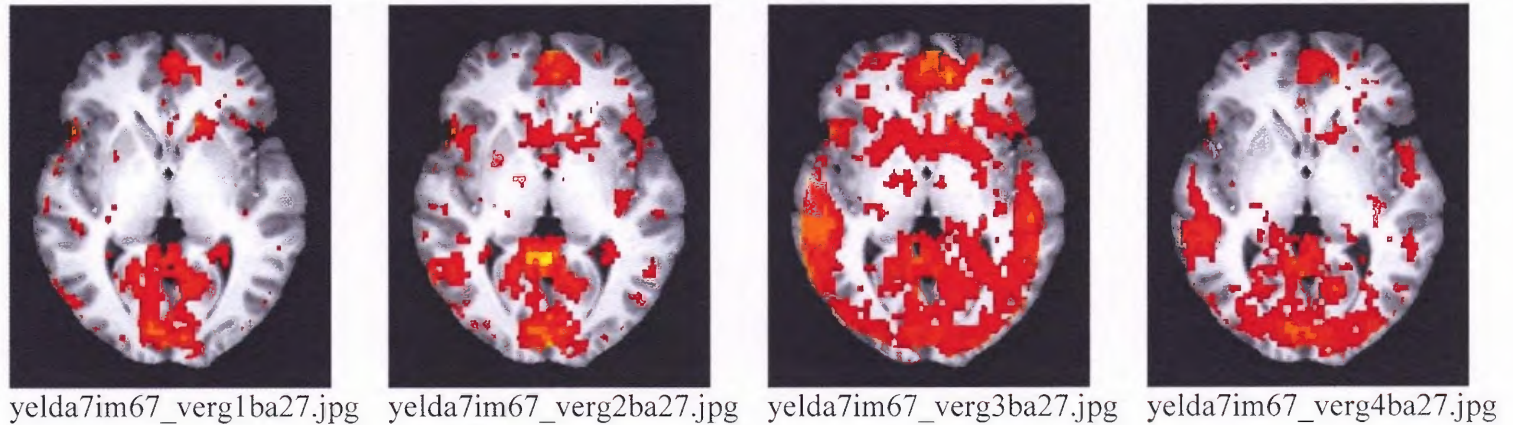


Figure 3.47 Image 67 for vergence trials 2, 3, 5 and 7 of subject 2 for observing growing of regions

BA 10, BA 13,
 BA 17, BA 18,
 BA 19, BA 21,
 BA 22, BA 24,
 BA 25, BA 27,
 BA 29, BA 30,
 BA 32, BA 37,
 BA 39, BA 41,
 BA 44, BA 45,
 BA 46, BA
 47
 Caudate
 Putamen
 Globus pallidus
 Pulvinar

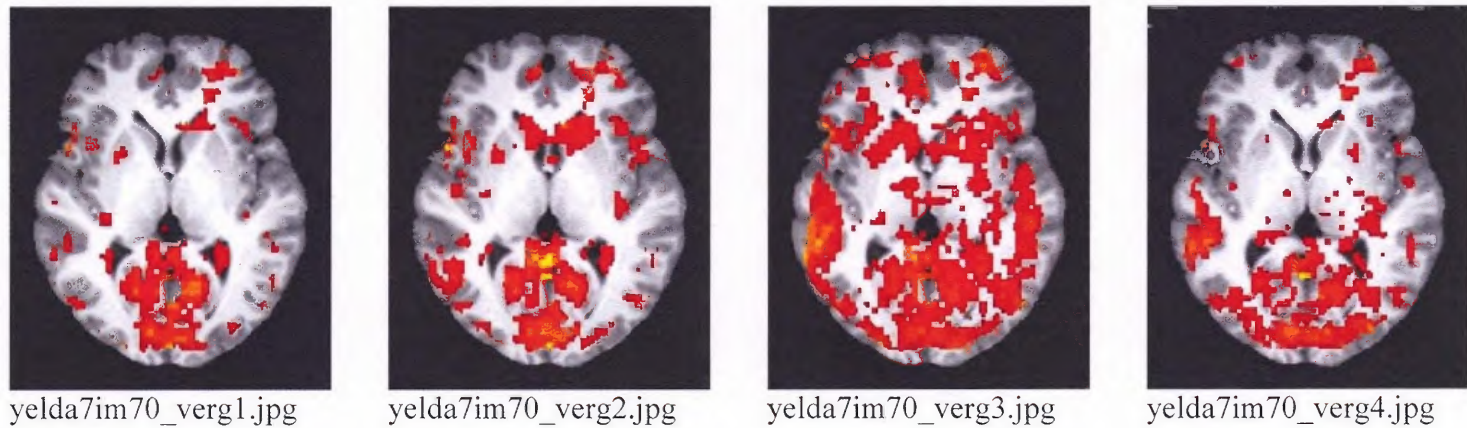


Figure 3.48 Image 70 for vergence trials 2, 3, 5 and 7 of subject 2 for observing growing of regions

This observation on areas is done for observing clearly activation on BA 41, BA 42, and BA 43.

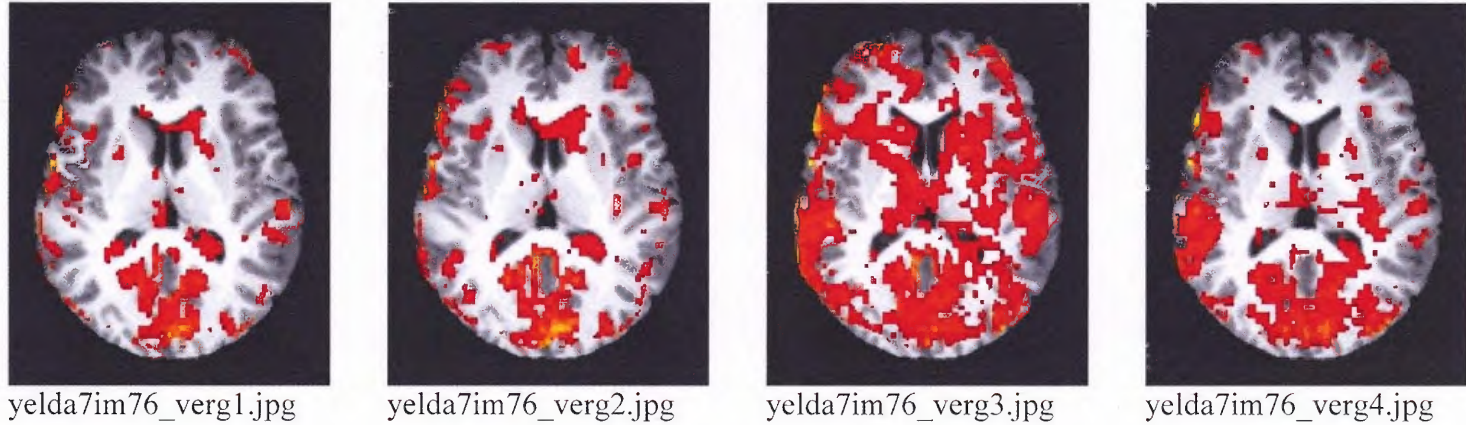


Figure 3.49 Image 76 for vergence trials 2, 3, 5 and 7 of subject 2 for observing growing of regions

1-Image#80 is for observation of activation on BA 33 for vergence 1, vergence 2, and vergence 3 trials.

2-Image#84 is for observation of activation on BA 33 for vergence 4 trial.

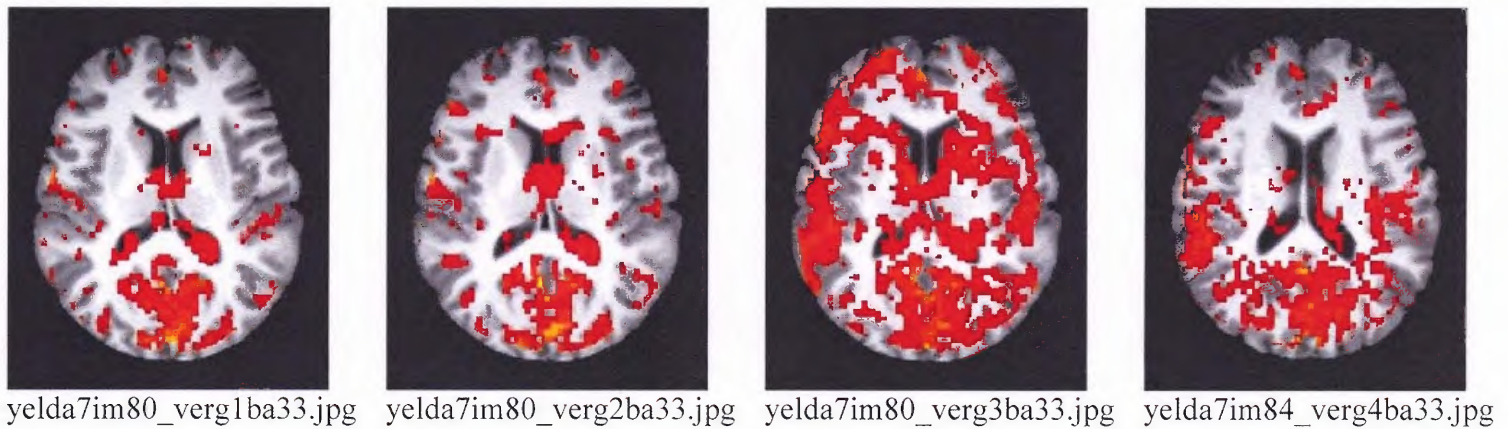
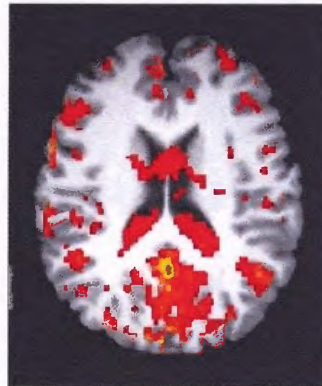


Figure 3.50 Image 80 for vergence trials 2, 3, 5 and 7 of subject 2 for observing growing of regions

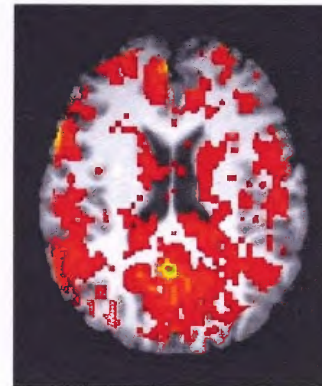
BA 1, BA 2,
 BA 3, BA 4,
 BA 6, BA 9,
 BA 10, BA 13,
 BA 17, BA 18,
 BA 19, BA 22,
 BA 23, BA 24,
 BA 29, BA 30,
 BA 31, BA 33,
 BA 32, BA 39,
 BA 40, BA 41,
 BA 42, BA 43,
 BA 44, BA 45,
 BA 46
 Pulvinar



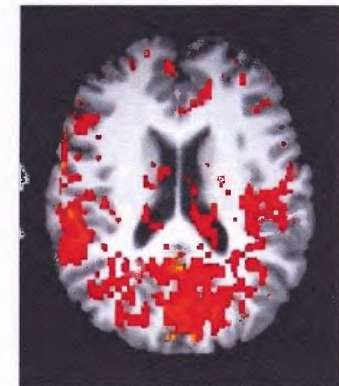
yelda7im86_verg1.jpg



yelda7im86_verg2.jpg



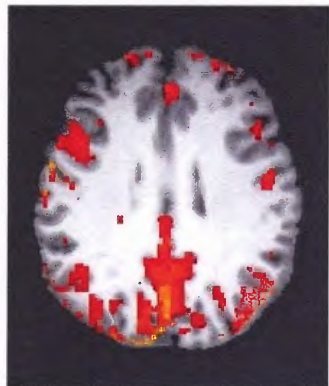
yelda7im86_verg3.jpg



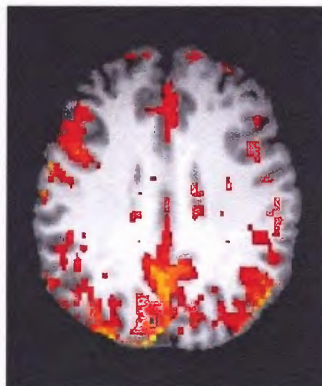
yelda7im86_verg4.jpg

Figure 3.51 Image 86 for vergence trials 2, 3, 5 and 7 of subject 2 for observing growing of regions

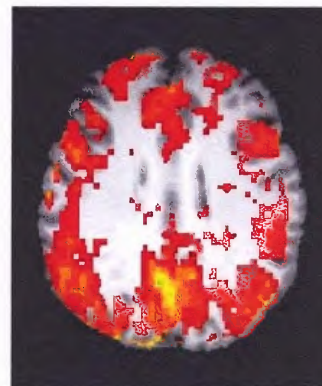
This observation on areas is done for observing clearly activation on BA 1, BA 2, BA 3, and BA 4.



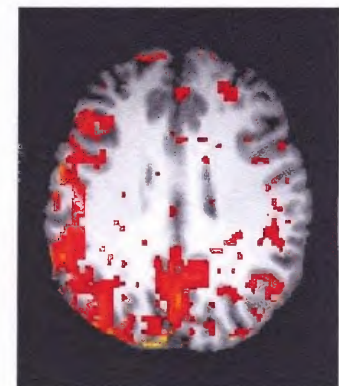
yelda7im95_verg1.jpg



yelda7im95_verg2.jpg



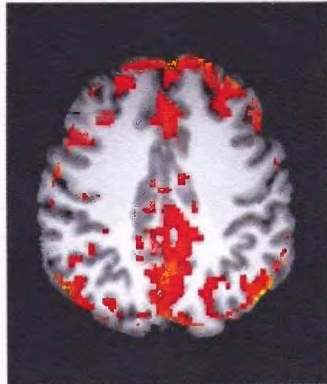
yelda7im95_verg3.jpg



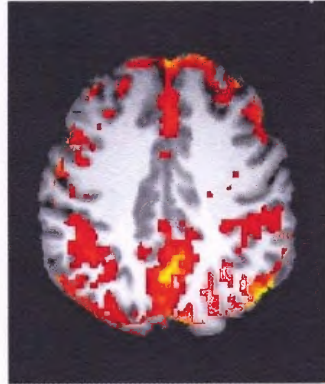
yelda7im95_verg4.jpg

Figure 3.52 Image 95 for vergence trials 2, 3, 5 and 7 of subject 2 for observing growing of regions

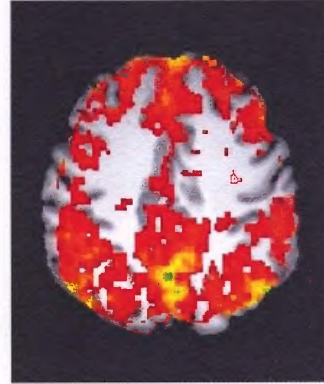
BA 1, BA 2,
 BA 3, BA 4,
 BA 6, BA 7,
 BA 8, BA 9,
 BA 19, BA 23,
 BA 24, BA 31,
 BA 32, BA 39,
 BA 40,
 SMA



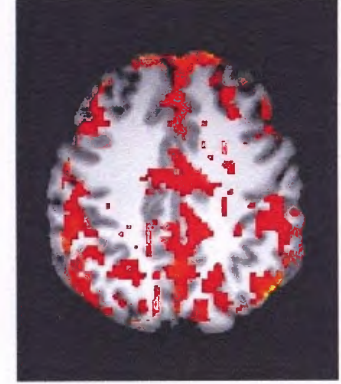
yelda7im103_verg1.jpg



yelda7im103_verg2.jpg



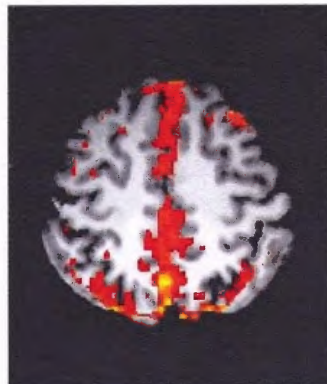
yelda7im103_verg3.jpg



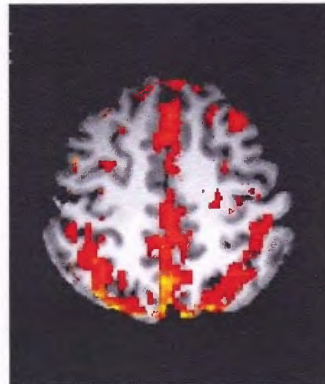
yelda7im103_verg4.jpg

Figure 3.53 Image 103 for vergence trials 2, 3, 5 and 7 of subject 2 for observing growing of regions

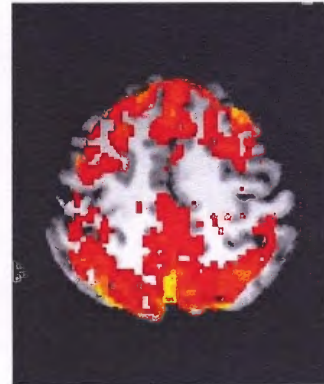
BA 1, BA 2,
 BA 3, BA 4,
 BA 5, BA 6,
 BA 7, BA 8,
 BA 24, BA 31,
 BA 32, BA 39,
 BA 40
 SMA



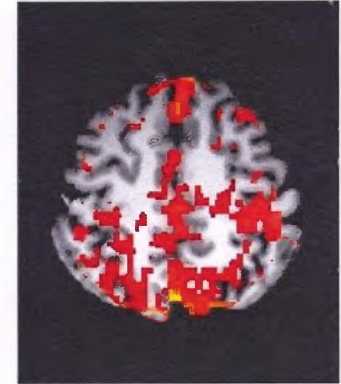
yelda7im114_verg1.jpg



yelda7im114_verg2.jpg



yelda7im114_verg3.jpg

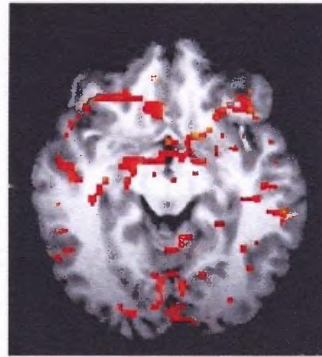


yelda7im114_verg4.jpg

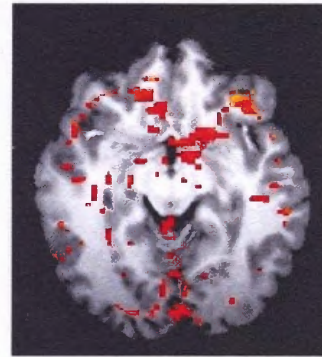
Figure 3.54 Image 114 for vergence trials 2, 3, 5 and 7 of subject 2 for observing growing of regions

IMAGE#55

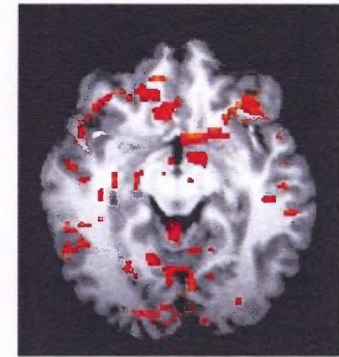
This observation on areas is done for observing clearly activation on BA 28, BA 34, BA 35, and BA 36.



yelda5im55_sac1.jpg



yelda5im55_sac2.jpg

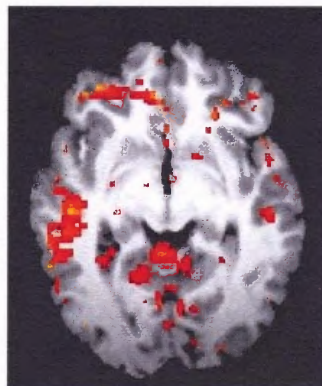


yelda5im55_sac3.jpg

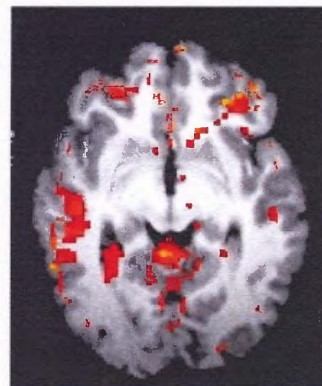
Figure 3.55 Image 55 for saccade trials 1, 3, and 5 of subject 7 for observing increase in intensity

IMAGE#58

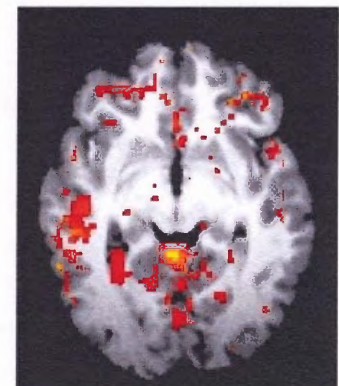
BA 10, BA 11, BA 13, BA 17, BA 18, BA 19, BA 20, BA 21, BA 22, BA 24, BA 25, BA 27, BA 28, BA 30, BA 32, BA 34, BA 35, BA 36, BA 37, BA 38, BA 47
Caudate
Putamen
Globus pallidus



yelda5im58_sac1.jpg



yelda5im58_sac2.jpg

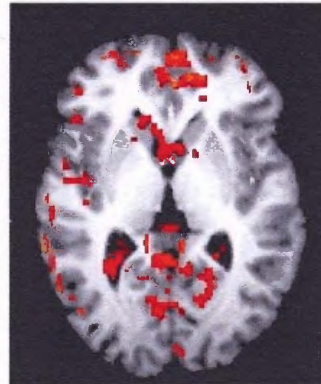


yelda5im58_sac3.jpg

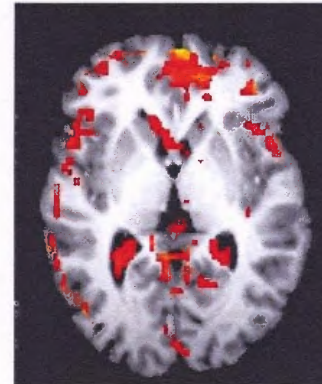
Figure 3.56 Image 58 for saccade trials 1, 3, and 5 of subject 7 for observing increase in intensity

IMAGE#67

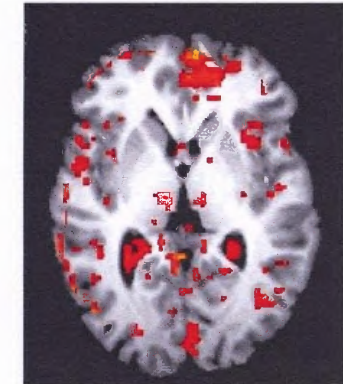
This image is for observation of activation on BA 27.



yelda5im67_sac1ba27.jpg



yelda5im67_sac2ba27.jpg



yelda5im67_sac3ba27.jpg

Figure 3.57 Image 67 for saccade trials 1, 3, and 5 of subject 7 for observing increase in intensity

IMAGE#70

BA 6, BA 10, BA 13, BA 17, BA 18, BA 19, BA 21, BA 22, BA 24, BA 27, BA 29, BA 30, BA 32, BA 37, BA 39, BA 41, BA 42, BA 43, BA 44, BA 45, BA 46, BA 47

Caudate

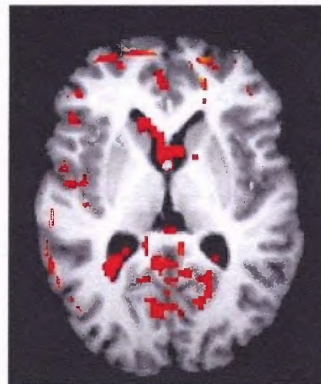
Putamen

Globus pallidus

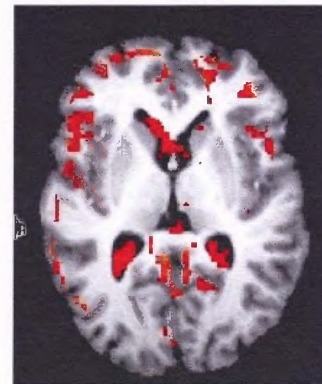
Pulvinar

P.S

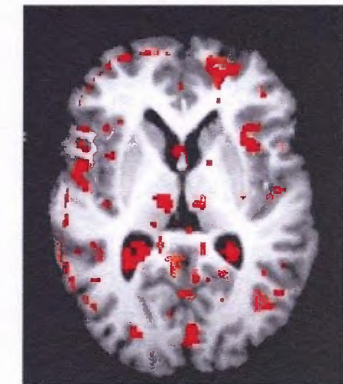
1-Activation on BA 23 and 25 observed in saccade 1 and saccade 3 trials.



yelda5im70_sac1.jpg



yelda5im70_sac2.jpg

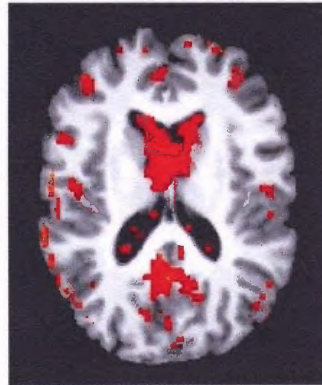


yelda5im70_sac3.jpg

Figure 3.58 Image 70 for saccade trials 1, 3, and 5 of subject 7 for observing increase in intensity

IMAGE#80

This image is for observation of activation on BA 33.



yelda5im80_sac1ba33.jpg



yelda5im80_sac2ba33.jpg

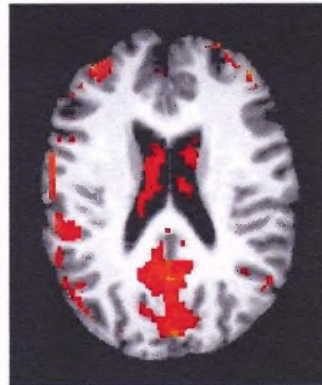


yelda5im80_sac3ba33.jpg

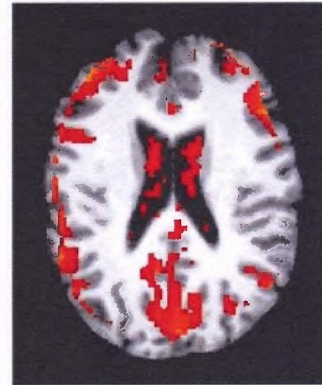
Figure 3.59 Image 80 for saccade trials 1, 3, and 5 of subject 7 for observing increase in intensity

IMAGE#86

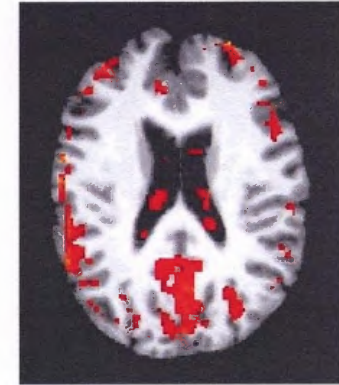
BA 1, BA 2, BA 3, BA 4,
BA 6, BA 9, BA 10, BA
13, BA 17, BA 18, BA 19,
BA 22, BA 23, BA 24, BA
29, BA 30, BA 31, BA 32,
BA 33, BA 39, BA 40, BA
41, BA 42, BA 43, BA 44,
BA 45, BA 46
Pulvinar



yelda5im86_sac1.jpg



yelda5im86_sac2.jpg

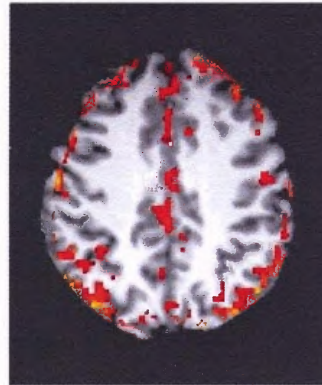


yelda5im86_sac3.jpg

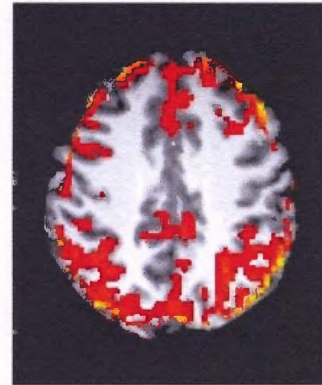
Figure 3.60 Image 86 for saccade trials 1, 3, and 5 of subject 7 for observing increase in intensity

IMAGE#103

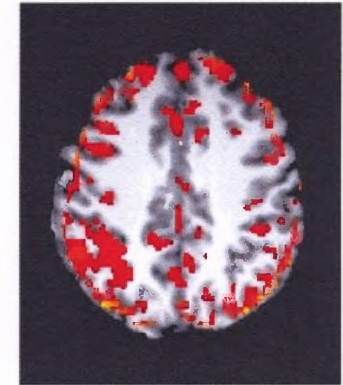
BA 1, BA 2, BA 3, BA 4,
BA 6, BA 7, BA 8, BA 9,
BA 19, BA 23 BA 24, BA
31, BA 32, BA 39, BA 40
SMA



yelda5im103_sac1.jpg



yelda5im103_sac2.jpg

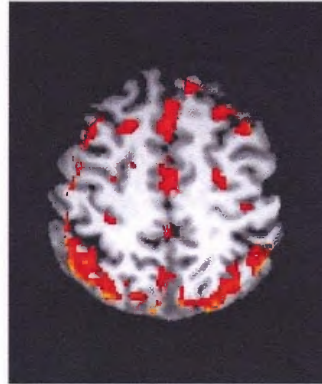


yelda5im103_sac3.jpg

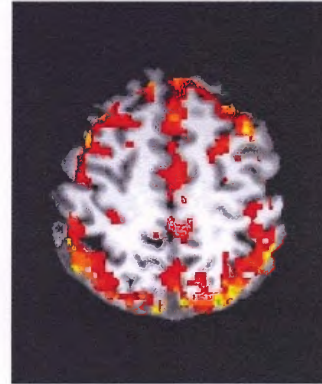
Figure 3.61 Image 103 for saccade trials 1, 3, and 5 of subject 7 for observing increase in intensity

IMAGE#114

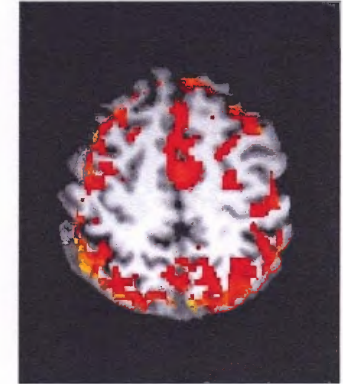
BA 1, BA 2, BA 3, BA 4,
BA 5, BA 6, BA 7, BA 8,
BA 19, BA 24, BA 31, BA
32, BA 39, BA 40
SMA



yelda5im114_sac1.jpg



yelda5im114_sac2.jpg



yelda5im114_sac3.jpg

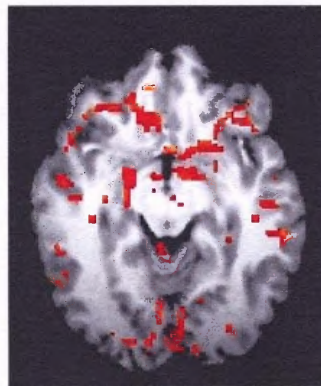
Figure 3.62 Image 114 for saccade trials 1, 3, and 5 of subject 7 for observing increase in intensity

SUBJECT 7
Threshold:
0.0515
IMAGE#55

OBSERVED
ACTIVATED AREAS

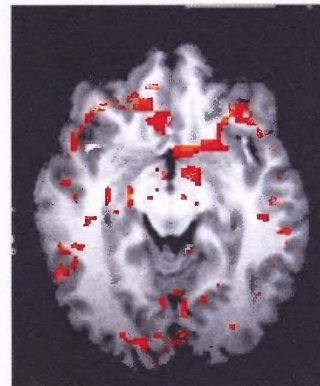
This observation on areas
is done for observing
clearly activation on BA
28, BA 34, BA 35,
and BA 36.

TRIAL2
(VERG1)



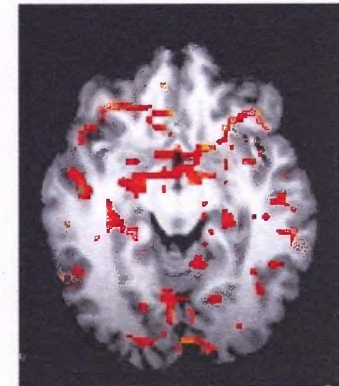
yelda5im55_verg1.jpg

TRIAL4
(VERG2)



yelda5im55_verg2.jpg

TRIAL6
(VERG3)

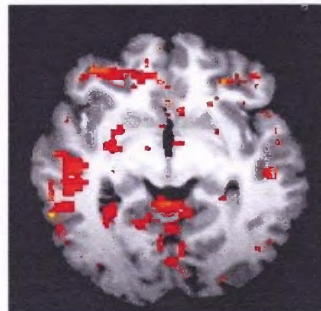


yelda5im55_verg3.jpg

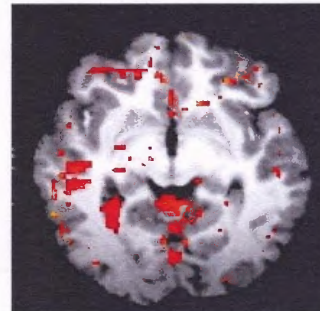
Figure 3.63 Image 55 for vergence trials 2, 4, and 6 of subject 7 for observing increase in intensity

IMAGE#58

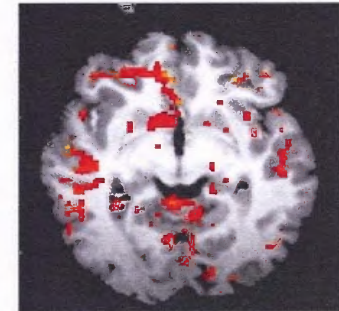
BA 10, BA 11, BA 13, BA
17, BA 18, BA 19, BA 20,
BA 21, BA 22, BA 24, BA
25, BA 27, BA 28, BA 30,
BA 32, BA 35, BA 36,
BA 37, BA 38, BA 47
Caudate
Putamen
Globus pallidus



yelda5im58_verg1.jpg



yelda5im58_verg2.jpg

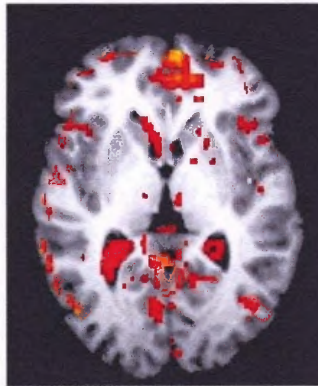


yelda5im58_verg3.jpg

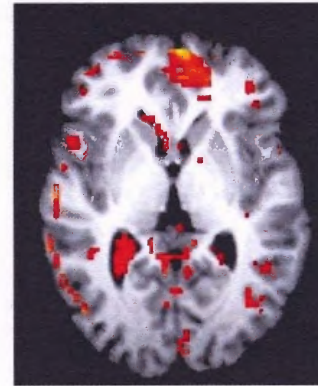
Figure 3.64 Image 58 for vergence trials 2, 4, and 6 of subject 7 for observing increase in intensity

IMAGE#67

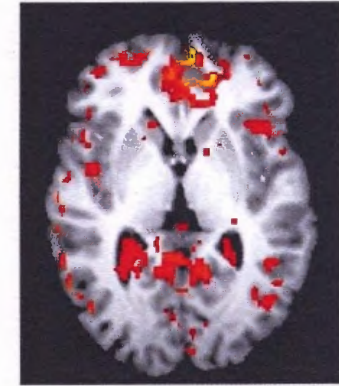
This image is for observation of activation on BA 27.



yelda5im67_verg1ba27.jpg



yelda5im67_verg2ba27.jpg

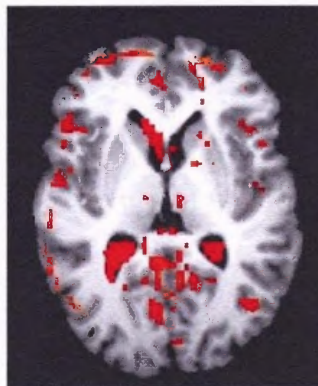


yelda5im67_verg3ba27.jpg

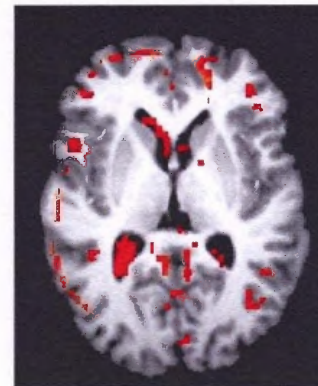
Figure 3.65 Image 67 for vergence trials 2, 4, and 6 of subject 7 for observing increase in intensity

IMAGE#70

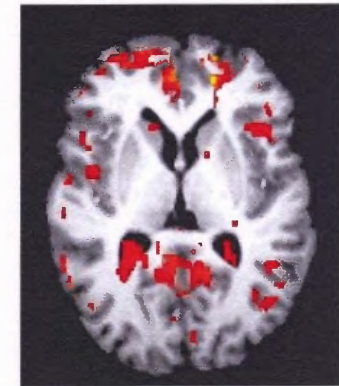
BA 6, BA 10, BA 13, BA 17, BA 18, BA 19, BA 21, BA 22, BA 23, BA 24, BA 25, BA 27, BA 29, BA 30, BA 32, BA 37, BA 39, BA 41, BA 42, BA 43, BA 44, BA 45, BA 46, BA 47
Caudate
Putamen
Globus pallidus
Pulvinar



yelda5im70_verg1.jpg



yelda5im70_verg2.jpg

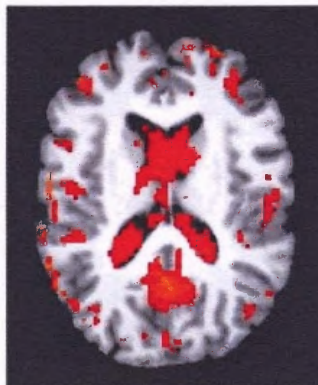


yelda5im70_verg3.jpg

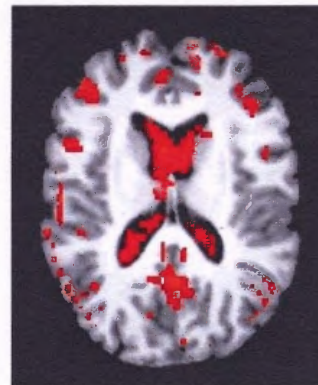
Figure 3.66 Image 70 for vergence trials 2, 4, and 6 of subject 7 for observing increase in intensity

IMAGE#80

This image is for observation of activation on BA 33.



yelda5im80_verg1ba33.jpg



yelda5im80_verg2ba33.jpg

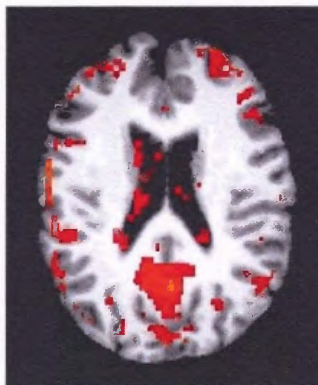


yelda5im80_verg3ba33.jpg

Figure 3.67 Image 80 for vergence trials 2, 4, and 6 of subject 7 for observing increase in intensity

IMAGE#86

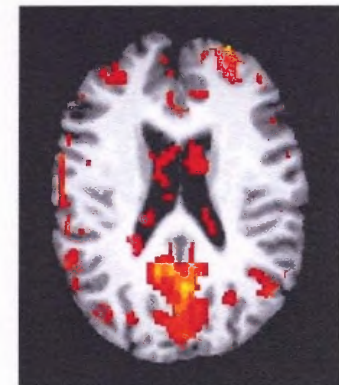
BA 1, BA 2, BA 3, BA 4,
BA 6, BA 9, BA 10, BA
13, BA 17, BA 18, BA 19,
BA 22, BA 23, BA 24, BA
29, BA 30, BA 31, BA 32,
BA 33, BA 39, BA 40, BA
41, BA 42, BA 43, BA 44,
BA 45, BA 46
Pulvinar



yelda5im86_verg1.jpg



yelda5im86_verg2.jpg

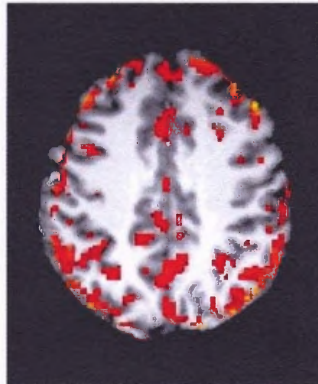


yelda5im86_verg3.jpg

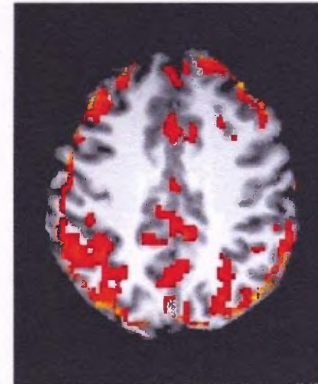
Figure 3.68 Image 86 for vergence trials 2, 4, and 6 of subject 7 for observing increase in intensity

IMAGE#103

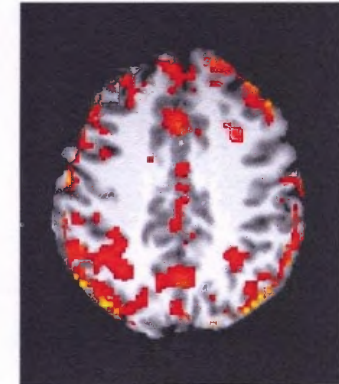
BA 1, BA 2, BA 3, BA 4,
BA 6, BA 7, BA 8, BA 9,
BA 19, BA 23, BA 24, BA
31, BA 32, BA 39, BA 40
SMA



yelda5im103_verg1.jpg



yelda5im103_verg2.jpg

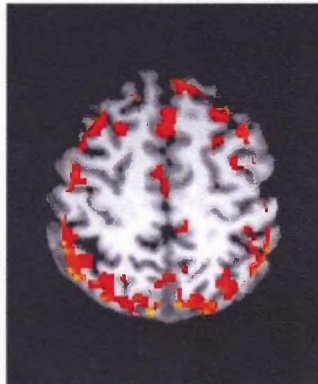


yelda5im103_verg3.jpg

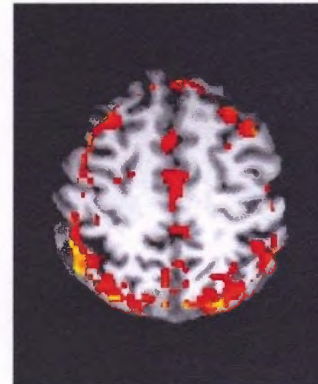
Figure 3.69 Image 103 for vergence trials 2, 4, and 6 of subject 7 for observing increase in intensity

IMAGE#114

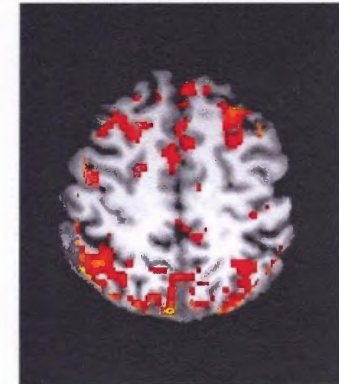
BA 1, BA 2, BA 3, BA 4,
BA 5, BA 6, BA 7, BA 8,
BA 19, BA 24, BA 31, BA
32, BA 39, BA 40
SMA



yelda5im114_verg1.jpg



yelda5im114_verg2.jpg



yelda5im114_verg3.jpg

Figure 3.70 Image 114 for vergence trials 2, 4, and 6 of subject 7 for observing increase in intensity

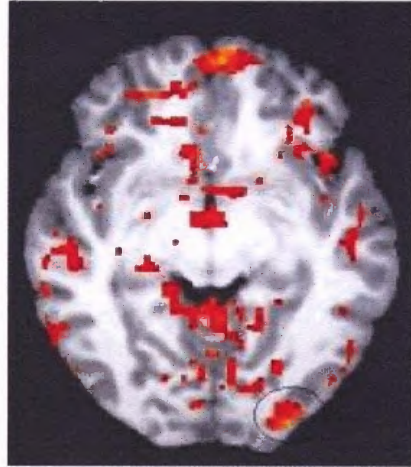
3.4 Quantification of Brodmann Areas for Subject 2

Another aim of this study was to quantify how much area was involved in a specific activated region in terms of millimeter square (mm^2). The Figures between figures 3.71 to 3.100 which are shown below indicate images with 0.0515 threshold ($p < 0.001$) for subject two before and after MatLab image processing for each saccade and vergence trials. The quantification of areas was done for Brodmann areas 8, 9, 17, SMA (supplementary motor area) and the basal ganglia components. The first images in these figures indicate activated regions, the second row that belongs to the images shows tracing of boundaries of that specific regions with the pixel values and the last row represents the images and the pixel values when the regions cropped from the main image. Each pixel is 3 mm x 3mm in size. This portion of the thesis is a proof of concept and will be expanded to perform volumetric quantification in future experiments.

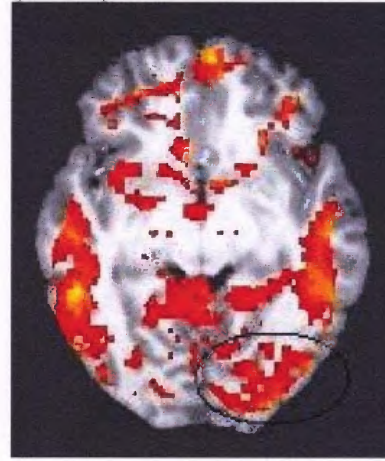
Brodmann area 17

Image#58 before
Matlab application

**TRIAL1
(SAC1)**



**TRIAL4
(SAC2)**



**TRIAL6
(SAC3)**

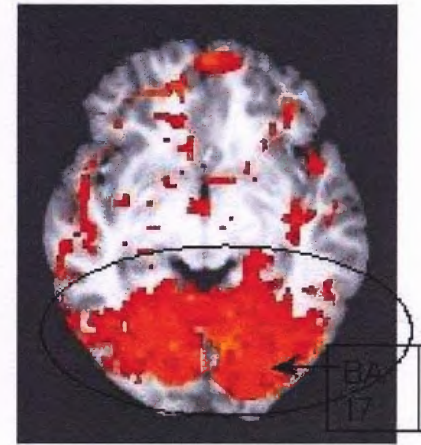


Figure 3.71 Image 58 for saccade trials 1, 4, and 6 of subject 2 before MatLab application for Brodmann area 17

Image#58 Tracing
boundaries of BA 17



of pixels=108 (972 mm²)



of pixels=498 (4482 mm²)



#of pixels=3558 (32022 mm²)

Figure 3.72 Image 58 for saccade trials 1, 4, and 6 of subject 2 after tracing of boundaries for Brodmann area 17

Image #58 cropped view of traced region



of pixels=108 (972 mm²)



#of pixels=601 (5409 mm²)

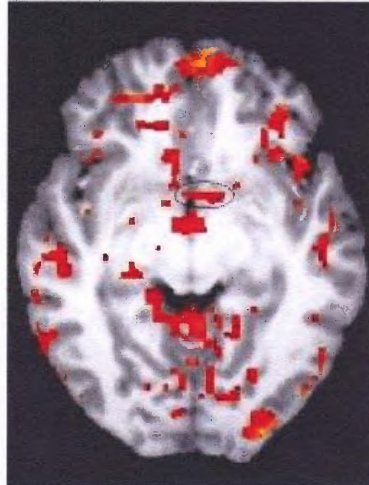


#of pixels=3689 (33201 mm²)

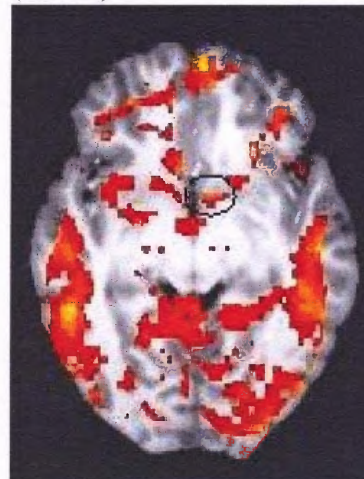
Figure 3.73 Image 58 for saccade trials 1, 4, and 6 of subject 2 after cropping the traced regions for Brodmann area 17

Components of basal ganglia
Image#58 before Matlab application

TRIAL1 (SAC1)



TRIAL4 (SAC2)



TRIAL6 (SAC3)

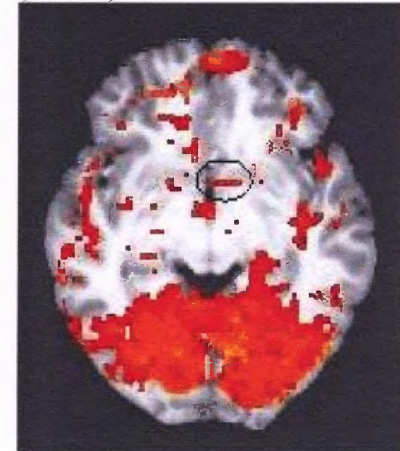


Figure 3.74 Image 58 for saccade trials 1, 4, and 6 of subject 2 before MatLab application for components of basal ganglia

Image#58 Tracing boundaries of caudate, putamen, globus pallidus and # of pixels



of pixels=66 (594 mm²)



#of pixels=34 (306 mm²)



#of pixels=39 (351 mm²)

Figure 3.75 Image 58 for saccade trials 1, 4, and 6 of subject 2 after tracing of boundaries for components of basal ganglia

Image #58 cropped view of traced region and # of pixels



#of pixels=66 (594 mm²)



#of pixels=34 (306 mm²)



#of pixels=39 (351 mm²)

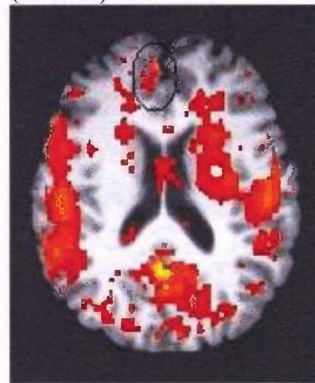
Figure 3.76 Image 58 for saccade trials 1, 4, and 6 of subject 2 after cropping the traced regions for components of basal ganglia

**Brodmann
area 9**
Image#86 before
Matlab application

**TRIAL1
(SAC1)**



**TRIAL4
(SAC2)**



**TRIAL6
(SAC3)**

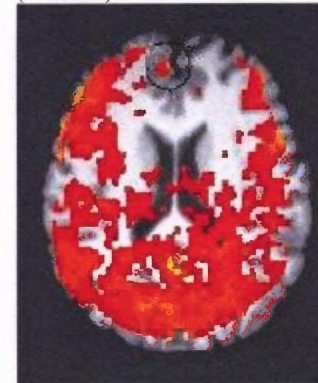
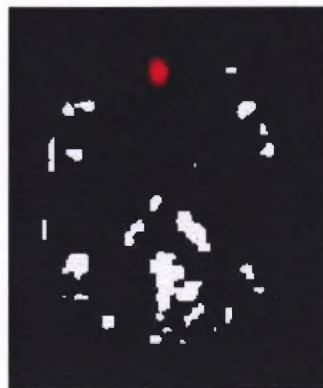


Figure 3.77 Image 86 for saccade trials 1, 4, and 6 of subject 2 before MatLab application for Brodmann area 9

Image#86 Tracing
boundaries of
Brodmann area 9 and
of pixels



of pixels=14 (126 mm²)



#of pixels=90 (810 mm²)



#of pixels=54 (486 mm²)

Figure 3.78 Image 86 for saccade trials 1, 4, and 6 of subject 2 after tracing of boundaries for Brodmann area 9

Image #86 cropped
view of traced region
and # of pixels



of pixels=14 (126 mm²)



#of pixels=90 (810 mm²)



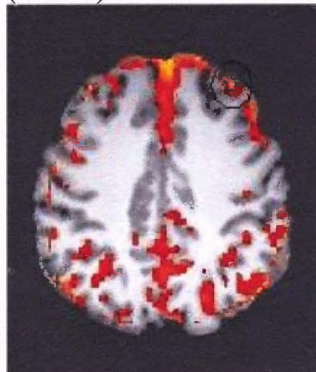
#of pixels=54 (486 mm²)

Figure 3.79 Image 86 for saccade trials 1, 4, and 6 of subject 2 after cropping the traced regions for Brodmann area 9

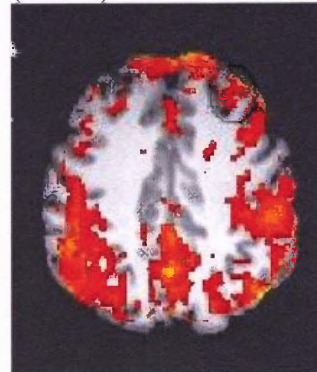
Brodmann area 8

Image#103 before
Matlab application

**TRIAL1
(SAC1)**



**TRIAL4
(SAC2)**



**TRIAL6
(SAC3)**

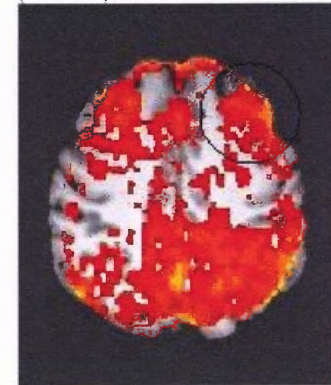


Figure 3.80 Image 103 for saccade trials 1, 4, and 6 of subject 2 before MatLab application for Brodmann area 8

Image#103 Tracing
boundaries of
Brodmann area 8 and
of pixels



of pixels=42 (378 mm²)



of pixels=131 (1179 mm²)



of pixels=771 (6939 mm²)

Figure 3.81 Image 103 for saccade trials 1, 4, and 6 of subject 2 after tracing of boundaries for Brodmann area 8

Image #103 cropped
view of traced region
and # of pixels



of pixels=42 (378 mm²)



of pixels=137 (1233 mm²)



of pixels=941 (8469 mm²)

Figure 3.82 Image 103 for saccade trials 1, 4, and 6 of subject 2 after cropping the traced regions for Brodmann area 8

Supplementary motor area (SMA)
Image#103
before
Matlab
application



Figure 3.83 Image 103 for saccade trials 1, 4, and 6 of subject 2 before MatLab application for supplementary motor area (SMA)

Image#103 Tracing
boundaries of
SMA and # of
pixels

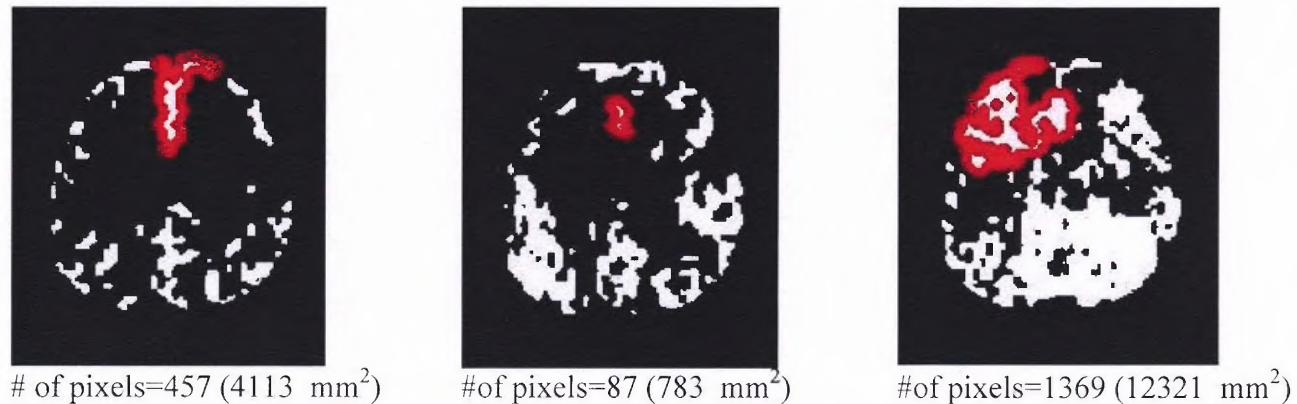


Figure 3.84 Image 103 for saccade trials 1, 4, and 6 of subject 2 after tracing of boundaries for supplementary motor area (SMA)

Image #103
cropped view of
traced region and #
of pixels



#of pixels=457 (4113 mm²)



of pixels=87 (783 mm²)

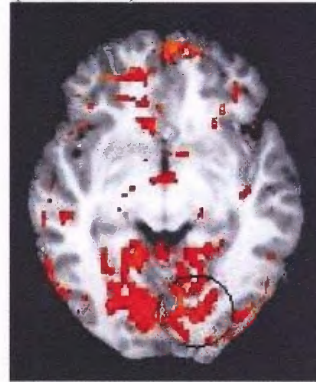


#of pixels=1497 (13473 mm²)

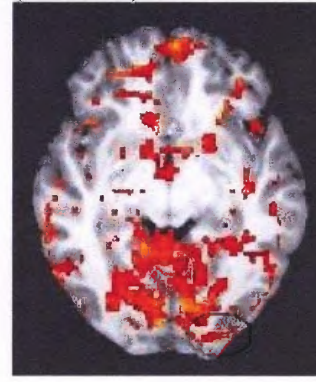
Figure 3.85 Image 103 for saccade trials 1, 4, and 6 of subject 2 after cropping the traced regions for supplementary motor area (SMA)

Brodmann area 17
Image#58 before Matlab application

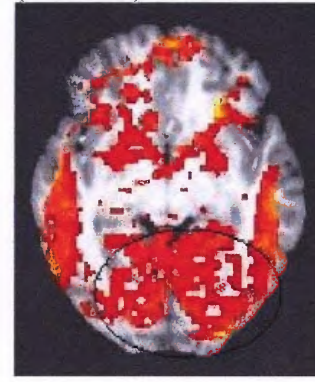
TRIAL2 (VERG1)



TRIAL3 (VERG2)



TRIAL5 (VERG3)



TRIAL 7 (VERG4)

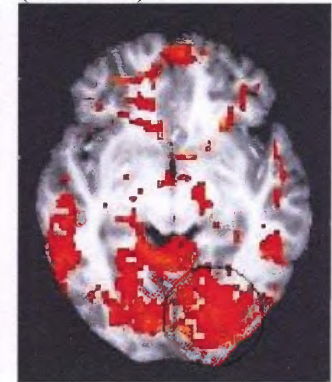
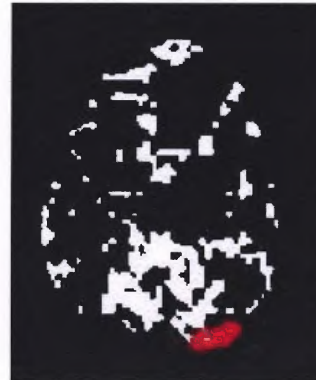


Figure 3.86 Image 58 for vergence trials 2, 3, 5 and 7 of subject 2 before MatLab application for Brodmann area 17

Image#58 Tracing boundaries of BA 17



of pixels=232 (2088 mm²)



of pixels=64 (576 mm²)



#of pixels=3232 (29088 mm²)



of pixels=2172 (19548 mm²)

Figure 3.87 Image 58 for vergence trials 2, 3, 5 and 7 of subject 2 after tracing of boundaries for Brodmann area 17

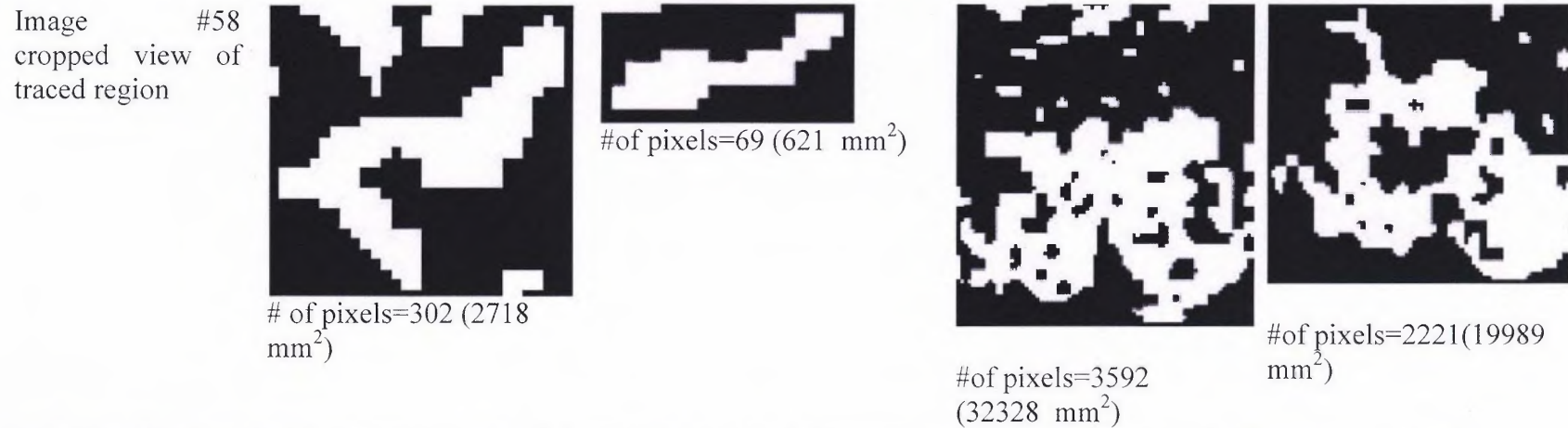


Figure 3.88 Image 58 for vergence trials 2, 3, 5 and 7 of subject 2 after cropping the traced regions for Brodmann area 17

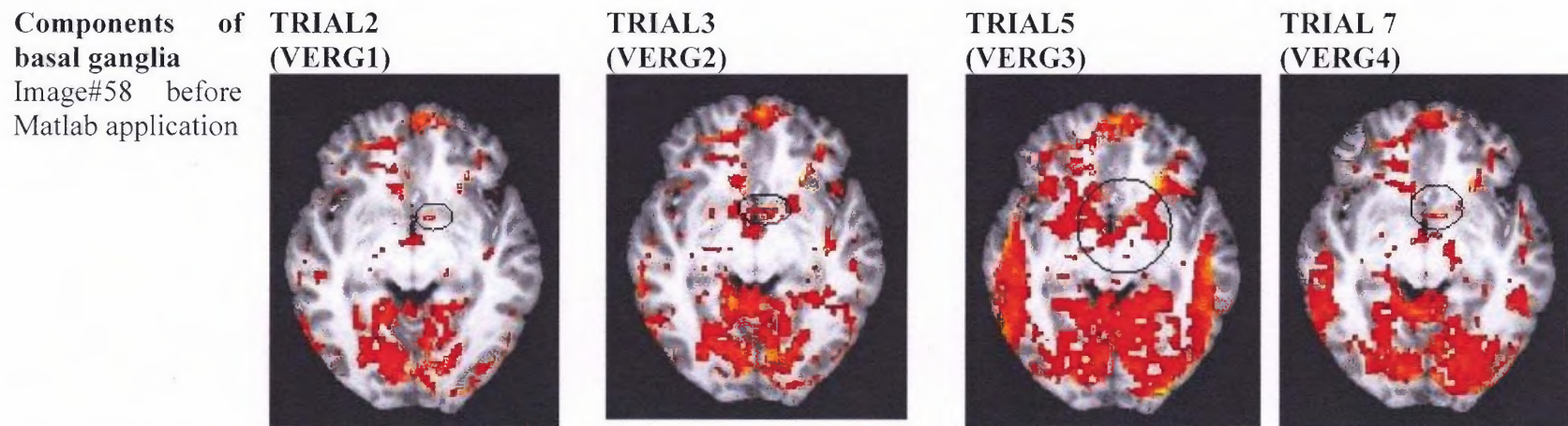


Figure 3.89 Image 58 for vergence trials 2, 3, 5 and 7 subject 2 before MatLab application for components of basal ganglia

Image#58 Tracing boundaries of caudate, putamen, globus pallidus and # of pixels

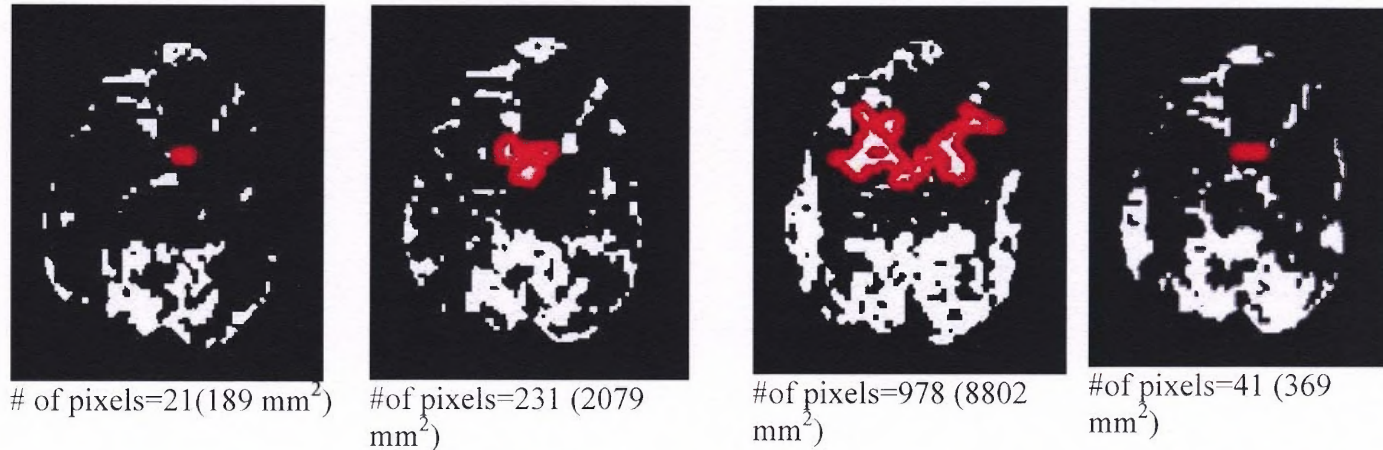


Figure 3.90 Image 58 for vergence trials 2, 3, 5 and 7 of subject 2 after tracing of boundaries for components of basal ganglia

Image #58 cropped view of traced region and # of pixels

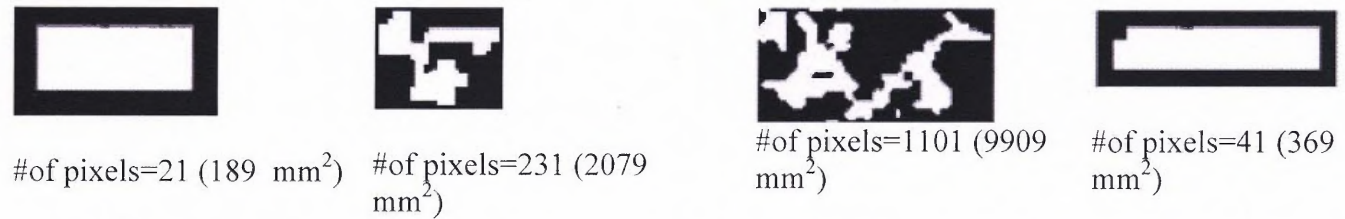


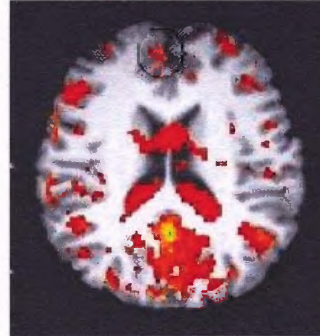
Figure 3.91 Image 58 for vergence trials 2, 3, 5 and 7 of subject 2 after cropping the traced regions for components of basal ganglia

**Brodmann
area 9**
Image#86 before
Matlab application

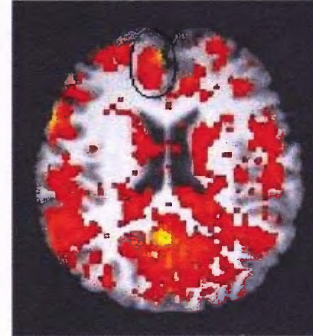
**TRIAL2
(VERG1)**



**TRIAL3
(VERG2)**



**TRIAL5
(VERG3)**



**TRIAL 7
(VERG4)**

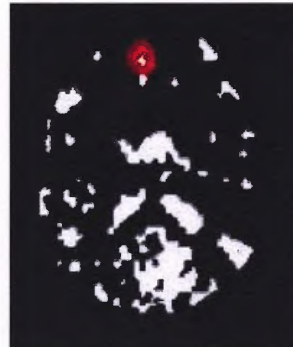


Figure 3.92 Image 86 for vergence trials 2, 3, 5 and 7 of subject 2 before MatLab application for Brodmann area 9

Image#86 Tracing
boundaries of
Brodman area 9
and # of pixels



of pixels=39 (351
mm²)



#of pixels=58 (522 mm²)



#of pixels=268 (2412
mm²)



#of pixels=36 (324
mm²)

Figure 3.93 Image 86 for vergence trials 2, 3, 5 and 7 of subject 2 after tracing of boundaries for Brodmann area 9

Image #86
cropped view of
traced region and
of pixels



of pixels=39 (351
mm²)



#of pixels=58 (522 mm²)



#of pixels=268 (2412
mm²)



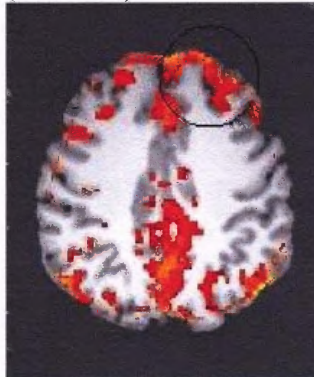
of pixels=36 (324
mm²)

Figure 3.94 Image 86 for vergence trials 2, 3, 5 and 7 of subject 2 after cropping the traced regions for Brodmann area 9

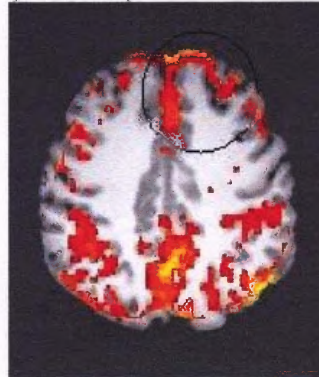
Brodmann area 8

Image#103 before
Matlab application

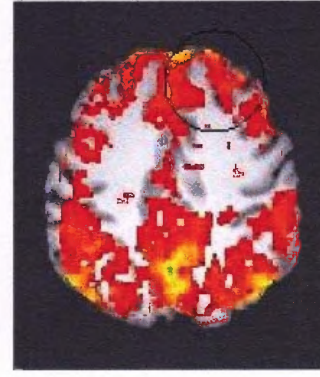
**TRIAL2
(VERG1)**



**TRIAL3
(VERG2)**



**TRIAL5
(VERG3)**



**TRIAL 7
(VERG4)**

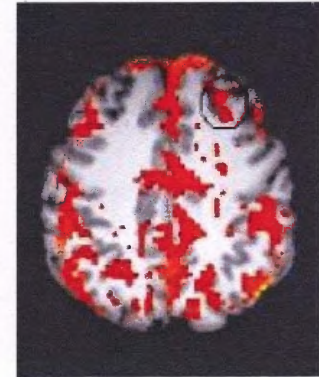


Figure 3.95 Image 103 for vergence trials 2, 3, 5 and 7 of subject 2 before MatLab application for Brodmann area 8

Image#1
03
Tracing
boundari
es of
Brodman
n area 8
and # of
pixels



of pixels=452 (4068
mm²)



#of pixels=511 (4599
mm²)



#of pixels=1319 (11871
mm²)



#of pixels=110 (990
mm²)

Figure 3.96 Image 103 for vergence trials 2, 3, 5 and 7 of subject 2 after tracing of boundaries for Brodmann area 8

Image
#103
cropped
view of
traced
region
and # of
pixels



#of pixels=643 (5787
mm²)



#of pixels=511 (4599
mm²)



#of pixels=1511 (13599
mm²)



#of pixels=110 (990
mm²)

Figure 3.97 Image 103 for vergence trials 2, 3, 5 and 7 of subject 2 after cropping the traced regions for Brodmann area 8

Supplementary motor area (SMA)
Image#103 before Matlab application

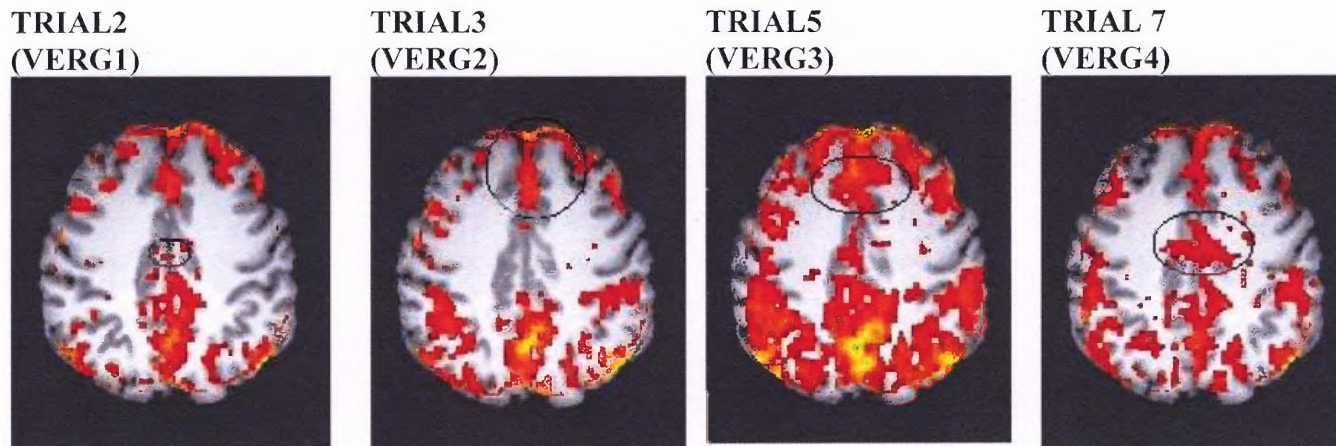


Figure 3.98 Image 103 for vergence trials 2, 3, 5 and 7 of subject 2 before MatLab application for supplementary motor area (SMA)

Image#103 Tracing boundaries of SMA and # of pixels

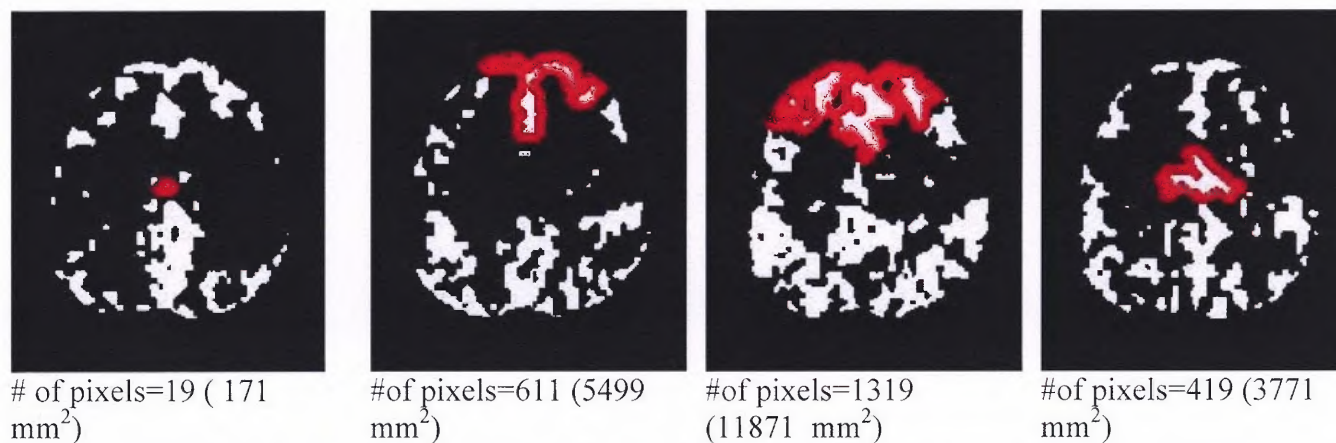


Figure 3.99 Image 103 for vergence trials 2, 3, 5 and 7 of subject 2 after tracing of boundaries for supplementary motor area (SMA)

Image #103 cropped
view of traced region
and # of pixels



#of pixels=19 (171 mm²)



of pixels=637 (5733
mm²)



#of pixels=1511
(13599 mm²)



#of pixels=431 (3879
mm²)

Figure 3.100 Image 103 for vergence trials 2, 3, 5 and 7 of subject 2 after cropping the traced regions for supplementary motor area (SMA)

CHAPTER 4

DISCUSSION

FMRI studies provide good temporal resolution as seen in this investigation. This research showed that many areas are involved in accomplishing visual tasks. Activation on Brodmann's areas 17, 18, and 19 were anticipated because of the two different visual tasks which can occur because the visual stimulus presented where in different temporal areas of the visual field.. The parietal eye field (PEF), including Brodmann's area seven (BA 7) and Brodmann's area 39 is located in the posterior parietal cortex was activated during this study. The activation occurred because the PEF is responsible for providing attention and spatial perception (Kaas, 2004, pp.1080; Colby and Olson, 2003, pp. 1230). Furthermore, the activation of frontal eye field (FEF or Brodmann's area eight), supplementary motor area (SMA), dorsolateral prefrontal cortex (DLPFC or Brodmann's area nine (BA 9)/46) and frontopolar area (Brodmann's area ten or BA 10) were activated during this investigation. Analysis of each subject's data indicated that these regions were some of the common observed activated areas. The only difference occurred in activation on FEF and Brodmann;s area 7 (BA 7) when evaluation on averaged of eight subjects was done. This assessment showed that the neurons on the FEF were active for vergence, but not in saccades which can be supported by the study that is done by Gamlin and Yoon. According to their study that is done on rhesus monkey, it is claimed that FEF is responsible not only in saccadic and smooth pursuit eye movements, but also in vergence and ocular accommodation (Gamlin and Yoon, 2000). We speculate that BA 7 was active due to differences in the amount of attention required for the tasks. Supplementary motor area (SMA), containing supplementary eye field (SEF), was another region which

was active where it may play a role on oculomotor control for subjects during this study. The excitatory effects on the neurons of the dorsolateral prefrontal cortex (DLPFC) were expected from subjects because this region is involved with memory which indicates the participants were remembering the locations of the target in terms of learning the given task and is used during prediction (Deseilligny-Pierrot et al. 2004). Frontopolar area (Brodmann's area ten (BA 10)) is also involved in cognitive functions such as planning future events was activated for accomplishing given tasks (Semendeferi et al. 2001). It can be evaluated as predictable sequence of the given task in the experiment may cause activation of neurons of this region for preparing subjects to be ready for next movements which resulted in observing activation on this region.

The other two questions this investigation sought to answer were why activation was observed on many areas and especially why the temporal lobe activation occurred in the subjects. The explanation for the first question that can be given is recruitment of other areas for accomplishing the given task which can be linked to the answer of the second question where the ventral and the dorsal visual processing streams take place on the stage. Ventral stream is activated when a person has to understand the features of objects by considering "what" such as shape and color (Oliver and Schill, 2003; Horwitz et al. 1999). The pathway begins in primary visual cortex, transmits the signal into the temporal cortex and lastly reaches to the ventral frontal lobe (Horwitz et al. 1999). The dorsal stream is responsible for spatial vision in which spatial locations are important (Oliver and Schill, 2003; Horwitz et al. 1999). The dorsal stream starts within the occipital lobe, elongates through the parietal lobe and ends on the frontal lobe (Horwitz et al. 1999). These pathways may explain how recruitment of many areas occurred and why

the temporal lobe was activated while it is typically involved in auditory functions. The ventral visual processing stream in particular provides the best explanation for activation on the temporal lobe of the participants.

Another observation occurred in the cerebellar vermis (4/5) where the activation first increased and then decreased. The hypothesis for that while the participants was learning the task, the neurons on this region were activation, and then after the learning process was accomplished by the subjects, the activation on this area decreased which demonstrates the components of the cerebellum may be involved in cognitive learning functions. Furthermore, the activation on the components of basal ganglia took place because these subcomponents containing caudate, putamen and globus pallidus are involved in memorization process where this cognitive function used for remembering the next location of the target in predictable sequence of this investigation. The final issue that has to be considered is why activation on pulvinar appeared just for vergence, not for saccades. This can be answered as exhibition of illusion caused by the difference between thickness in the functional and anatomical images where the functional slices has five millimeter and anatomical slices one millimeter.

CHAPTER 5

CONCLUSION

The primary goal of this thesis was to evaluate which areas are involved in processing of visual tasks by using saccadic and vergence eye movements and how correlation occurs among cortical areas during oculomotor learning. During this investigation, it was hypothesized that the activation on some regions such as Brodmann's areas 17, 18, and 19, supplementary motor area, and especially dorsolateral prefrontal cortex would be involved in oculomotor learning and visual processing. The first outcome after analysis of each subjects' data was to observe beyond the regions mentioned above many cortical regions had activation to accomplish the given target. Moreover, the processed data from each participants showed similar activation areas for saccadic and vergence eye movements.

The second step was decided as if there were any nuance or not when the average of eight subject' data would taken. This step indicated that the activation on frontal eye field (FEF) and parietal eye field (PEF) created differences for applied oculomotor movements during this experimental research. These regions had different areas of activation for vergence compared to saccadic eye movements where this conclusion was supported by a single cell recording investigation on primates done by Gamlin and Yoon. The other conclusion that had been reached after assessment of individual data was to observe oculomotor learning indications on subject two and seven. The learning strategy on participant two's data emerged as recruitment of other areas shown as an increase in the area of activation. The subject seven exhibited learning via synchronization on areas

observed as an increase in intensity of activation appeared on the regions, in particular the cerebellar vermis (4/5).

The quantification by using Matlab program during this research provided how many pixel values contributed to the activation on the specific region. The quantification worked well for understanding the enlargement of the regions but it has to be expanded through volumetric investigations because when recruitment occurs, the pixel values of other regions are getting involved to the calculation which can be result in perception mistake on computing activation growth that belongs to the particular region.

CHAPTER 6

FUTURE RESEARCH

The human brain is a mystery with so many questions waiting to be answered. The visual processing stream in the cortical level is well understood but there is still much to be learned. Thirty percent of the brain is involved for accomplishing the visual tasks. This percentage implies how a complicated the visual system or circuit is. The basic science of how we processing visual information is under investigation for healthy controls and is just beginning for those who have binocular or neurological disorders. The next steps of this investigation will be to study subjects who have convergence insufficiency, and for further studies will continue with traumatic brain injury (TBI) or stroke patients. Convergence insufficiency is a binocular dysfunction where convergence has a reduced velocity compared to people with normal binocular vision system, on the other hand, their divergence is normal. Preliminary studies have started with two subjects. Firstly, some vision parameters are measured, and then fMRI technique is applied to be able to understand these participants's visual system in cortical levels, and then after six weeks of optometric vision therapy (eye exercises), their visual parameters and fMRI data will be recorded again to be able to compare with the first datum. Moreover, all experimental steps applied these subjects will be applied to the healthy controls again to be able to see or understand the difference in visual level and cortical level. The outcome that is expected from this research is to observe activation and quantify neuroplasticity. This investigation will also establish the fundamentals of the next steps for TBI or stroke oculomotor vision research. The cortical level of this investigation will also be done by applying fMRI technique to see how visual processing stream is affected on these

patients and if there is an opportunity to improve damaged pathway with an optometric vision therapy by studying their neuroplasticity capability.

The one of the future research on cognitive levels will also continue with understanding how memory is used during learning process of the visual tasks by applying oculomotor movements. The hypothesis behind that if the velocity value of the signal emerging from learning of the given target categorized as fast to slow, how the activation on memory regions will be influenced. Moreover, the isolation of regions that are activated between predictable sequence and random sequence will be done for visual tasks that can be learned and which can not be learned. In addition to all these, the other issue never considered before which is age difference among subjects will be evaluated for understanding if the motor learning strategies such as synchronization or recruitment of other regions is correlated to age. Furthermore, for all these studies neural circuits which are utilized during visual tasks while executing eye movements will be established by using other imaging techniques beside the fMRI such as diffusion tensor imaging (DTI).

The final but not end investigation for relationship between the eye movements and cortical regions will continue with quantification. The masking of the specific area which will be the region of interest and the volumetric measurements will be done for prospective studies.

APPENDIX A

ACTIVATED REGIONS OF SUBJECT 1 FOR SACCADE AND VERGENCE TRIALS

The Appendix A includes the activated regions that belongs to the saccadic and vergence trials for subject 1. The different image numbers were used for clear observation of cortical activation..

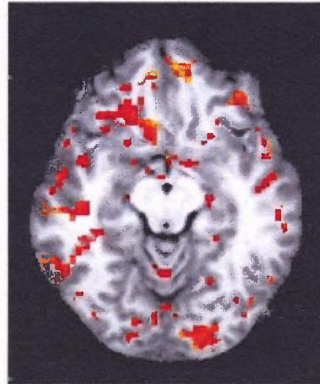
Part 1 Saccade Trials for Subject 1 (Data 1)

SUBJECT 1
Threshold:
0.0515
IMAGE#55

OBSERVED
ACTIVATED AREAS

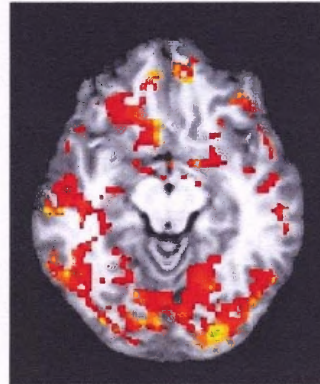
This observation on
areas is done for
observing clearly
activation on BA 28,
BA 34, BA 35,
and BA 36.

TRIAL1
(SAC1)



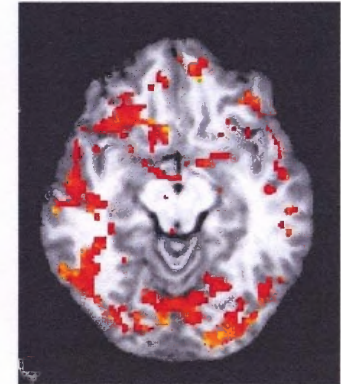
yelda6im55_sac1.jpg

TRIAL4
(SAC2)



yelda6im55_sac2.jpg

TRIAL6
(SAC3)



yelda6im55_sac3.jpg

IMAGE#58

BA 10, BA 11, BA 13,
BA 17, BA 18, BA 19,
BA 20, BA 21, BA 22,
BA 24, BA 25, BA 28,
BA 32, BA 34, BA 35,
BA 36, BA 37, BA 38,
BA 47

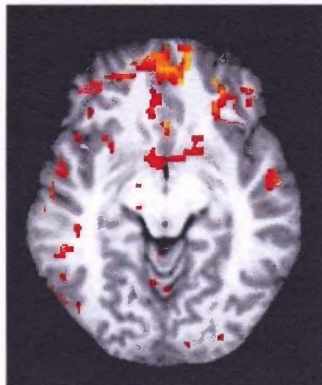
Caudate

Putamen

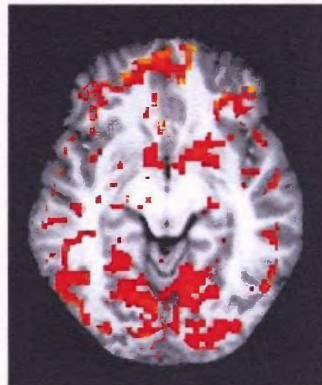
Globus pallidus

P.S

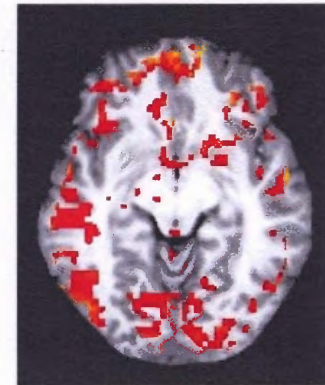
1-Activation on BA 27
and BA 30 is observed
saccade 2 trial.



yelda6im58_sac1.jpg



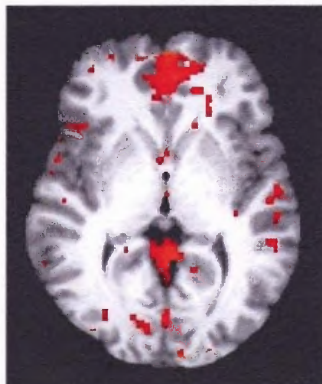
yelda6im58_sac2.jpg



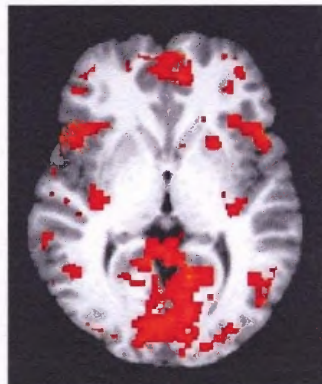
yelda6im58_sac3.jpg

IMAGE#67

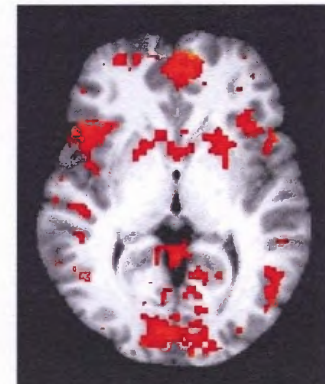
This image is for
observation of
activation on BA 27.



yelda6im67_sac1ba27.jpg



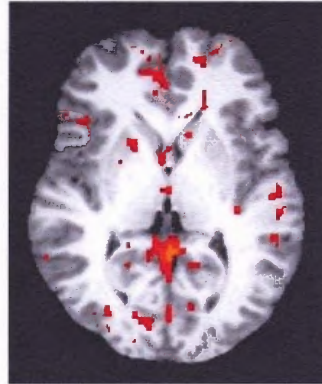
yelda6im67_sac2ba27.jpg



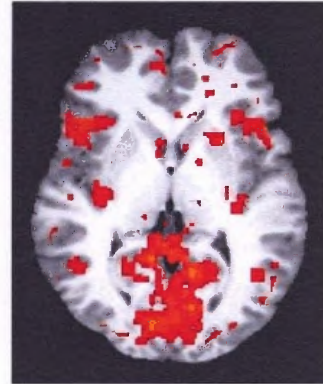
yelda6im67_sac3ba27.jpg

IMAGE#70

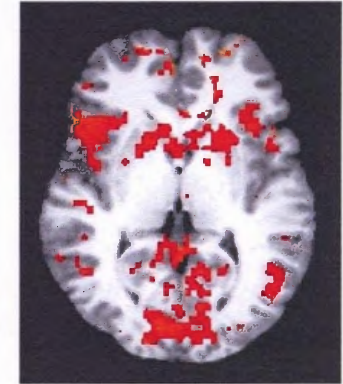
BA 6, BA 10, BA 13,
BA 17, BA 18, BA 19,
BA 21, BA 22, BA 24,
BA 25, BA 27, BA 29,
BA 30, BA 32, BA 37,
BA 39, BA 41, BA 42,
BA 43, BA 44, BA 45,
BA 46, BA 47
Caudate
Putamen
Globus pallidus
Pulvinar



yelda6im70_sac1.jpg



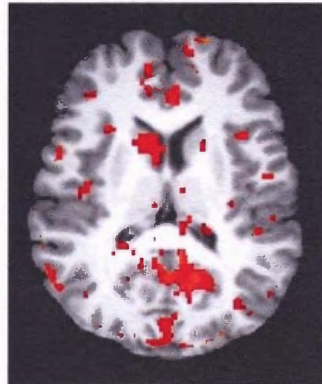
yelda6im70_sac2.jpg



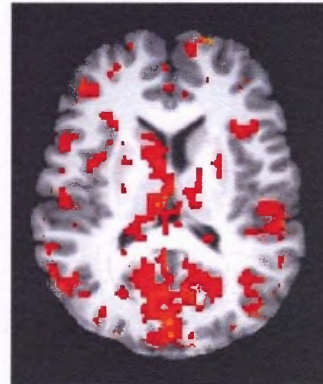
yelda6im70_sac3.jpg

IMAGE#80

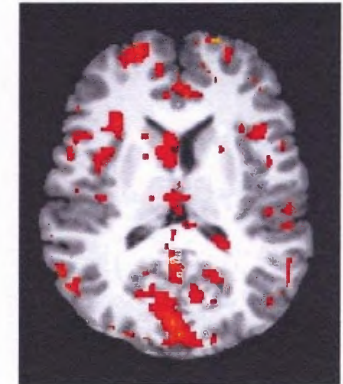
This image is for
observation of
activation on BA 33



yelda6im80_sac1ba33.jpg



yelda6im80_sac2ba33.jpg



yelda6im80_sac3ba33.jpg

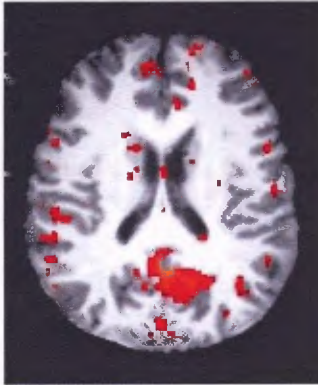
IMAGE#86

BA 1, BA 2, BA 3, BA 4, BA 6, BA 9, BA 10, BA 13, BA 17, BA 18, BA 19, BA 22, BA 23, BA 24, BA 29, BA 30, BA 31, BA 32, BA 39, BA 40, BA 41, BA 42, BA 43, BA 44, BA 45, BA 46

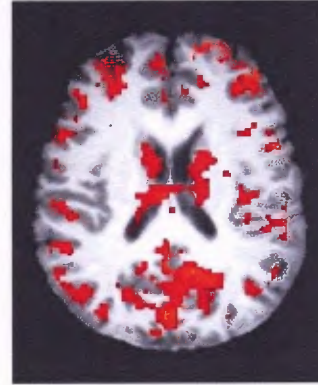
P.S

1- Activation on BA 33 is observed in saccade 3 trial.

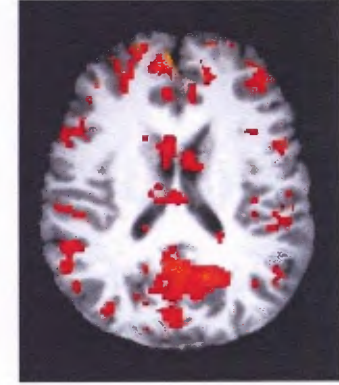
2-Activation on pulvinar is observed in saccade 2 and saccade 3 trials.



yelda6im86_sac1.jpg



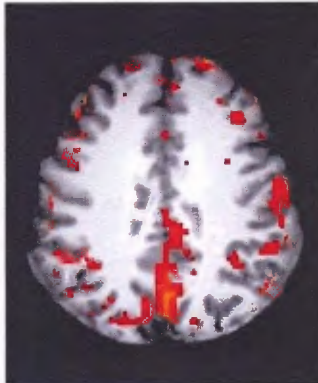
yelda6im86_sac2.jpg



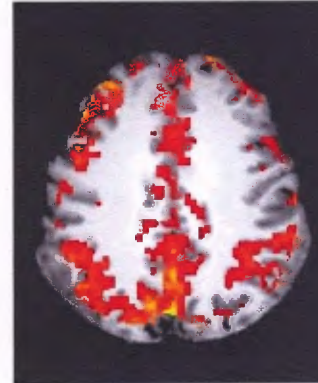
yelda6im86_sac3.jpg

IMAGE#103

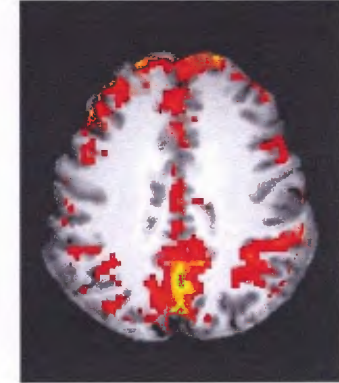
BA 1, BA 2, BA 3, BA 4, BA 6, BA 7, BA 8, BA 9, BA 19, BA 23, BA 24, BA 31, BA 32, BA 39, BA 40, SMA



yelda6im103_sac1.jpg



yelda6im103_sac2.jpg



yelda6im103_sac3.jpg

IMAGE#114

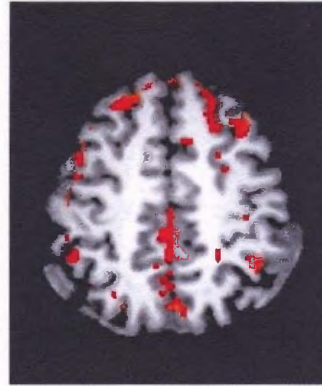
BA 1, BA 2, BA 3, BA 4, BA 5, BA 6, BA 7, BA 8, BA 24, BA 31, BA 32, BA 40

SMA

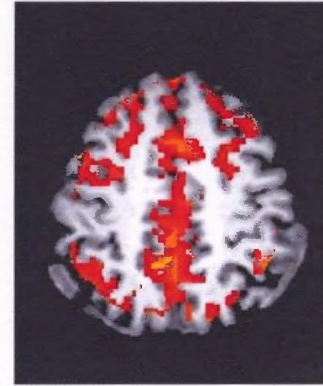
P.S

1-Activation on BA 19 is observed in saccade 2 and saccade 3 trials.

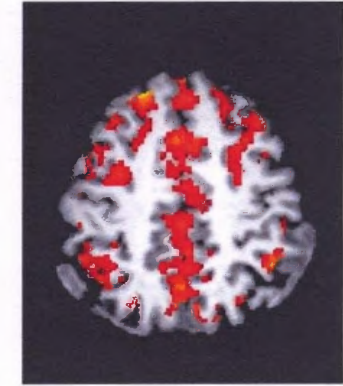
2-Activation on BA 39 is observed in saccade 3 trial.



yelda6im114_sac1.jpg



yelda6im114_sac2.jpg



yelda6im114_sac3.jpg

Part 2 Vergence Trials for Subject 1 (Data 1)

SUBJECT 1
Threshold:
0.0515

OBSERVED
ACTIVATED AREAS

TRIAL2
(VERG1)

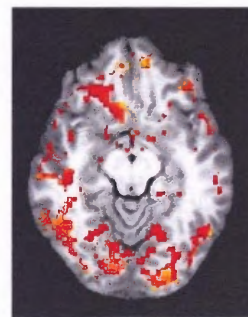
TRIAL3
(VERG2)

TRIAL5
(VERG3)

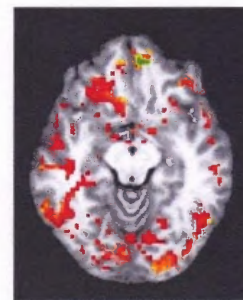
TRIAL7
(VERG4)

IMAGE#55

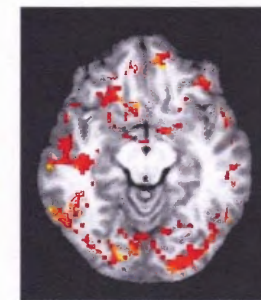
This observation on areas is done for observing clearly activation on BA 28, BA 34, BA 35, and BA 36, but activation on BA 35 is just observed in vergence 1, vergence 2, and vergence 4 trials.



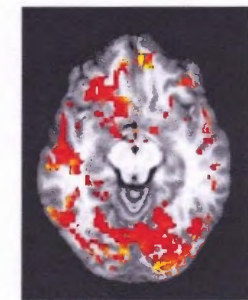
yelda6im55_verg1.jpg



yelda6im55_verg2.jpg



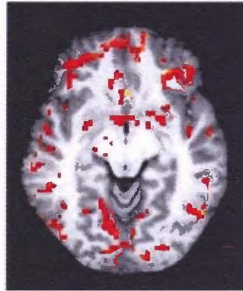
yelda6im55_verg3.jpg



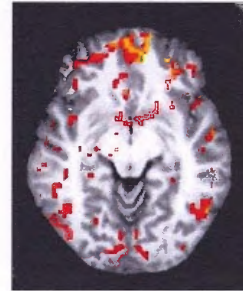
yelda6im55_verg4.jpg

IMAGE#58

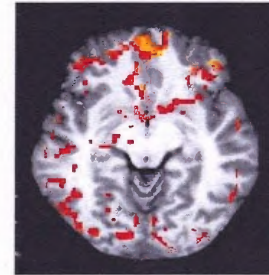
BA 10, BA 11, BA 13,
BA 17, BA 18, BA 19,
BA 20, BA 21, BA 22,
BA 24, BA 25, BA 28,
BA 32, BA 34, BA 35,
BA 36, BA 37, BA 38,
BA 47
Caudate
Putamen
Globus pallidus



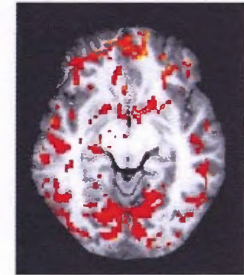
yelda6im58_
verg1.jpg



yelda6im58_
verg2.jpg



yelda6im58_
verg3.jpg



yelda6im58_
verg4.jpg

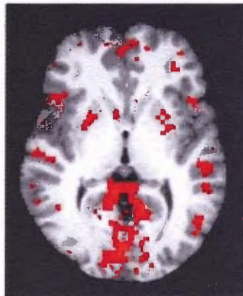
P.S 1-Activation on BA 30 is observed in vergence 1, vergence 2, and vergence 4 trials.

IMAGE#67

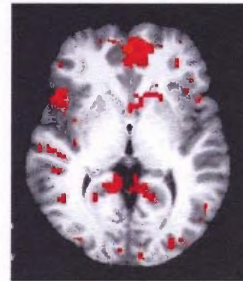
1-Image#67 is for
observation of activation
on BA 27 for vergence 1,
vergence 2, and vergence
4 trials.

IMAGE#72

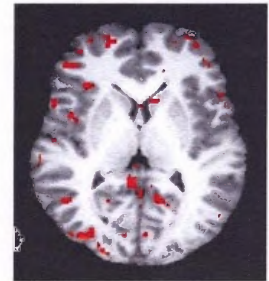
2- Image#72 is for
observation of activation
on BA 27 for vergence 3
trial.



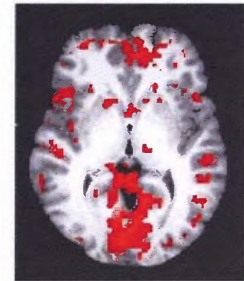
yelda6im67_
verg1ba27.jpg



yelda6im67_
verg2ba27.jpg



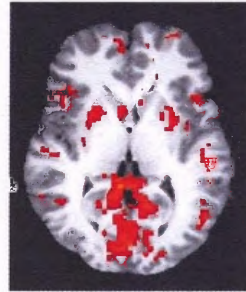
yelda6im72_
verg3ba27.jpg



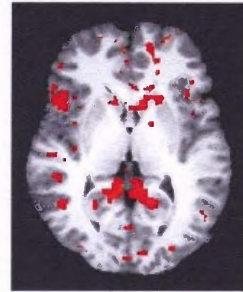
yelda6im67_
verg4ba27.jpg

IMAGE#70

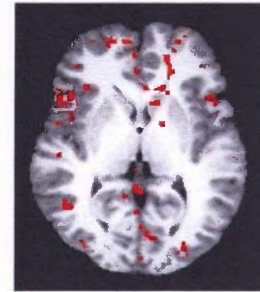
BA 10, BA 13, BA 17,
BA 18, BA 19, BA 21,
BA 22, BA 29, BA 30,
BA 32, BA 37, BA 39,
BA 41, BA 44, BA 45,
BA 47
Caudate, Putamen, Globus
pallidus, Pulvinar.



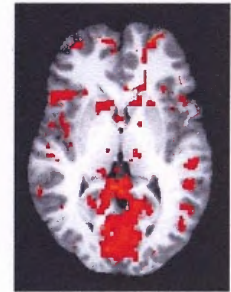
yelda6im70_
verg1.jpg



yelda6im70_
verg2.jpg



yelda6im70_
verg3.jpg



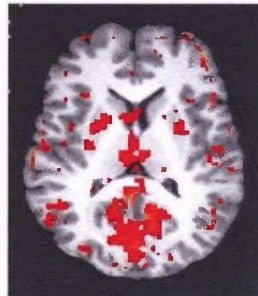
yelda6im70_
verg4.jpg

P.S

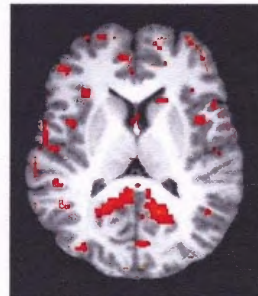
- 1-Activation on BA 24 and BA 46 is observed in vergence 2, vergence 3, and vergence 4 trials.
- 2-Activation on BA 6 is observed in vergence 1, vergence 3, and vergence 4 trials.
- 3-Activation on BA 25 is observed in vergence 1 and vergence 4 trials.
- 4-Activation on BA 43 is observed in vergence 1, vergence 3, and vergence 4 trials.
- 5-Activation on BA 27 and 42 is observed in vergence 1, vergence 2, and vergence 4 trials

IMAGE#76

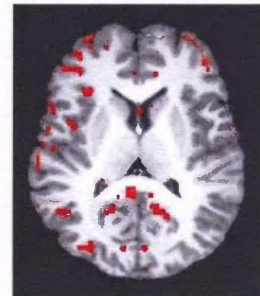
This observation on
areas is done for
observing clearly
activation on BA 41, BA
42, and BA 43.



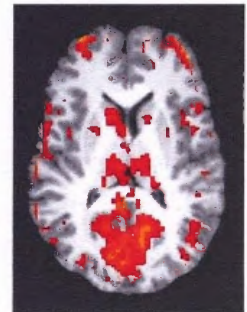
yelda6im76_
verg1.jpg



yelda6im76_
verg2.jpg



yelda6im76_
verg3.jpg



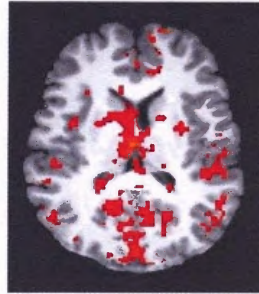
yelda6im76_
verg4.jpg

IMAGE#80

1-Image#80 is for observation of activation on BA 33 for vergence 1, vergence 3, and vergence 4 trials.

IMAGE#83

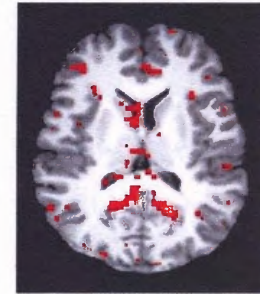
2- Image#83 is for observation of activation on BA 33 for vergence 2.



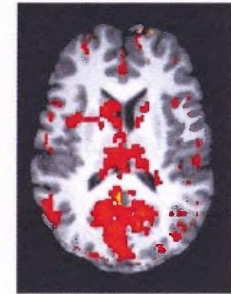
yelda6im80_verg1ba33.jpg



yelda6im83_verg2ba33.jpg



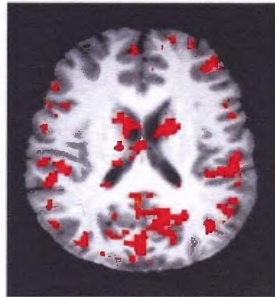
yelda6im80_verg3ba33.jpg



yelda6im80_verg4ba33.jpg

IMAGE#86

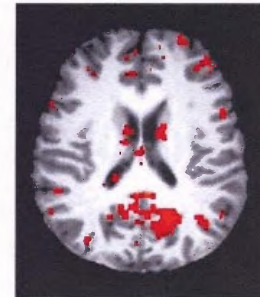
BA 6, BA 9, BA 10, BA 13, BA 17, BA 18, BA 19, BA 22, BA 23, BA 24, BA 29, BA 30, BA 31, BA 32, BA 39, BA 40, BA 44, BA 45, BA 46



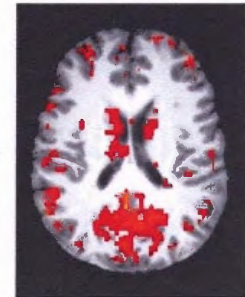
yelda6im86_verg1.jpg



yelda6im86_verg2.jpg



yelda6im86_verg3.jpg



yelda6im86_verg4.jpg

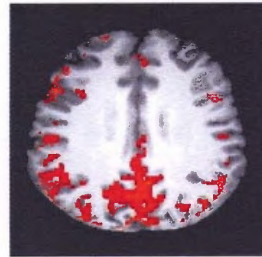
P.S

1-Activation on pulvinar is observed in vergence 1, vergence 3, and vergence 4 trials.

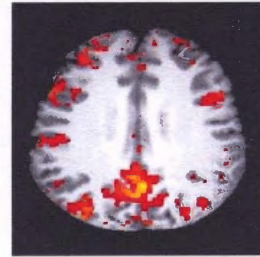
2-Activation on BA 4 is observed in vergence 1 and vergence 4 trials.

3-Activation on BA 1, BA 2, BA 3, BA 4, BA 33, BA 41, BA 42, and BA 43 is observed in vergence 1, vergence 2, and vergence 4 trials.

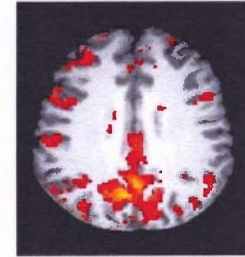
IMAGE#95 This observation on areas is done for observing clearly activation on BA 1, BA 2, BA 3, and BA 4.



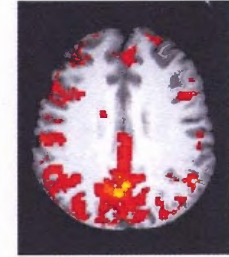
yelda6im95_
verg1.jpg



yelda6im95_
verg2.jpg

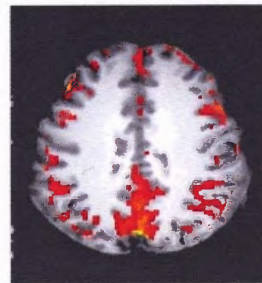


yelda6im95_
verg3.jpg

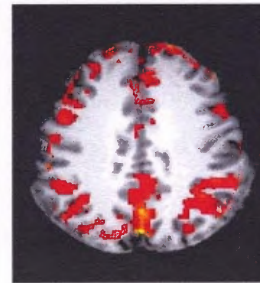


yelda6im95_
verg4.jpg

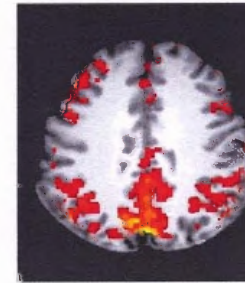
IMAGE#103 BA 1, BA 2, BA 3, BA 4, BA 6, BA 7, BA 8, BA 9, BA 19, BA 24, BA 31, BA 32, BA 39, BA 40
SMA
P.S
1-Activation on BA 23 is observed in vergence 1, vergence 3, and vergence 4 trials.



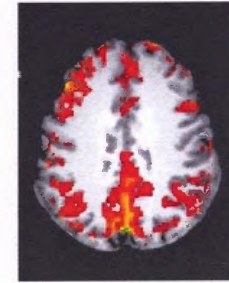
yelda6im103_
verg1.jpg



yelda6im103_
verg2.jpg

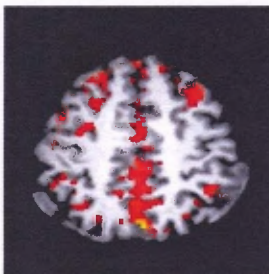


yelda6im103_
verg3.jpg

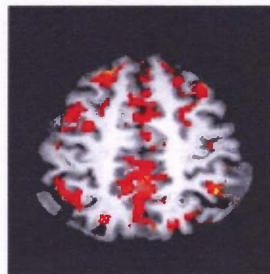


yelda6im103_
verg4.jpg

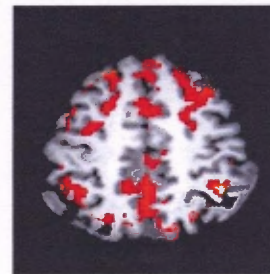
IMAGE#114 BA 1, BA 2, BA 3, BA 4, BA 5, BA 6, BA 7, BA 8, BA 24, BA 31, BA 32, BA 39, BA 40 SMA



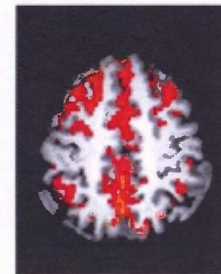
yelda6im114_
verg1.jpg



yelda6im114_
verg2.jpg



yelda6im114_
verg3.jpg



yelda6im114_
verg4.jpg

APPENDIX B

ACTIVATED REGIONS OF SUBJECT 2 FOR SACCADE AND VERGENCE TRIALS

The Appendix B includes the activated regions that belongs to the saccadic and vergence trials for subject 2. The different image numbers were used for clear observation of cortical activation..

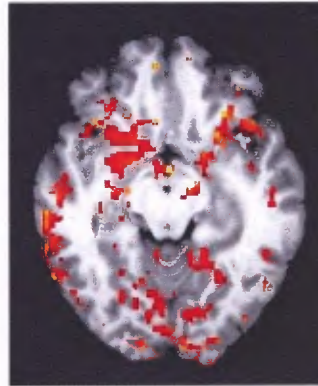
Part 1 Saccade Trials for Subject 2 (Data 2)

SUBJECT 2
 Threshold:
 0.0515
 IMAGE#55

OBSERVED
 ACTIVATED AREAS

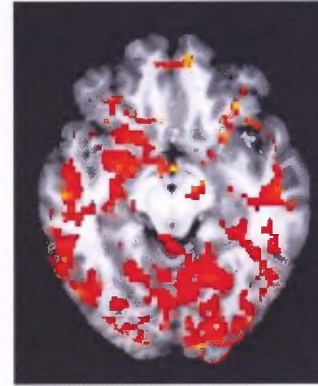
This observation on areas
 is done for observing
 clearly activation on BA
 28, BA 34, BA 35,
 and BA 36.

TRIAL1
 (SAC1)



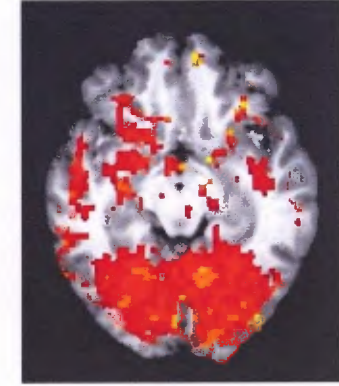
yelda7im55_sac1.jpg

TRIAL4
 (SAC2)



yelda7im55_sac2.jpg

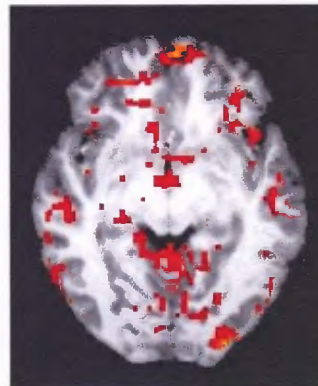
TRIAL6
 (SAC3)



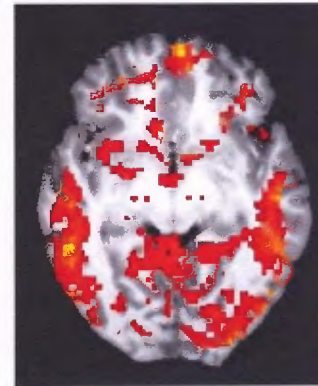
yelda7im55_sac3.jpg

IMAGE#58

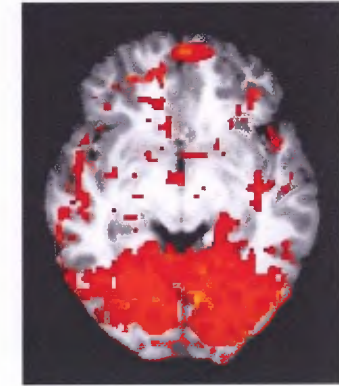
BA 10, BA 11, BA 13,
 BA 17, BA 18, BA 19,
 BA 20, BA 21, BA 22,
 BA 24, BA 25, BA 27,
 BA 28, BA 30, BA 32,
 BA 34, BA 35, BA 36,
 BA 37, BA 38, BA 47
 Caudate
 Putamen
 Globus pallidus



yelda7im58_sac1.jpg



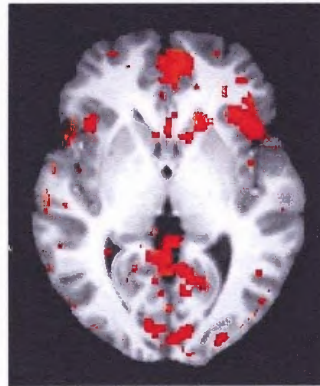
yelda7im58_sac2.jpg



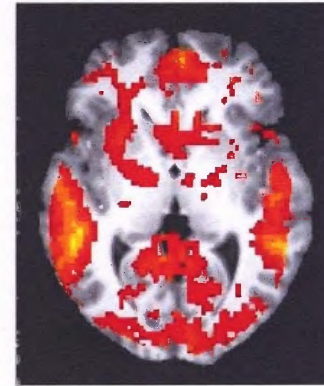
yelda7im58_sac3.jpg

IMAGE#67

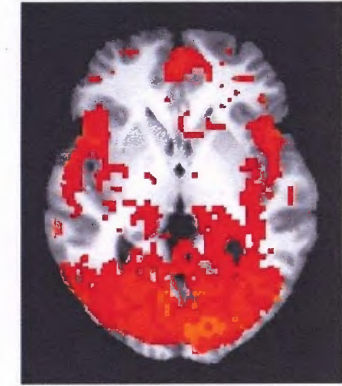
This image is for observation of activation on BA 27.



yelda7im67_sac1ba27.jpg



yelda7im67_sac2ba27.jpg



yelda7im67_sac3ba27.jpg

IMAGE#70

BA 6, BA 10, BA 13, BA 17, BA 18, BA 19, BA 21, BA 22, BA 24, BA 25, BA 27, BA 29, BA 30, BA 32, BA 37, BA 39, BA 41, BA 44, BA 45, BA 46, BA 47

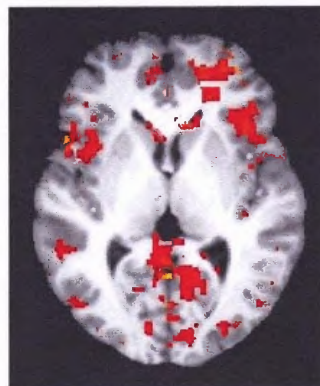
Caudate

Putamen

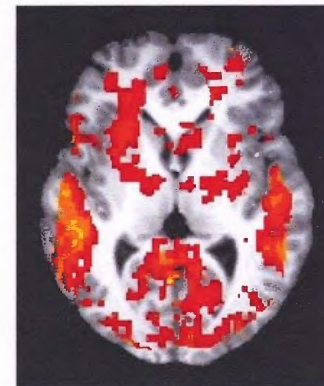
Pulvinar

P.S

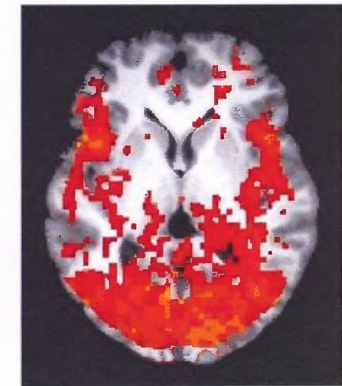
1-Activation on BA 42, BA 43, and globus pallidus is observed in saccade 2 and saccade 3 trials.



yelda7im70_sac1.jpg



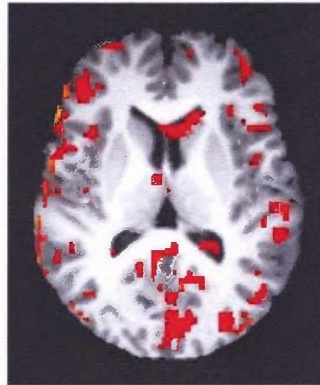
yelda7im70_sac2.jpg



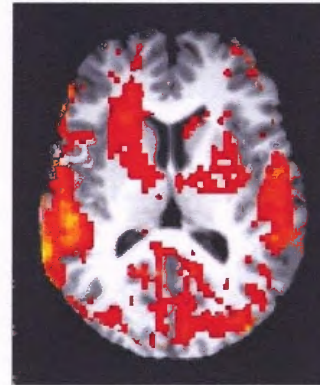
yelda7im70_sac3.jpg

IMAGE#76

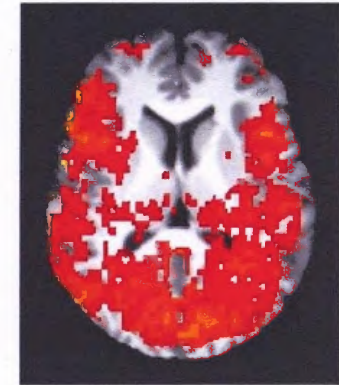
This observation on areas is done for observing clearly activation on BA 41, BA 42, and BA 43.



yelda7im76_sac1.jpg



yelda7im76_sac2.jpg



yelda7im76_sac3.jpg

IMAGE#77

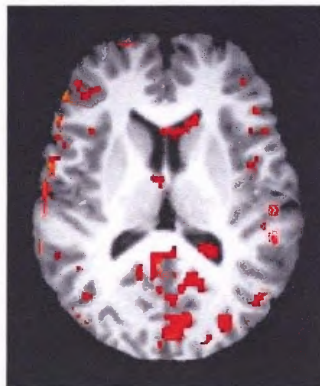
1-Image#77 is for observation of activation on BA 33 for saccade 1 trial.

IMAGE#80

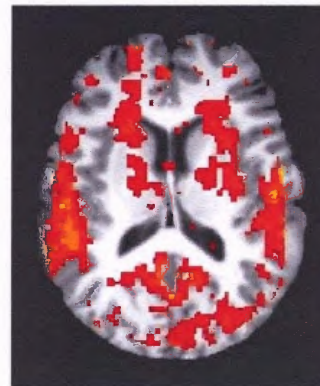
2-Image#80 is for observation of activation on BA 33 for saccade 2 trial.

IMAGE#97

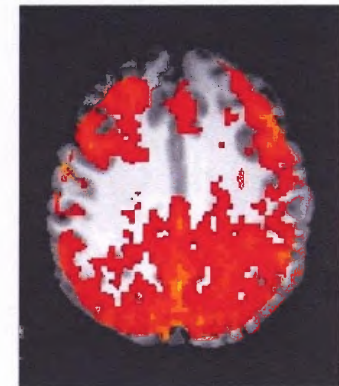
3-Image#97 is for observation of activation on BA 33 for saccade 3 trial.



yelda7im77_sac1ba33.jpg



yelda7im80_sac1ba33.jpg



yelda7im97_sac1ba33.jpg

IMAGE#86

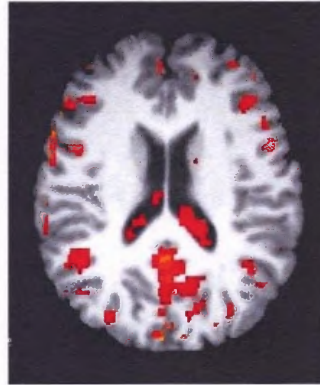
BA 1, BA 2, BA 3, BA 4,
BA 6, BA 9, BA 10, BA
13, BA 17, BA 18, BA
19, BA 22, BA 23, BA
29, BA 30, BA 31, BA
32, BA 39, BA 40, BA
41, BA 42, BA 43, BA
44, BA 45, BA 46

Pulvinar

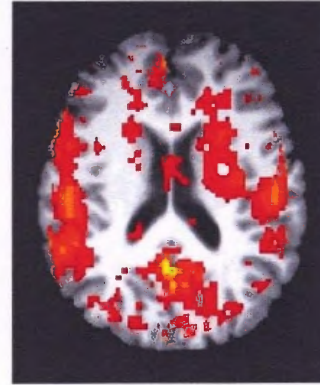
P.S

1- Activation on BA 33 is
observed in saccade 3
trial.

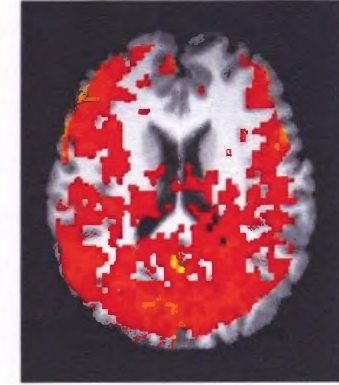
2-Activation on BA 24 is
observed in saccade 2 and
saccade 3 trials.



yelda7im86_sac1.jpg



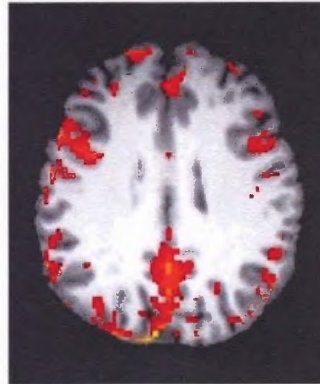
yelda7im86_sac2.jpg



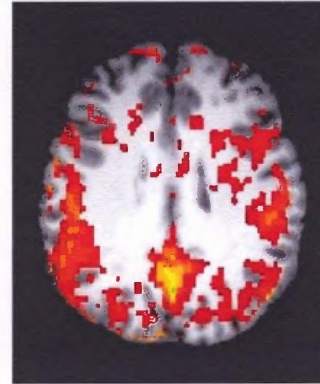
yelda7im86_sac3.jpg

IMAGE#95

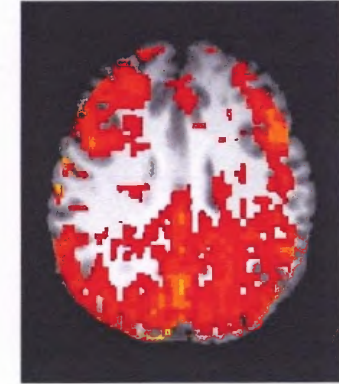
This observation on areas
is done for observing
clearly activation on BA
1, BA 2, BA 3, and BA 4.



yelda7im95_sac1.jpg



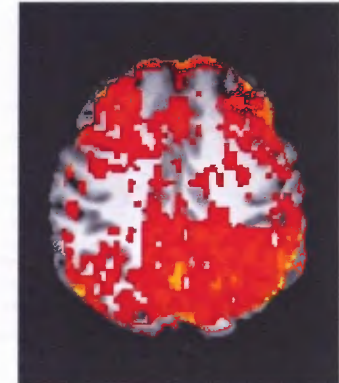
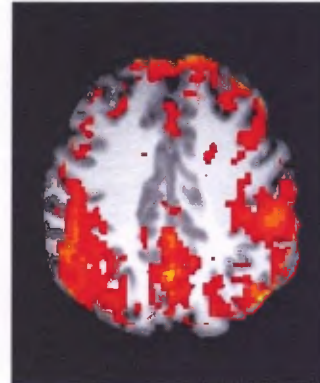
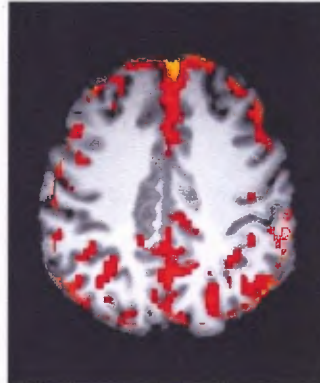
yelda7im95_sac2.jpg



yelda7im95_sac3.jpg

IMAGE#103

BA 1, BA 2, BA 3, BA 4,
BA 6, BA 7, BA 8, BA 9,
BA 19, BA 23 BA 24,
BA 31, BA 32, BA 39,
BA 40
SMA



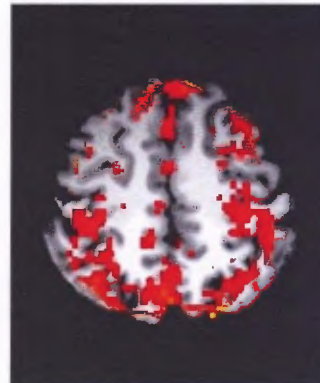
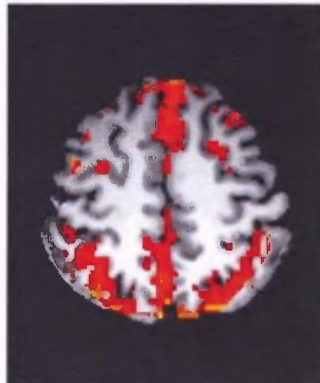
yelda7im103_sac1.jpg

yelda7im103_sac2.jpg

yelda7im103_sac3.jpg

IMAGE#114

BA 3, BA 4, BA 5, BA 6,
BA 7, BA 8, BA 19, BA
24, BA 31, BA 32, BA
39, BA 40
SMA
P.S
1-Activation on BA 1 and
BA 2 is observed in
saccade 2 and saccade 3
trials.



yelda7im114_sac1.jpg

yelda7im114_sac2.jpg

yelda7im114_sac3.jpg

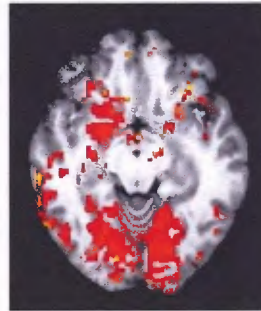
Part 2 Vergence Trials for Subject 2 (Data 2)

SUBJECT 2
 Threshold:
 0.0515
 IMAGE#55

OBSERVED
 ACTIVATED AREAS

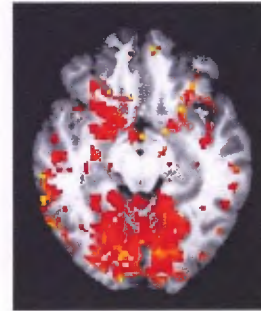
This observation on areas is done for observing clearly activation on BA 28, BA 34, BA 35, and BA 36.

TRIAL2
 (VERG1)



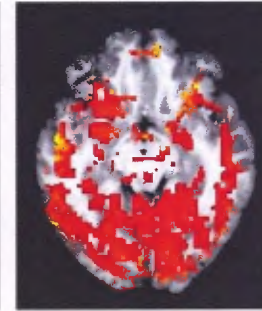
yelda7im55_
 verg1.jpg

TRIAL3
 (VERG2)



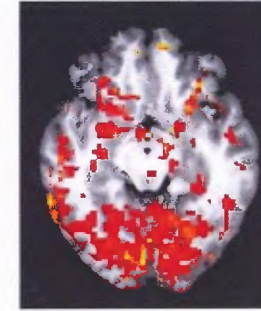
yelda7im55_
 verg2.jpg

TRIAL5
 (VERG3)



yelda7im55_
 verg3.jpg

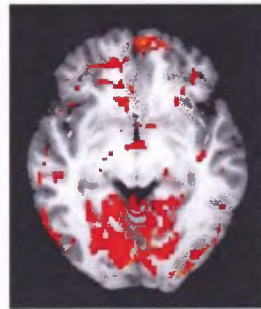
TRIAL7
 (VERG4)



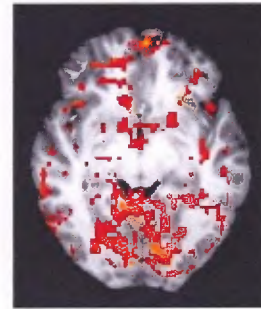
yelda7im55_
 verg4.jpg

IMAGE#58

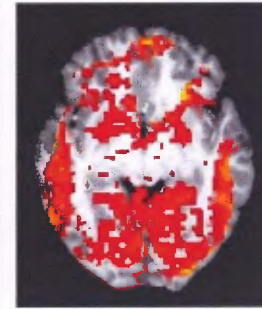
BA 10, BA 11, BA 13,
 BA 17, BA 18, BA 19,
 BA 20, BA 21, BA 22,
 BA 24, BA 25, BA 28,
 BA 30, BA 32, BA 34,
 BA 35, BA 36, BA 37,
 BA 38, BA 47
 Caudate
 Putamen
 Globus pallidus



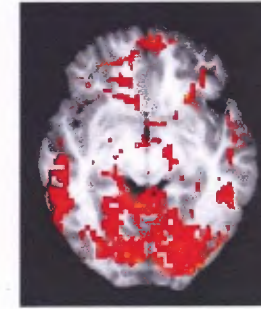
yelda7im58_
 verg1.jpg



yelda7im58_
 verg2.jpg



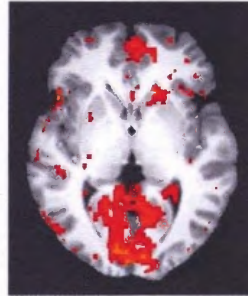
yelda7im58_
 verg3.jpg



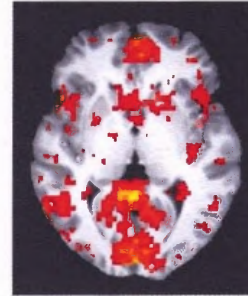
yelda7im58_
 verg4.jpg

IMAGE#67

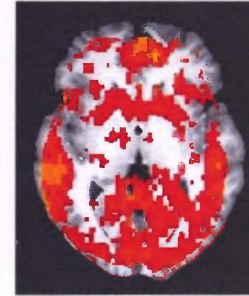
This image is for observation of activation on BA 27.



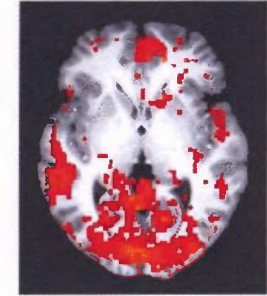
yelda7im67_
verg1ba27.jpg



yelda7im67_
verg2ba27.jpg



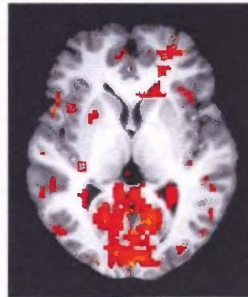
yelda7im67_
verg3ba27.jpg



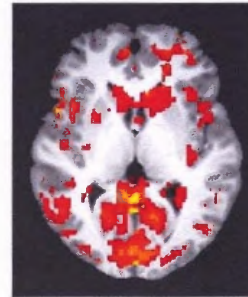
yelda7im67_
verg4ba27.jpg

IMAGE#70

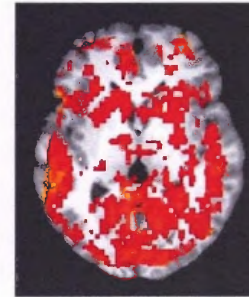
BA 10, BA 13, BA 17,
BA 18, BA 19, BA 21,
BA 22, BA 24, BA 25,
BA 27, BA 29, BA 30,
BA 32, BA 37, BA 39,
BA 41, BA 44, BA 45,
BA 46, BA 47
Caudate
Putamen
Globus pallidus
Pulvinar



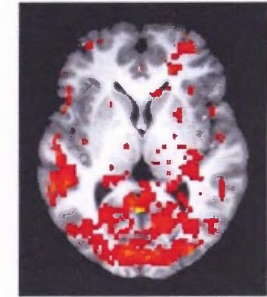
yelda7im70_
verg1.jpg



yelda7im70_
verg2.jpg



yelda7im70_
verg3.jpg



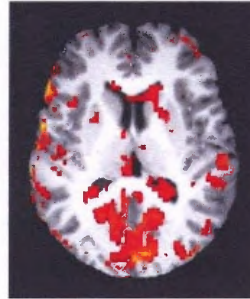
yelda7im70_
verg4.jpg

P.S

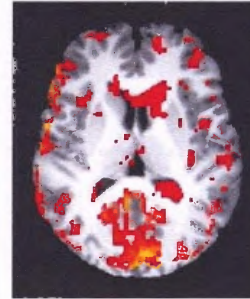
- 1-Activation on BA 6 and BA 43 is observed in vergence 2, vergence 3, and vergence 4 trials.
- 2-Activation on BA 42 is observed in vergence 1, vergence 3, and vergence 4 trials.

IMAGE#76

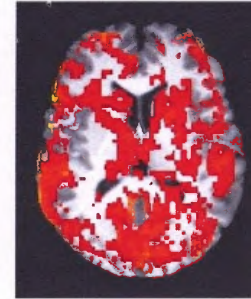
This observation on areas is done for observing clearly activation on BA 41, BA 42, and BA 43.



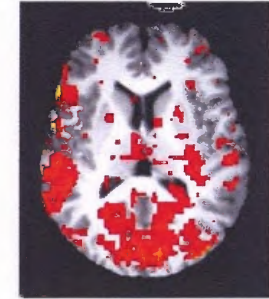
yelda7im76_
verg1.jpg



yelda7im76_
verg2.jpg



yelda7im76_
verg3.jpg



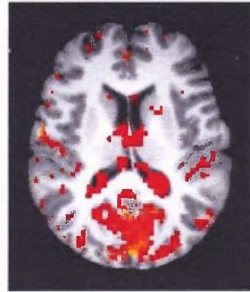
yelda7im76_
verg4.jpg

IMAGE#80

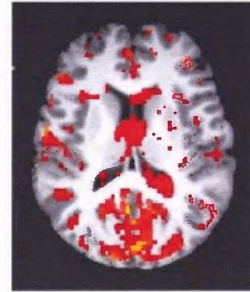
1-Image#80 is for observation of activation on BA 33 for vergence 1, vergence 2, and vergence 3 trials.

IMAGE#84

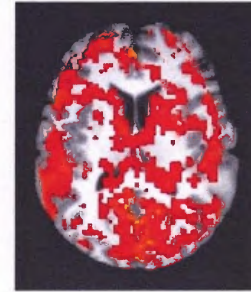
2-Image#84 is for observation of activation on BA 33 for vergence 4 trial.



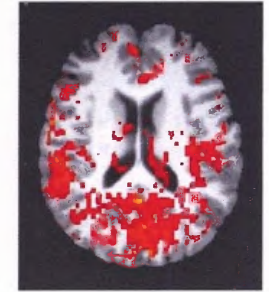
yelda7im80_
verg1ba33.jpg



yelda7im80_
verg2ba33.jpg



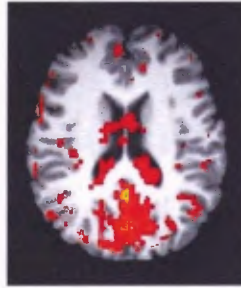
yelda7im80_
verg3ba33.jpg



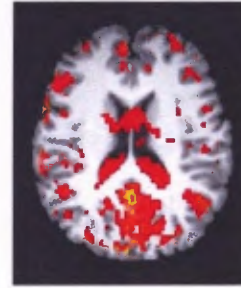
yelda7im84_
verg4ba33.jpg

IMAGE#86

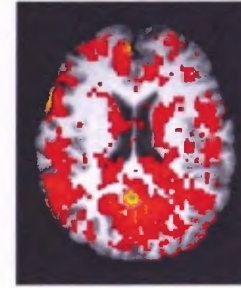
BA 1, BA 2, BA 3, BA 4, BA 6, BA 9, BA 10, BA 13, BA 17, BA 18, BA 19, BA 22, BA 23, BA 24, BA 29, BA 30, BA 31, BA 33, BA 32, BA 39, BA 40, BA 41, BA 42, BA 43, BA 44, BA 45, BA 46
Pulvinar



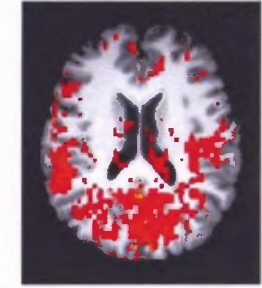
yelda7im86_
verg1.jpg



yelda7im86_
verg2.jpg



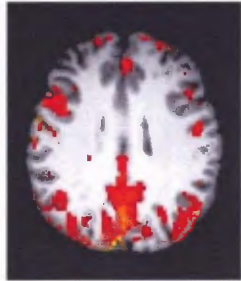
yelda7im86_
verg3.jpg



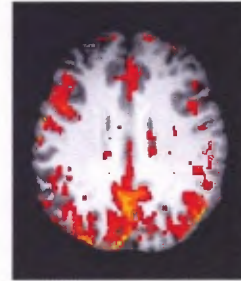
yelda7im86_
verg4.jpg

IMAGE#95

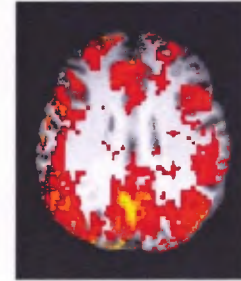
This observation on areas is done for observing clearly activation on BA 1, BA 2, BA 3, and BA 4.



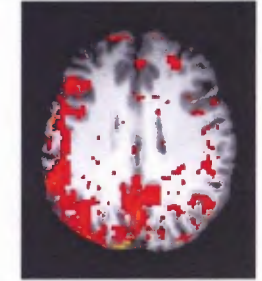
yelda7im95_
verg1.jpg



yelda7im95_
verg2.jpg



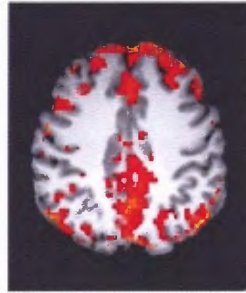
yelda7im95_
verg3.jpg



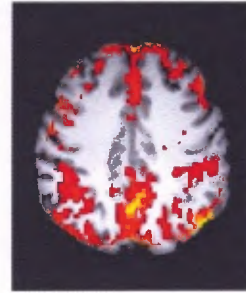
yelda7im95_
verg4.jpg

IMAGE#103

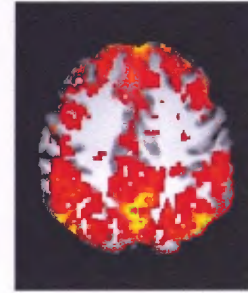
BA 1, BA 2, BA 3, BA 4, BA 6, BA 7, BA 8, BA 9, BA 19, BA 23, BA 24, BA 31, BA 32, BA 39, BA 40, SMA



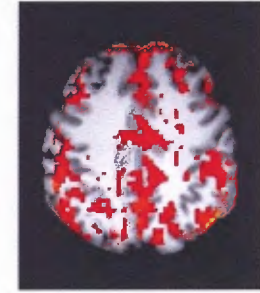
yelda7im103_
verg1.jpg



yelda7im103_
verg2.jpg



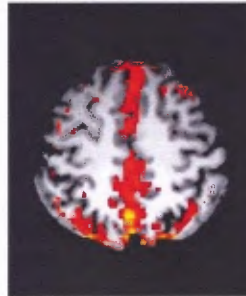
yelda7im103_
verg3.jpg



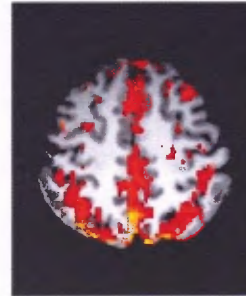
yelda7im103_
verg4.jp

IMAGE#114

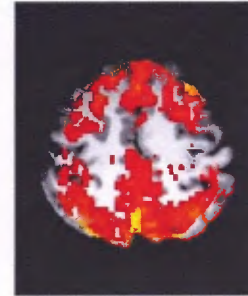
BA 1, BA 2, BA 3, BA 4, BA 5, BA 6, BA 7, BA 8, BA 24, BA 31, BA 32, BA 39, BA 40 SMA



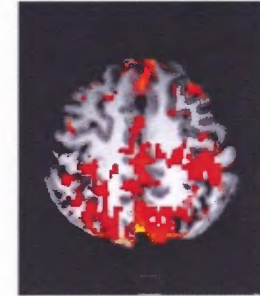
yelda7im114_
verg1.jpg



yelda7im114_
verg2.jpg



yelda7im114_
verg3.jpg



yelda7im114_
verg4.jpg

APPENDIX C

ACTIVATED REGIONS OF SUBJECT 3 FOR SACCADE AND VERGENCE TRIALS

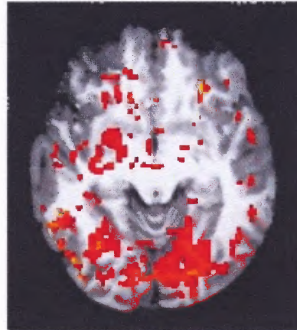
The Appendix C includes the activated regions that belongs to the saccadic and vergence trials for subject 3. The different image numbers were used for clear observation of cortical activation..

Part 1 Saccade Trials for Subject 3 (Data 3)

SUBJECT 3
 Threshold:
 0.0515
 IMAGE#58

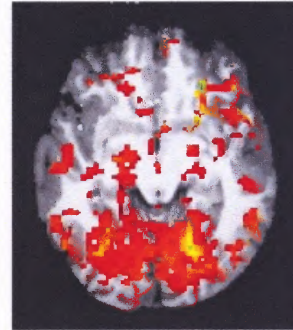
OBSERVED
 ACTIVATED AREAS
 BA 10, BA 11, BA 13,
 BA 17,
 BA 18, BA 19, BA 20,
 BA 21,
 BA 22, BA 24, BA 25,
 BA 27, BA 28, BA 30,
 BA 32, BA 34,
 BA 35, BA 36,
 BA 37, BA 38, BA 47
 Caudate,
 Putamen,
 Globus pallidus

TRIAL1
 (SAC1)



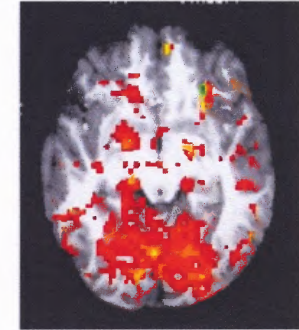
yelda1im58_sac1.jpg

TRIAL3
 (SAC2)



yelda1im58_sac2.jpg

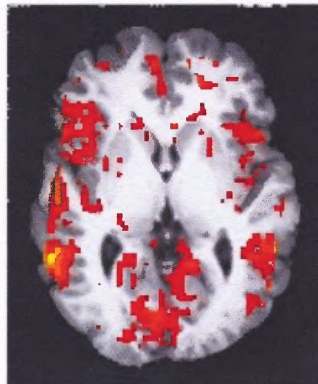
TRIAL5
 (SAC3)



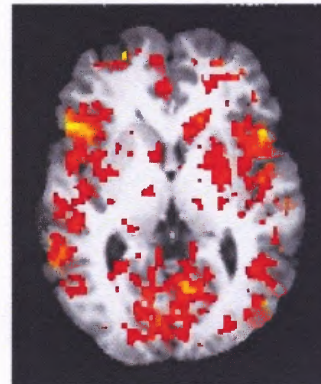
yelda1im58_sac3.jpg

IMAGE#70

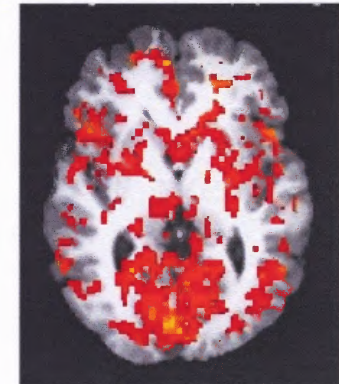
BA 6, BA 10, BA 13, BA
 17, BA 18, BA 19, BA
 21, BA 22, BA 23, BA
 24, BA 25, BA 27, BA
 29, BA 30, BA 32, BA
 37, BA 39, BA 41, BA
 42, BA 43, BA 44, BA 45,
 BA 46, BA 47,
 Caudate
 Putamen
 Globus pallidus
 Pulvinar



yelda1im70_sac1.jpg



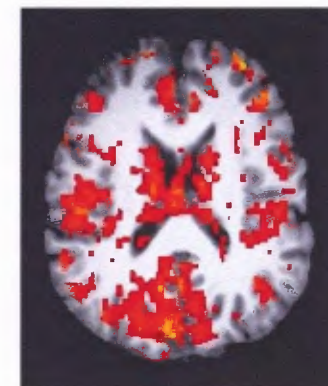
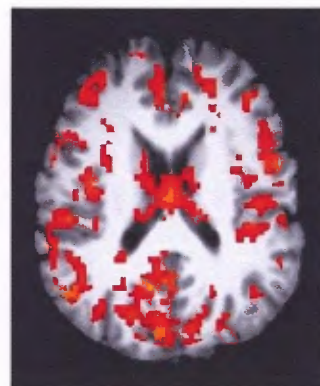
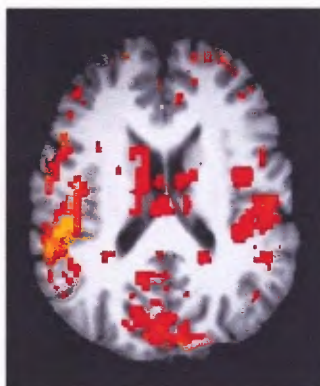
yelda1im70_sac2.jpg



yelda1im70_sac3.jpg

IMAGE#86

BA 1, BA 2, BA 3, BA 4,
BA 6, BA 9, BA 10, BA
13, BA 17, BA 18,
BA 19, BA 22, BA 23,
BA 24, BA 29, BA 30,
BA 31, BA 32, BA 33,
BA 39, BA 40, BA 41,
BA 42, BA 43, BA 44,
BA 45, BA 46
Pulvinar



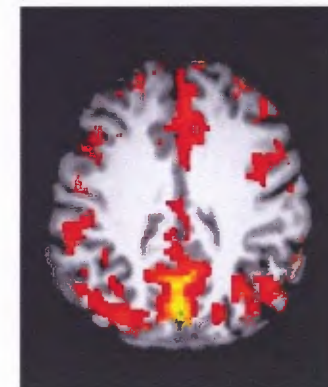
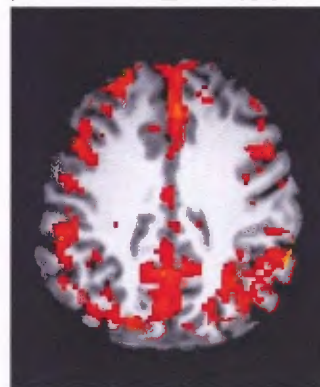
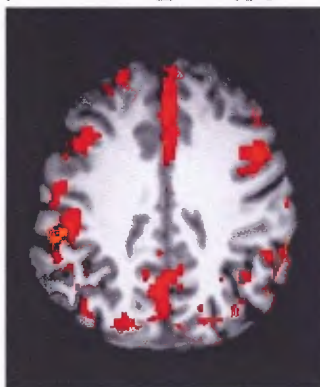
yelda1im86_sac1.jpg

yelda1im86_sac2.jpg

yelda1im86_sac3.jpg

IMAGE#103

BA 1, BA 2, BA 3, BA 4,
BA 6, BA 7, BA 8, BA 9,
BA 19, BA 24, BA 31,
BA 32, BA 39, BA 40,
SMA (supplementary
motor area)



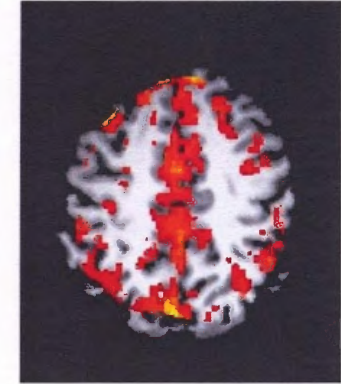
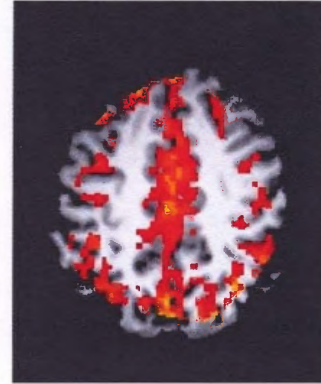
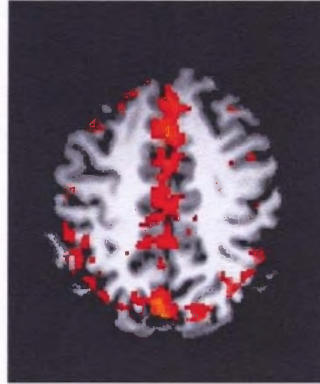
yelda1im103_sac1.jpg

yelda1im103_sac2.jpg

yelda1im103_sac3.jpg

IMAGE#114

BA 1, BA 2, BA 3, BA 4,
BA 5, BA 6, BA 7, BA 8,
BA 19, BA 24,
BA 31, BA 32, BA 39,
BA 40
SMA



yeldalim114_sac1.jpg

yeldalim114_sac2.jpg

yeldalim114_sac3.jpg

IMAGE#119

This image is for
observation of activation
on SMA.



yeldalim119_sac1sma.jpg

yeldalim119_sac2sma.jpg

yeldalim119_sac3sma.jpg

Part 2 Vergence Trials for Subject 3 (Data 3)

SUBJECT 3
Threshold:
0.0515

OBSERVED
ACTIVATED AREAS

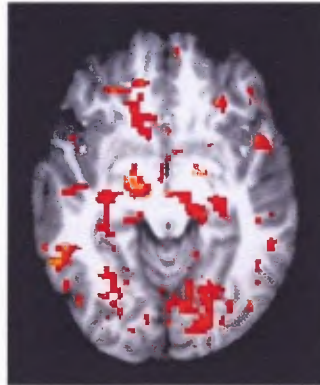
TRIAL2
(VERG1)

TRIAL4
(VERG2)

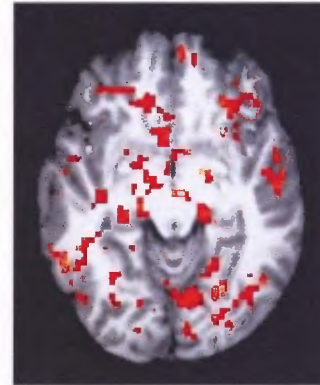
TRIAL6
(VERG3)

IMAGE#58

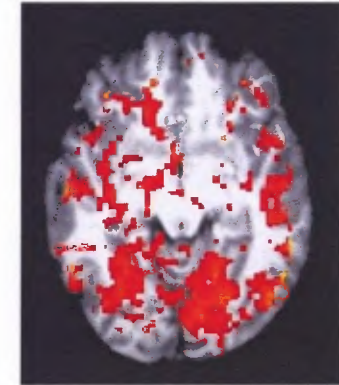
BA 10, BA11, BA 13, BA
17, BA 18, BA 19, BA
20, BA 21, BA 22, BA24,
BA 25, BA 27, BA 28,
BA 30, BA 32, BA 34,
BA 35, BA 36, BA 37,
BA 38, BA 47
Caudate
Putamen
Globus pallidus



yelda1im58_verg1.jpg



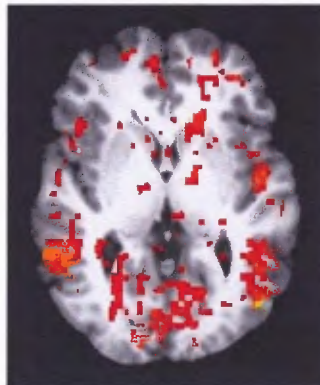
yelda1im58_verg2.jpg



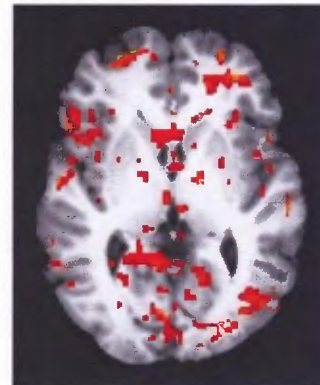
yelda1im58_verg3.jpg

IMAGE#70

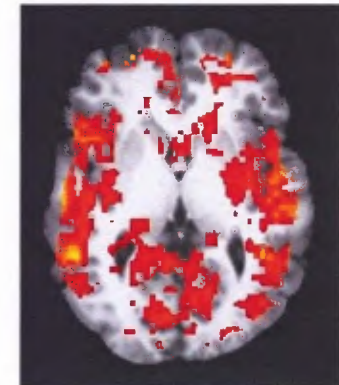
BA 6, BA 10,
BA 13, BA 17, BA 18,
BA 19, BA 21, BA 22,
BA 23, BA 24, BA 25,
BA 27, BA 29, BA 30,
BA 32, BA 37, BA 39,
BA 41, BA 42, BA 43 BA
44, BA 45, BA 46, BA
47,
Caudate, Putamen
Globus pallidus Pulvinar



yelda1im70_verg1.jpg



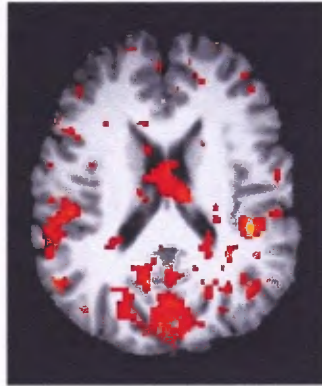
yelda1im70_verg2.jpg



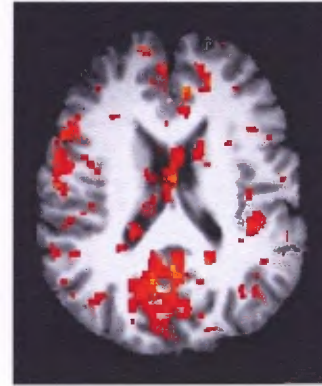
yelda1im70_verg3.jpg

IMAGE#86

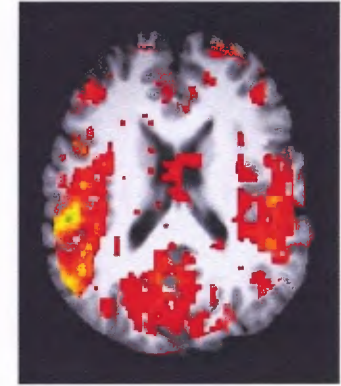
BA 1, BA 2, BA 3, BA 4,
BA 6, BA 9, BA 10, BA
13, BA 17, BA 18,
BA 19, BA 22, BA 23,
BA 24, BA 29, BA 30,
BA 31, BA 32, BA 33,
BA 39, BA 40, BA 41,
BA 42, BA 43, BA 44,
BA 45, BA 46
Pulvinar



yelda1im86_verg1.jpg



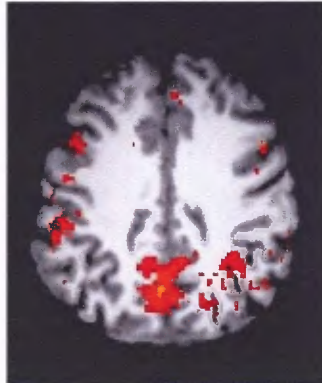
yelda1im86_verg2.jpg



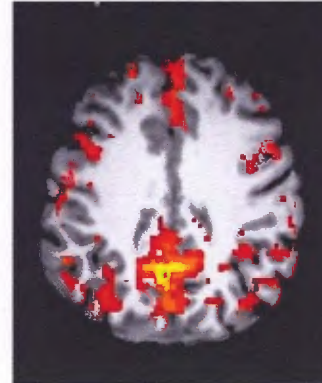
yelda1im86_verg3.jpg

IMAGE#103

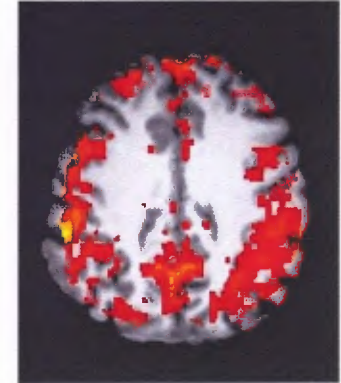
BA 1, BA 2, BA 3, BA 4,
BA 6, BA 7, BA 8, BA 9,
BA 19, BA 24, BA 31,
BA 32, BA 39, BA 40



yelda1im103_verg1.jpg

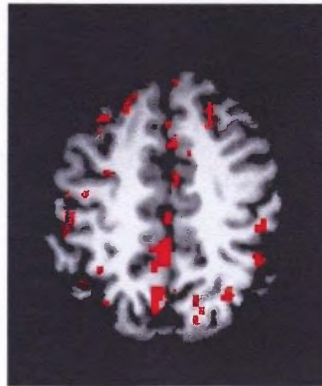


yelda1im103_verg2.jpg

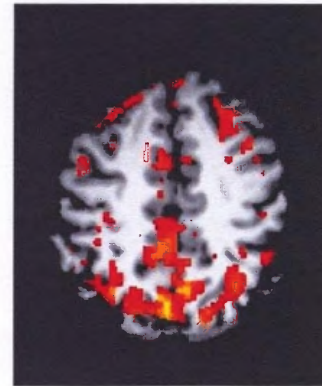


yelda1im103_verg3.jpg

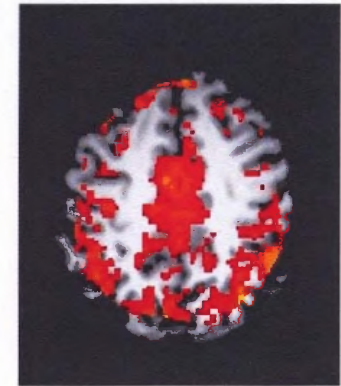
IMAGE#114 BA 1, BA 2, BA 3, BA 4,
BA 5, BA 6, BA 7, BA 8,
BA 19, BA 24,
BA 31, BA 32, BA 39,
BA 40
SMA



yeldalim114_verg1.jpg

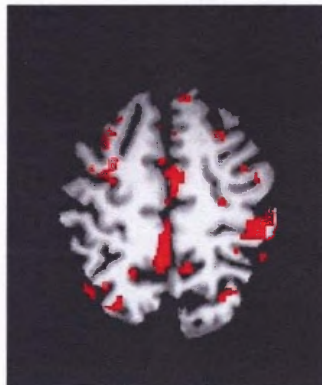


yeldalim114_verg2.jpg



yeldalim114_verg3.jpg

IMAGE#119 This image is for
observation of activation
on SMA and BA 24
(Images named as SMA
but there are other areas
activated but not
mentioned)



yeldalim119_verg1sma.jpg



yeldalim119_verg2sma.jpg



yeldalim119_verg3sma.jpg

APPENDIX D

ACTIVATED REGIONS OF SUBJECT 4 FOR SACCADE AND VERGENCE TRIALS

The Appendix D includes the activated regions that belongs to the saccadic and vergence trials for subject 4. The different image numbers were used for clear observation of cortical activation..

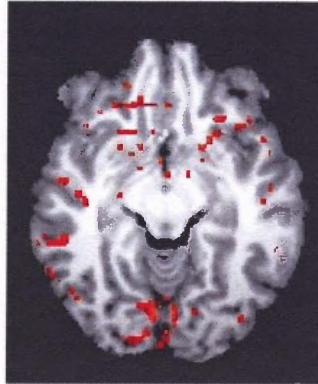
Part 1 Saccade Trials for Subject 4 (Data 4)

SUBJECT 4
Threshold:
0.0515
IMAGE#55

OBSERVED
ACTIVATED AREAS

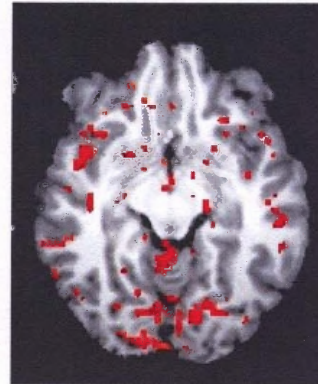
This image is for
observation of activation
on BA 36

TRIAL1
(SAC1)



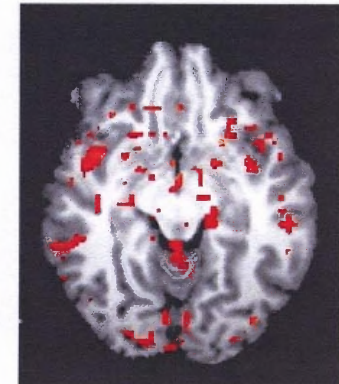
yelda2im55_sac1ba36.jpg

TRIAL3
(SAC2)



yelda2im55_sac2ba36.jpg

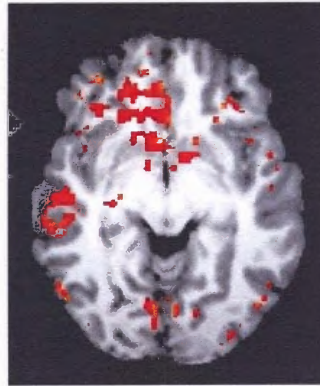
TRIAL5
(SAC3)



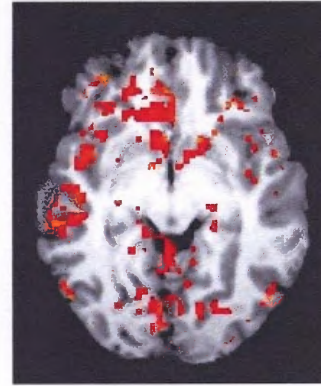
yelda2im55_sac3ba36.jpg

IMAGE#58

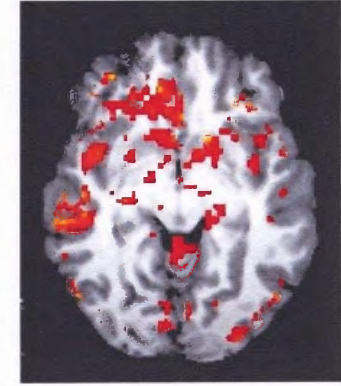
BA 10, BA11, BA 13,
BA 18, BA 19, BA 20,
BA 21, BA 22, BA 24,
BA 25, BA 28, BA 32,
BA 34, BA 35, BA 37,
BA 38, BA 47
Caudate
Putamen
Globus pallidus



yelda2im58_sac1.jpg



yelda2im58_sac2.jpg



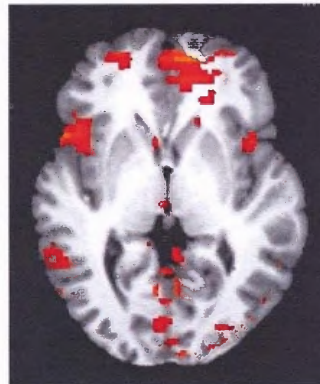
yelda2im58_sac3.jpg

P.S:

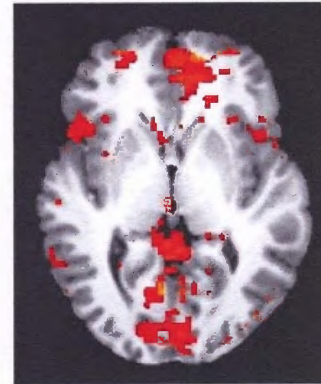
- 1-Activation on BA 46 is observed for image 58 saccade 2 trial.
- 2-Activation on BA 17 is just observed for saccade 2 and saccade 3 trials.

IMAGE#67

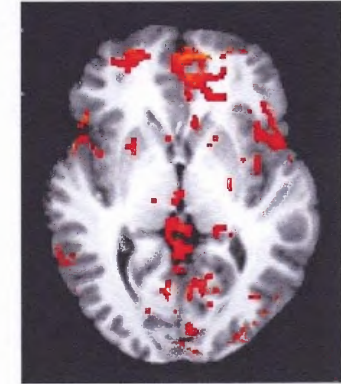
This image is for
observation of activation
on BA 27.



yelda2im67_sac1ba27.jpg



yelda2im67_sac2ba27.jpg



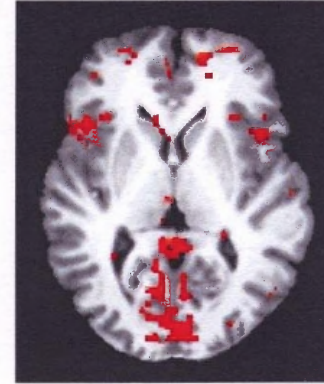
yelda2im67_sac3ba27.jpg

IMAGE#70

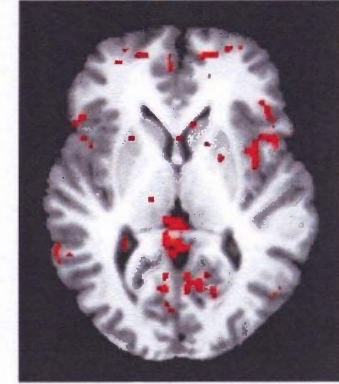
BA 10, BA 13, BA 17,
BA 18, BA 19, BA 21,
BA 22, BA 23, BA 29,
BA 30, BA 32, BA 37,
BA 44, BA 45, BA 46,
BA 47,
Caudate



yelda2im70_sac1.jpg



yelda2im70_sac2.jpg



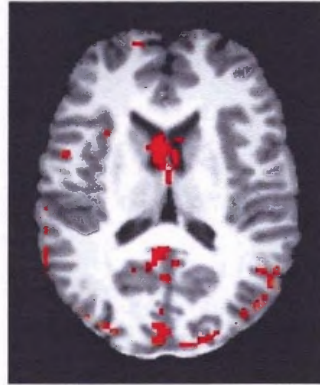
yelda2im70_sac3.jpg

P.S:

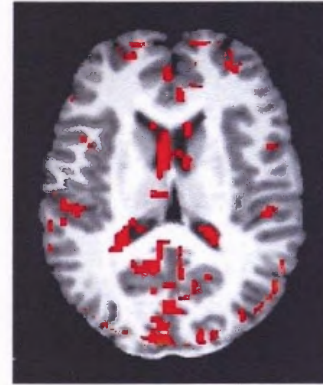
- 1-Activation on Brodmann areas 24, 41, 42, 43 is observed on image 70 for saccade 2, whereas these areas did not show up for saccades 1 and 3 trials.
- 2-In saccade 2 trial activation on pulvinar is seen.
- 3-Activation on caudate, putamen, globus pallidus, and pulvinar is seen on image 70 saccade 3 trial.
- 4-No activation is observed for BA 25 on this image number.
- 5-Activation on BA 39 is observed for saccade 1 trial.
- 6- BA 24 is just activated in saccade 2 and 3 trials.
- 7-Activation on BA 6 is observed in saccade 3 trial.

IMAGE#80

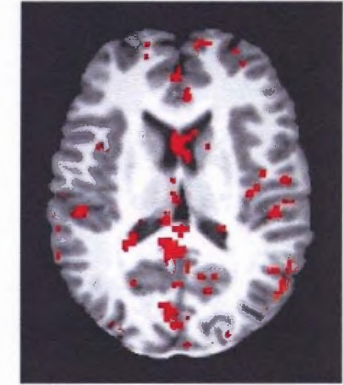
This image is for observation of activation on BA 33



yelda2im80_sac1ba33.jpg



yelda2im80_sac2ba33.jpg

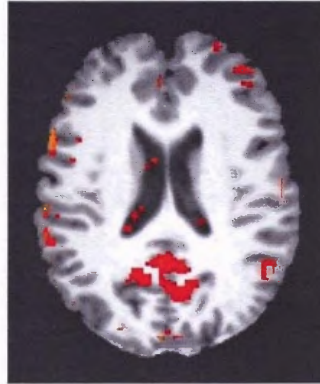


yelda2im80_sac3ba33.jpg

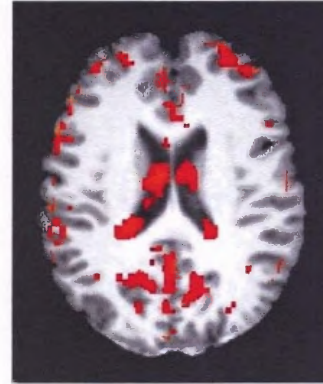
IMAGE#86

BA 1, BA 2, BA 3, BA 4, BA 6, BA 9, BA 10, BA 13, BA 18, BA 19, BA 22, BA 23, BA 24, BA 29, BA 30, BA 31, BA 32, BA 33, BA 39, BA 40, BA 41, BA 42, BA 43, BA 44, BA 45, BA 46
P. S

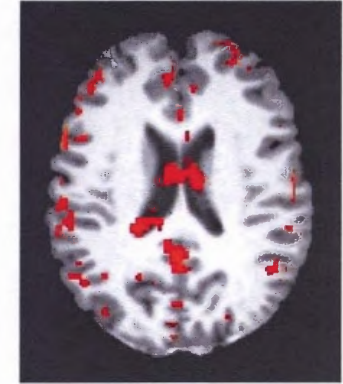
1-Activation on BA 17 is just observed for saccade 2 trial.



yelda2im86_sac1.jpg



yelda2im86_sac2.jpg



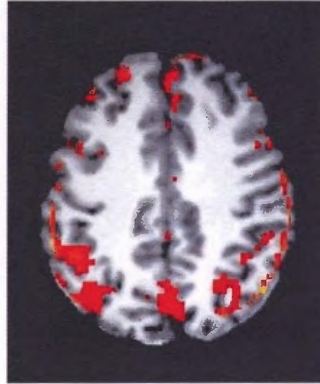
yelda2im86_sac3.jpg

IMAGE#103

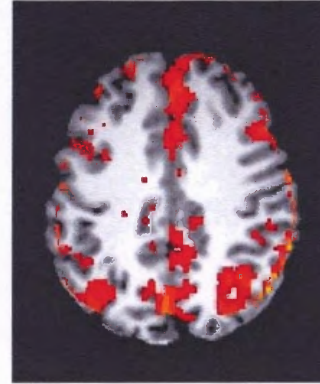
BA 1, BA 2, BA 3, BA 4,
BA 6, BA 7, BA 8, BA 9,
BA 19, BA 24, BA 31,
BA 32, BA 39, BA 40,

P.S

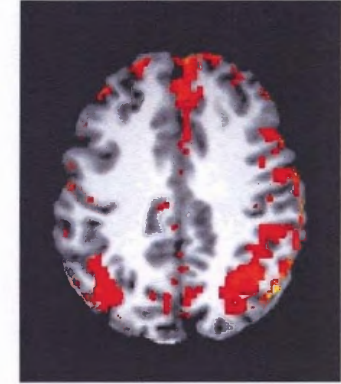
1-Activation on SMA
(supplementary area is
just observed in images
saccade 2 and saccade 3
trials.



yelda2im103_sac1.jpg



yelda2im103_sac2.jpg

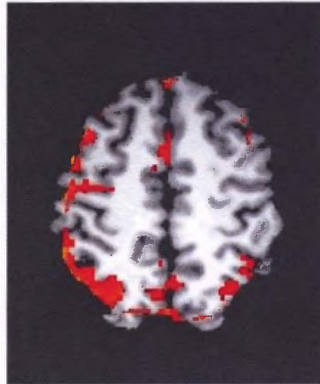


yelda2im103_sac3.jpg

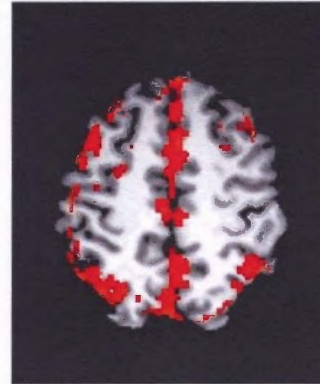
IMAGE#114

BA 1, BA 2, BA 3, BA 4,
BA 5, BA 6, BA 7, BA 8,
BA 19, BA 24, BA 31,
BA 32, BA 39, BA 40

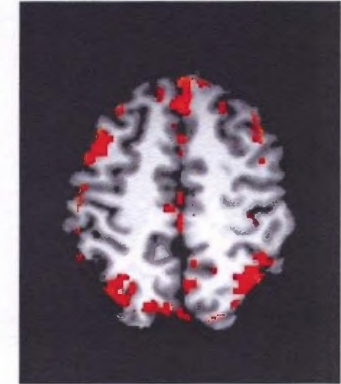
SMA (supplementary
motor area)



yelda2im114_sac1.jpg



yelda2im114_sac2.jpg



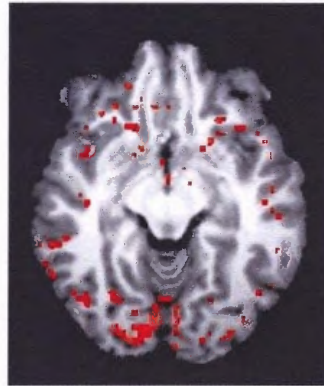
yelda2im114_sac3.jpg

Part 2 Vergence Trials for Subject 4 (Data 4)

SUBJECT 4
 Threshold:
 0.0515
 IMAGE#55

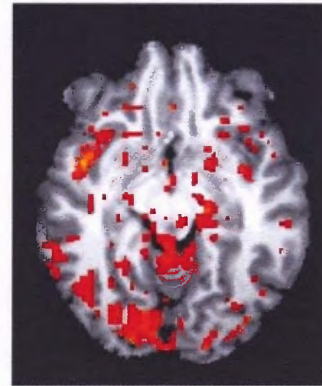
OBSERVED
 ACTIVATED
 AREAS
 This image is for
 observation of
 activation on BA 36.

TRIAL2
 (VERG1)



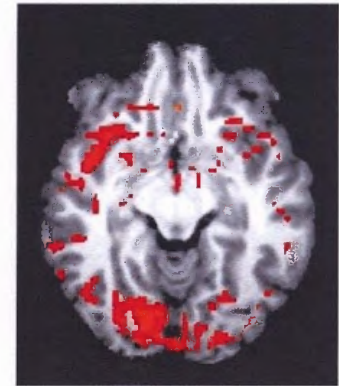
yelda2im55_verg1ba36.jpg

TRIAL4
 (VERG2)



yelda2im55_verg2ba36.jpg

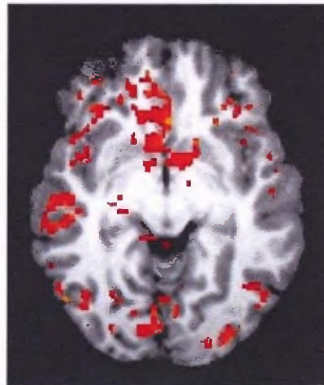
TRIAL6
 (VERG3)



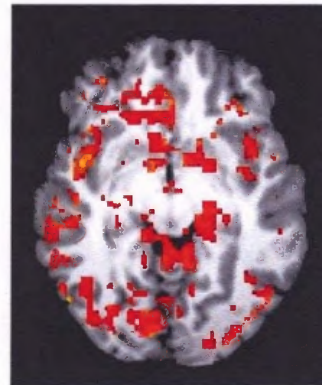
yelda2im55_verg3ba36.jpg

IMAGE#58

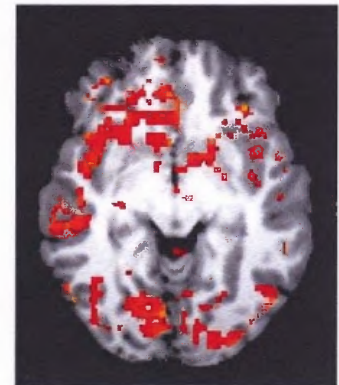
BA 10, BA11, BA 13,
 BA 17, BA 18, BA
 19, BA 20,BA 21, BA
 22, BA24, BA 25, BA
 28, BA 32, BA 34,
 BA 35, BA 37, BA
 38, BA 47
 Caudate,
 Putamen,
 Globus pallidus



yelda2im58_verg1.jpg



yelda2im58_verg2.jpg

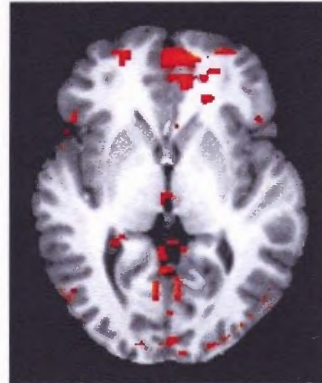


yelda2im58_verg3.jpg

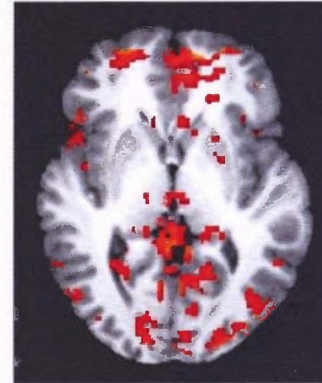
P.S 1-BA 27, 30, 36 is activated on vergence 1 and vergence 2 trials but not on vergence 3 trial.

IMAGE#67

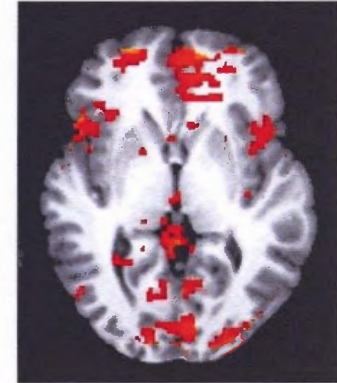
This image is for observation of activation on BA 27.



yelda2im67_verg1ba27.jpg



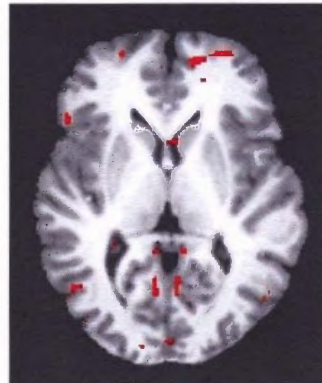
yelda2im67_verg2ba27.jpg



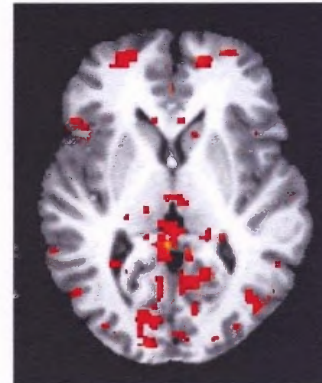
yelda2im67_verg3ba27.jpg

IMAGE#70

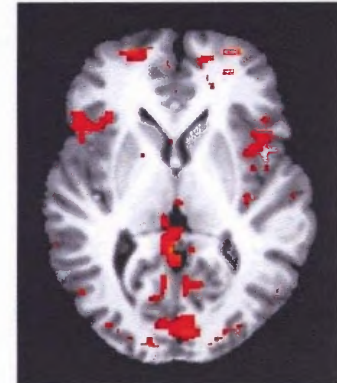
BA 10, BA 13, BA 17, BA 18, BA 19, BA 29, BA 37, BA 39, BA 44, BA 47, Caudate



yelda2im70_verg1.jpg



yelda2im70_verg2.jpg



yelda2im70_verg3.jpg

P.S

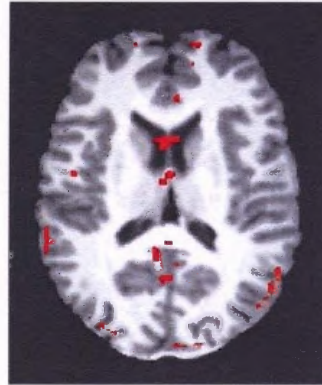
1-Activation on BA 21, 22, 23, 24, 27, 32, 41, 42, 43, pulvinar, putamen, globus pallidus is not observed on vergence 1 for this image number, on the other hand, activation on these areas are observed in vergence 2 and vergence 3 trials, except globus pallidus. Activation on globus pallidus is just seen on vergence 3 trial.

2-Activation on BA 46 is observed in vergence 1 and vergence 3 trials, not in vergence 2 trial.

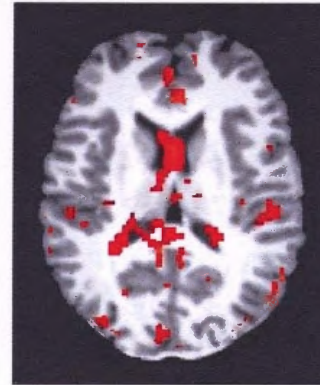
3-Activation on BA 6 is observed in vergence 3 trial.

IMAGE#80

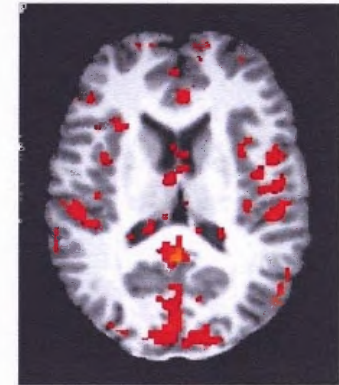
This image is for observation of activation on BA 33.



yelda2im80_verg1ba33.jpg



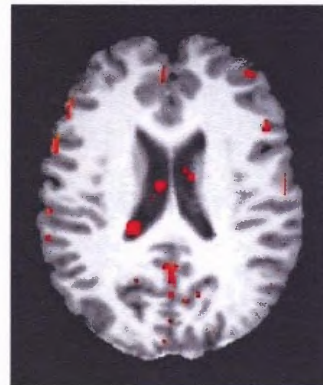
yelda2im80_verg2ba33.jpg



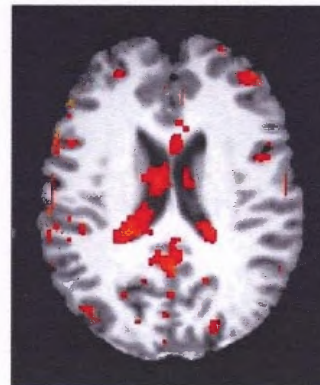
yelda2im80_verg3ba33.jpg

IMAGE#86

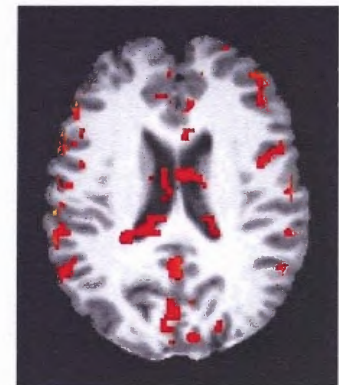
BA 1, BA 2, BA 3,
BA 4, BA 6, BA 9,
BA 10, BA 13, BA
18, BA 19, BA 22,
BA 23, BA 24, BA
29, BA 30, BA 31,
BA 32, BA 33, BA
40, BA 41, BA 42,
BA 43, BA 44, BA
45, BA 46
Pulvinar



yelda2im86_verg1.jpg



yelda2im86_verg2.jpg



yelda2im86_verg3.jpg

P.S

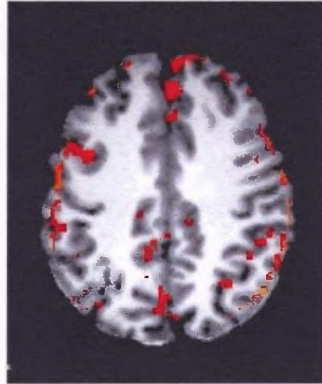
1-Activation on BA 17 and 39 is not observed in vergence 1 trial, on the other hand, activation on these areas observed for other trials which are vergence 2 and vergence 3.

IMAGE#103

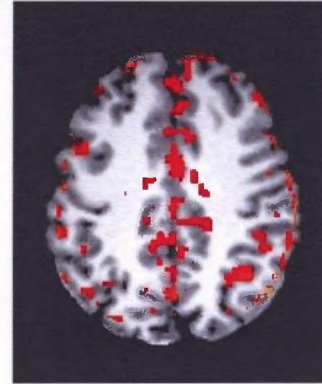
BA 1, BA 2, BA 3,
BA 4, BA 6, BA 7,
BA 8, BA 9, BA 19,
BA 31, BA 32, BA
39, BA 40. SMA
(supplementary motor
area)

P.S

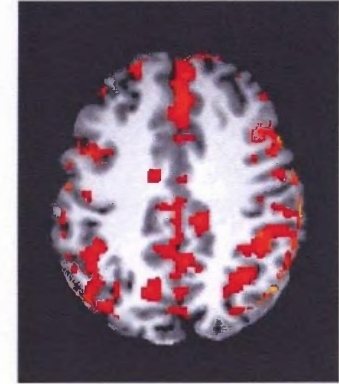
1-Activation on BA
23 and 24 is observed
for vergence 2 and
vergence 3 trials, but
not for vergence 1
trial.



yelda2im103_verg1.jpg



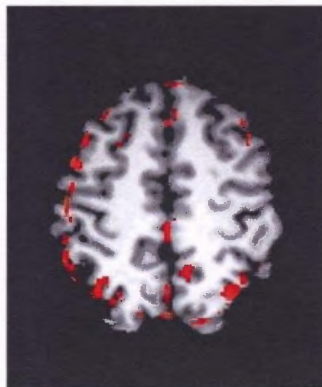
yelda2im103_verg2.jpg



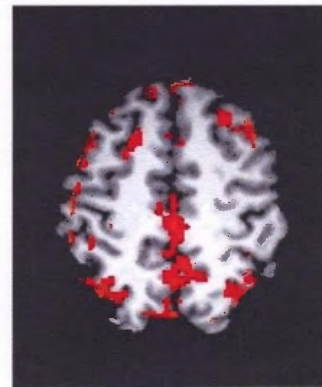
yelda2im103_verg3.jpg

IMAGE#114

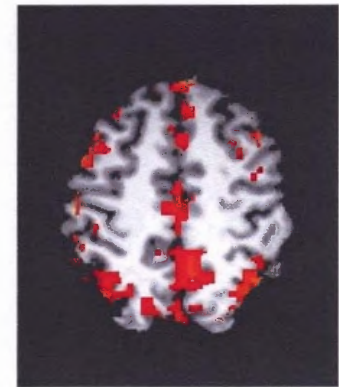
BA 1, BA 2, BA 3,
BA 4, BA 5, BA 6,
BA 7, BA 8, BA 19,
BA 24,
BA 31, BA 32, BA
39, BA 40
SMA (supplementary
motor area)



yelda2im114_verg1.jpg



yelda2im114_verg2.jpg



yelda2im114_verg3.jpg

APPENDIX E

ACTIVATED REGIONS OF SUBJECT 5 FOR SACCADE AND VERGENCE TRIALS

The Appendix E includes the activated regions that belongs to the saccadic and vergence trials for subject 5. The different image numbers were used for clear observation of cortical activation..

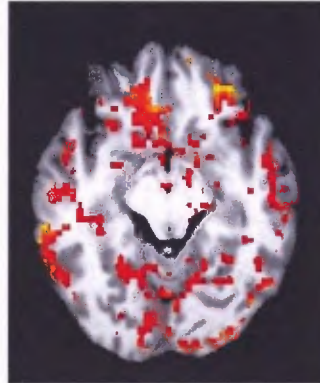
Part 1 Saccade Trials for Subject 5 (Data 6)

SUBJECT 5
 Threshold:
 0.0515
 IMAGE#55

OBSERVED
 ACTIVATED AREAS

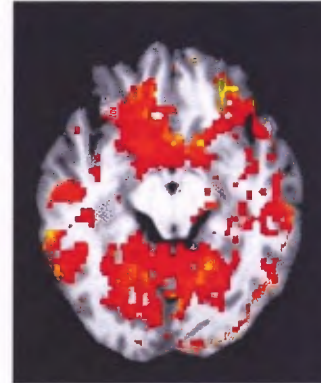
This image is for
 observation of activation
 on BA 36

TRIAL1
 (SAC1)



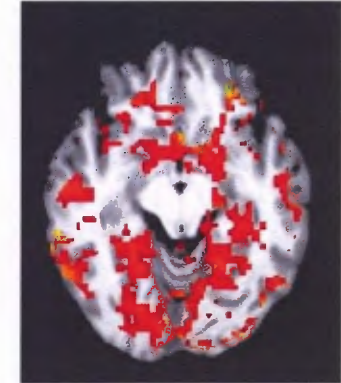
yelda3im55_sac1ba36.jpg

TRIAL3
 (SAC2)



yelda3im55_sac2ba36.jpg

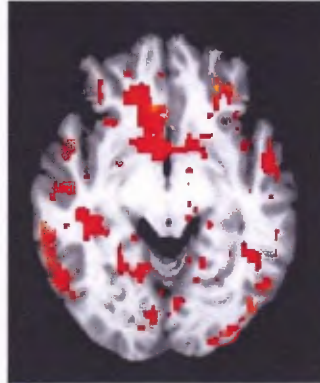
TRIAL5
 (SAC3)



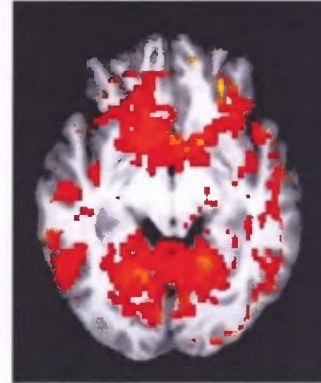
yelda3im55_sac3ba36.jpg

IMAGE#58

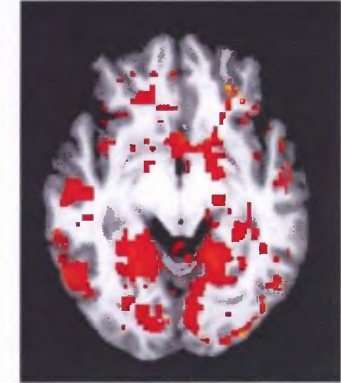
BA 10, BA 11, BA 13,
 BA 17, BA 18, BA 19,
 BA 20, BA 21, BA 22,
 BA 24, BA 25, BA 27,
 BA 28, BA 30, BA 32,
 BA 34, BA 35, BA 36,
 BA 37, BA 38, BA 47
 Caudate
 Putamen
 Globus pallidus



yelda3im58_sac1.jpg



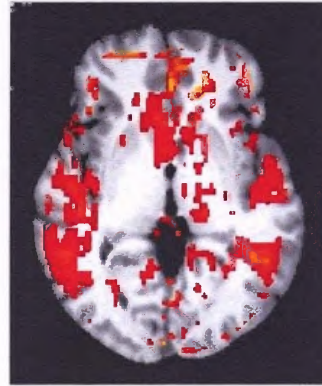
yelda3im58_sac2.jpg



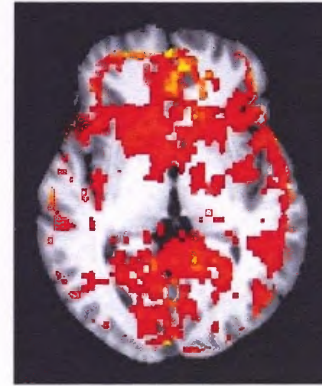
yelda3im58_sac3.jpg

IMAGE#67

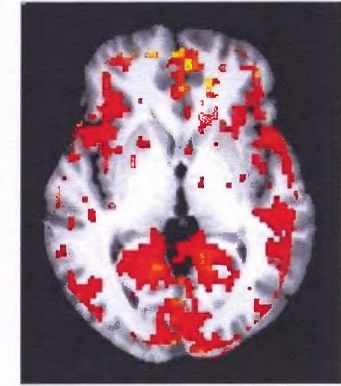
This image is for observation of activation on BA 27.



yelda3im67_sac1ba27.jpg



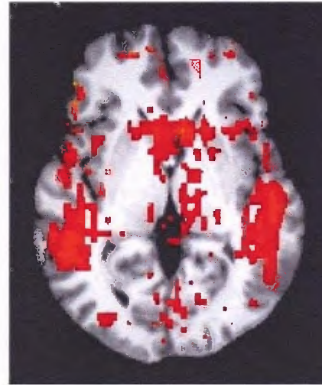
yelda3im67_sac2ba27.jpg



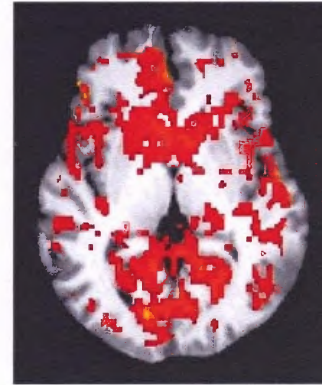
yelda3im67_sac3ba27.jpg

IMAGE#70

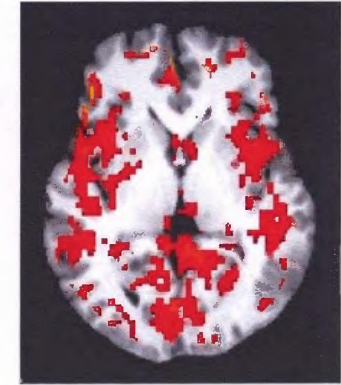
BA 6, BA 10, BA 13, BA 17, BA 18, BA 19, BA 21, BA 22, BA 23, BA 24, BA 25, BA 27, BA 29, BA 30, BA 32, BA 37, BA 39, BA 41, BA 42, BA 43, BA 44, BA 45, BA 46, BA 47, Caudate, Putamen, Globus pallidus, Pulvinar



yelda3im70_sac1.jpg



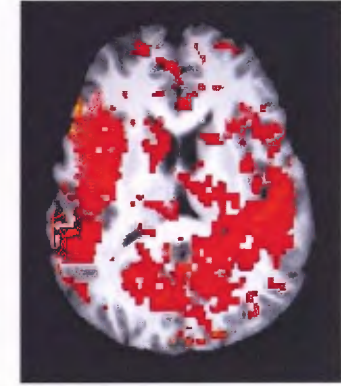
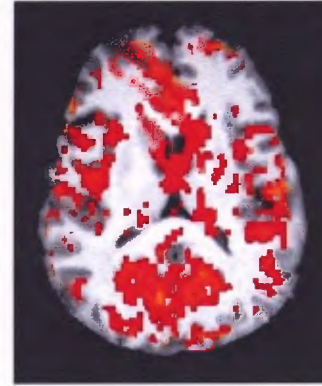
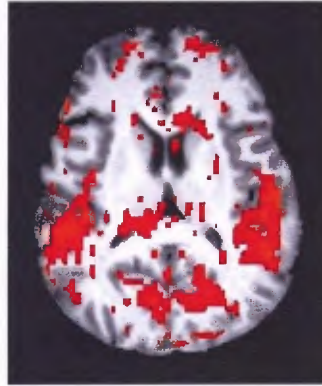
yelda3im70_sac2.jpg



yelda3im70_sac3.jpg

IMAGE#80

This image is for observation of activation on BA 33



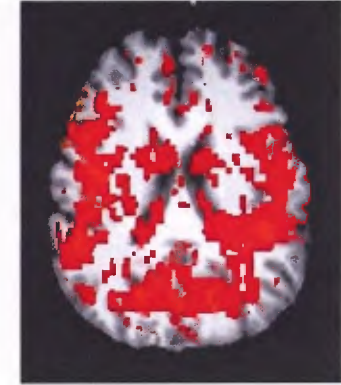
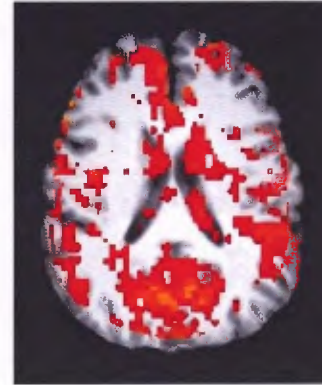
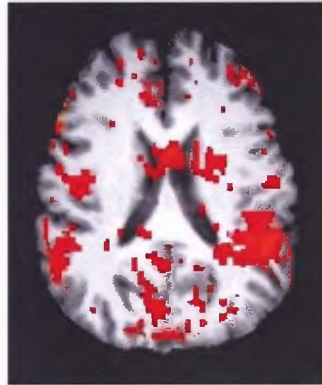
yelda3im80_sac1ba33.jpg

yelda3im80_sac2ba33.jpg

yelda3im80_sac3ba33.jpg

IMAGE#86

BA 1, BA 2, BA 3, BA 4,
BA 6, BA 9, BA 10, BA
13, BA 17, BA 18, BA
19, BA 22, BA 23, BA
24, BA 29, BA 30, BA
31, BA 32, BA 33, BA
39, BA 40, BA 41, BA
42, BA 43, BA 44, BA
45, BA 46
Pulvinar



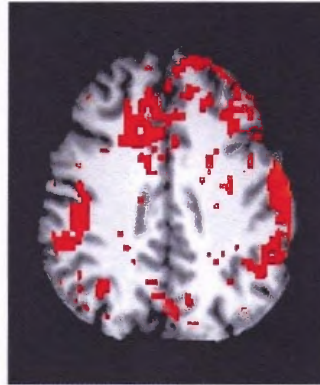
yelda3im86_sac1.jpg

yelda3im86_sac2.jpg

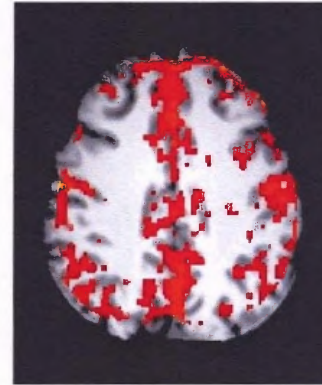
yelda3im86_sac3.jpg

IMAGE#103

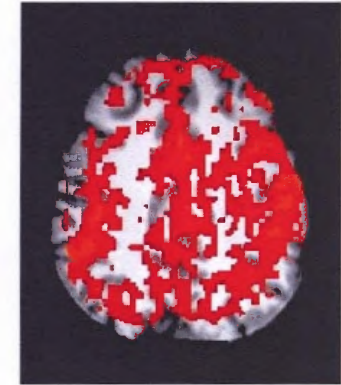
BA 1, BA 2, BA 3, BA 4,
BA 6, BA 7, BA 8, BA 9,
BA 19, BA 24, BA 31,
BA 32, BA 39, BA 40,



yelda3im103_sac1.jpg



yelda3im103_sac2.jpg



yelda3im103_sac3.jpg

P.S 1-Activation on SMA (supplementary motor area) and BA 23 is observed in saccade 2 and 3 trials, but not in saccade 1 trial.

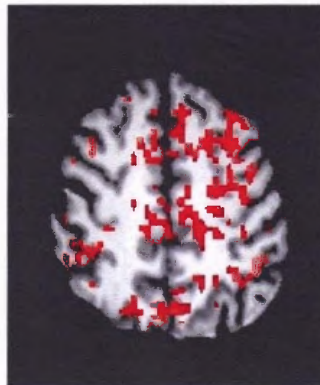
IMAGE#114

BA 1, BA 2, BA 3, BA 4,
BA 5, BA 6, BA 7, BA 8,
BA 24, BA 31, BA 32,
BA 40

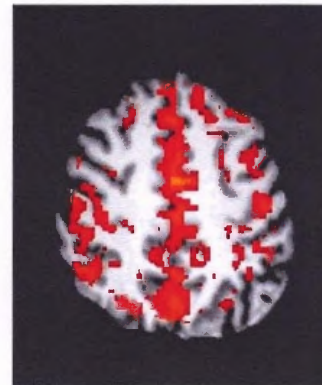
SMA (supplementary
motor area)

P.S

1-Activation on BA 19
and 39 is observed 7 mm
in saccade 1 trial. In
saccade 2 trial these areas
are activated very tiny.
In saccade 3 trial BA 19 and
39 are activated.



yelda3im114_sac1.jpg



yelda3im114_sac2.jpg



yelda3im114_sac3.jpg

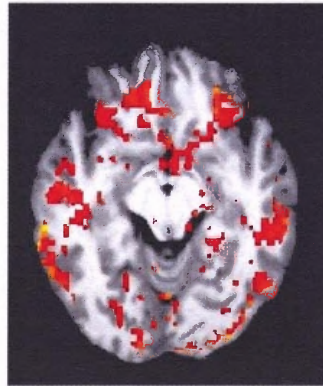
Part 2 Vergence Trials for Subject 5 (Data 6)

SUBJECT 5
Threshold:
0.0515
IMAGE#55

OBSERVED
ACTIVATED AREAS

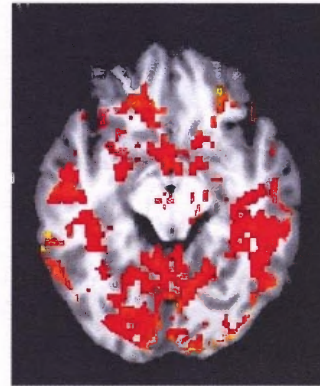
This image is for
observation of
activation on BA 36.

TRIAL2
(VERG1)



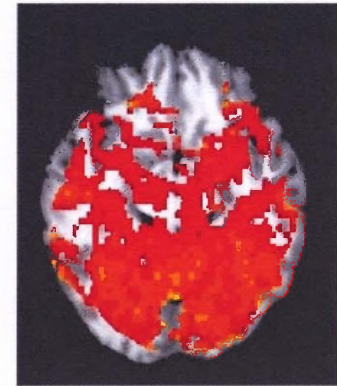
yelda3im55_verg1ba36.jpg

TRIAL4
(VERG2)



yelda3im55_verg2ba36.jpg

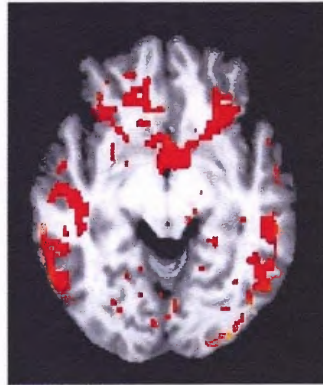
TRIAL6
(VERG3)



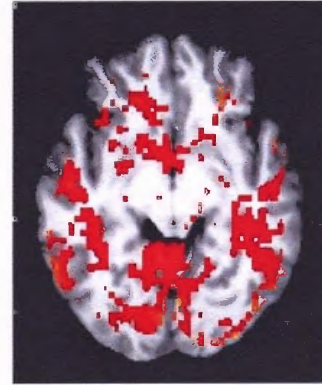
yelda3im55_verg3ba36.jpg

IMAGE#58

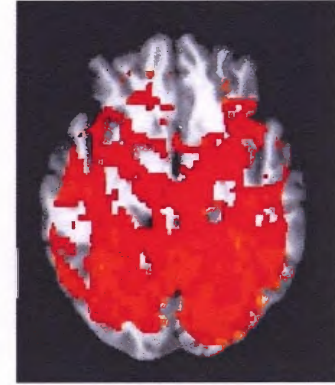
BA 10, BA 11, BA 13,
BA 17,
BA 18, BA 19, BA 20,
BA 21,
BA 22, BA 24, BA 25,
BA 27, BA 28, BA 30,
BA 32, BA 34,
BA 35, BA 36,
BA 37, BA 38, BA 47
Caudate
Putamen
Globus pallidus



yelda3im58_verg1.jpg



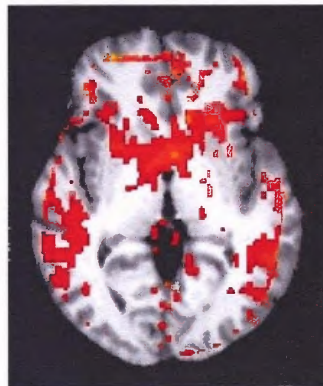
yelda3im58_verg2.jpg



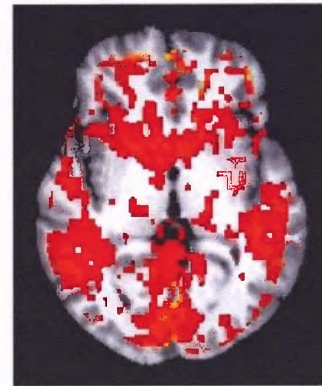
yelda3im58_verg3.jpg

IMAGE#67

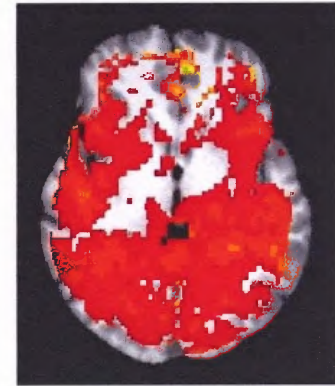
This image is for
observation of
activation on BA 27.



yelda3im67_verg1ba27.jpg



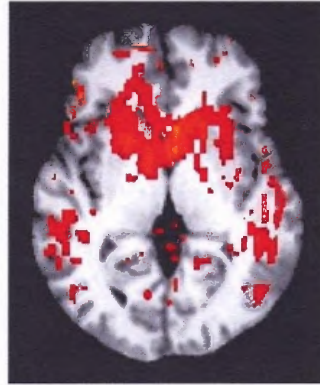
yelda3im67_verg2ba27.jpg



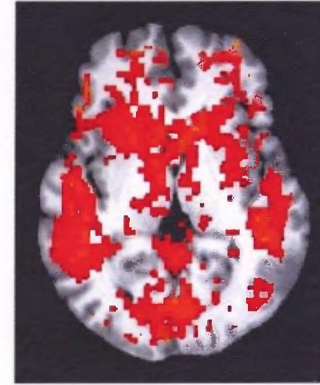
yelda3im67_verg3ba27.jpg

IMAGE#70

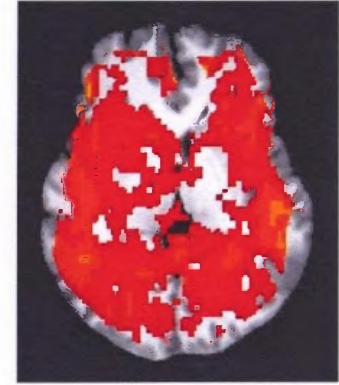
BA 6, BA 10,
BA 13, BA 17, BA 18,
BA 19, BA 21, BA 22,
BA 23, BA 24, BA 25,
BA 27, BA 29, BA 30,
BA 32, BA 37,
BA 39, BA 41, BA 42,
BA 43, BA 44, BA 45,
BA 46, BA 47,
Caudate
Putamen
Globus pallidus
Pulvinar



yelda3im70_verg1.jpg



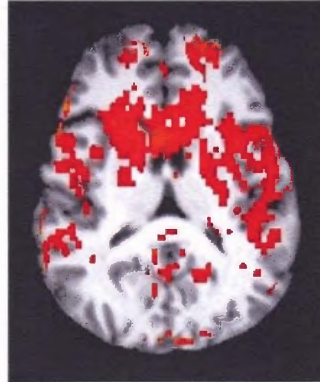
yelda3im70_verg2.jpg



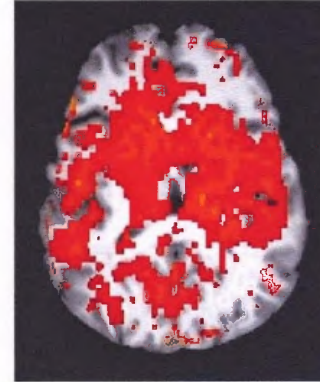
yelda3im70_verg3.jpg

IMAGE#80

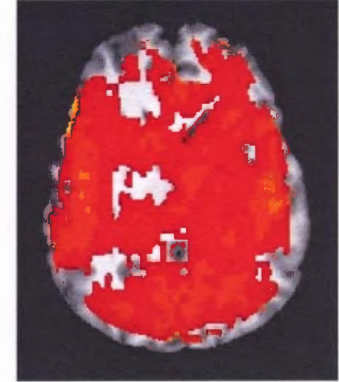
This image is for
observation of
activation on BA 33.



yelda3im80_verg1ba33.jpg



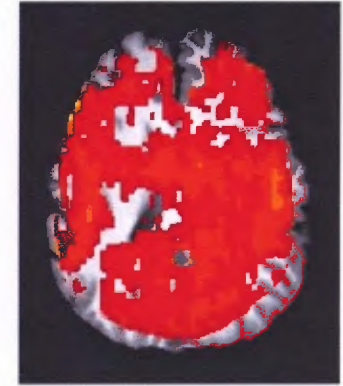
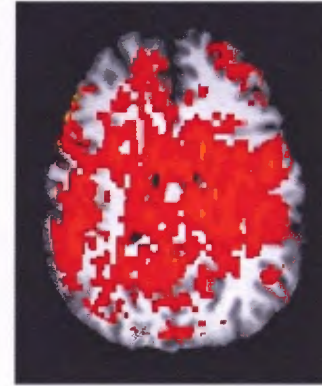
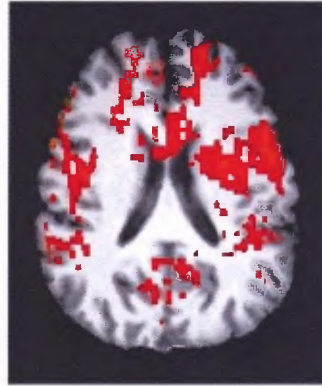
yelda3im80_verg2ba33.jpg



yelda3im80_verg3ba33.jpg

IMAGE#86

BA 1, BA 2, BA 3, BA 4, BA 6, BA 9, BA 10, BA 13, BA 17, BA 18, BA 19, BA 22, BA 23, BA 24, BA 29, BA 30, BA 31, BA 32, BA 33, BA 39, BA 40, BA 41, BA 42, BA 43, BA 44, BA 45, BA 46
Pulvinar



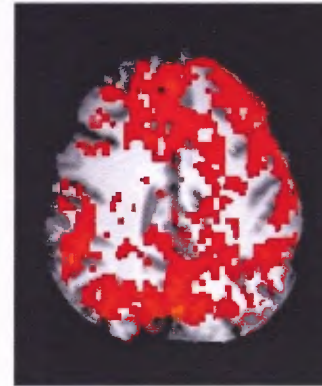
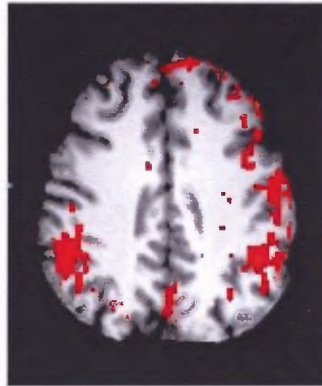
yelda3im86_verg1.jpg

yelda3im86_verg2.jpg

yelda3im86_verg3.jpg

IMAGE#103

BA 1, BA 2, BA 3, BA 4, BA 6, BA 7, BA 8, BA 9, BA 19, BA 24, BA 31, BA 32, BA 39, BA 40
P.S 1-Activation on SMA (supplementary motor area) and BA 23 is observed in vergence 2 and 3 trials, but not in vergence 1 trial.



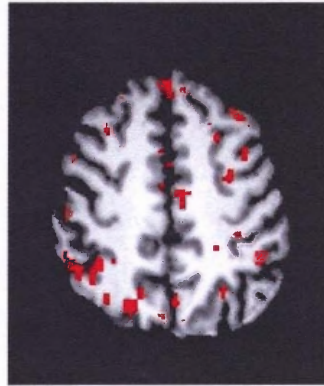
yelda3im103_verg1.jpg

yelda3im103_verg2.jpg

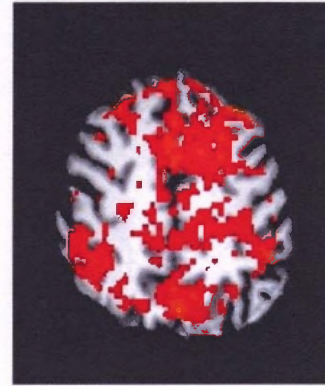
yelda3im103_verg3.jpg

IMAGE#114

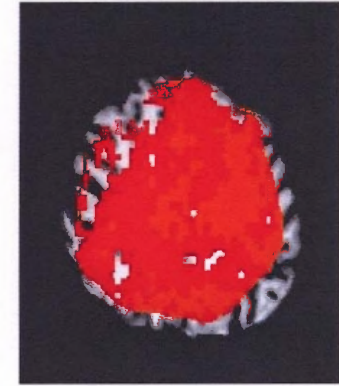
BA 1, BA 2, BA 3, BA 4, BA 5, BA 6, BA 7, BA 8, BA 19, BA 24, BA 31, BA 32, BA 40
SMA (supplementary motor area)



yelda3im114_verg1.jpg



yelda3im114_verg2.jpg



yelda3im114_verg3.jpg

P.S 1-Activation on BA 39 is not observed in vergence 1 trial. But activation on BA 39 is observed vergence 2 and vergence 3 trials.

APPENDIX F

ACTIVATED REGIONS OF SUBJECT 6 FOR SACCADE AND VERGENCE TRIALS

The Appendix F includes the activated regions that belongs to the saccadic and vergence trials for subject 6. The different image numbers are used for clear observation of cortical activation..

Part 1 Saccade Trials for Subject 6 (Data 7)

SUBJECT 6
Threshold:
0.0515

OBSERVED ACTIVATED
AREAS

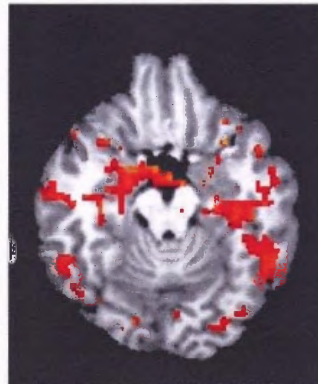
TRIAL1
(SAC1)

TRIAL3
(SAC2)

TRIAL5
(SAC3)

IMAGE#48

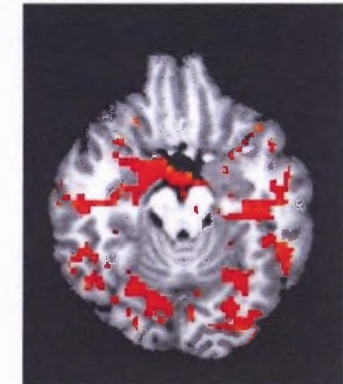
This image is for
observation of activation on
BA 28, BA 36, and BA 35.



yelda4im48_sac1.jpg



yelda4im48_sac2.jpg



yelda4im48_sac3.jpg

IMAGE#58

BA 10, BA 11, BA 13, BA
17, BA 18, BA 19, BA 20,
BA 21, BA 22, BA 24, BA
25, BA 32, BA 34, BA 37,
BA 38, BA 47

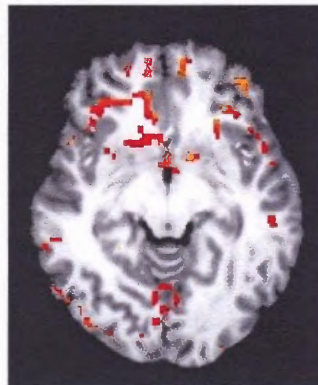
Caudate

Putamen

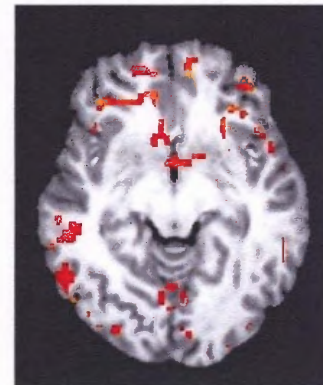
Globus pallidus

P.S

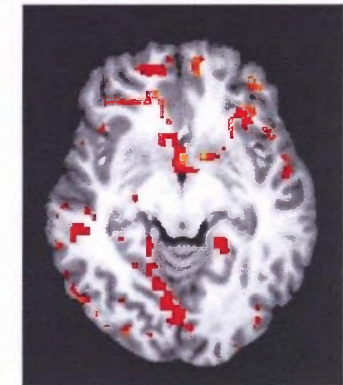
1-Activation on BA 27, 28,
30, 35, and 36 is observed in
saccade 3 trial, not in
saccade 1 and 2 trials.



yelda4im58_sac1.jpg



yelda4im58_sac2.jpg



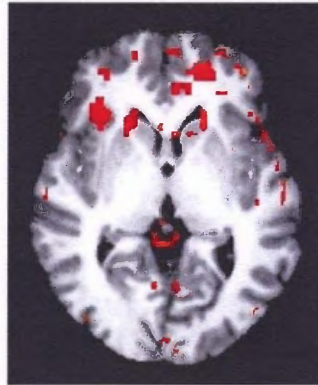
yelda4im58_sac3.jpg

IMAGE#67

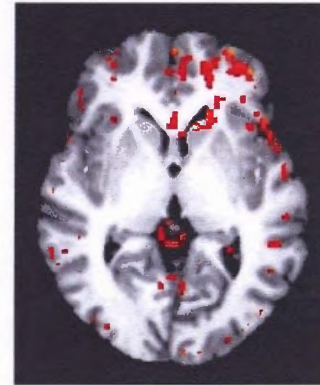
BA 6, BA 10, BA 13, BA 21, BA 22, BA 25, BA 27, BA 30, BA 44, BA 47

P.S

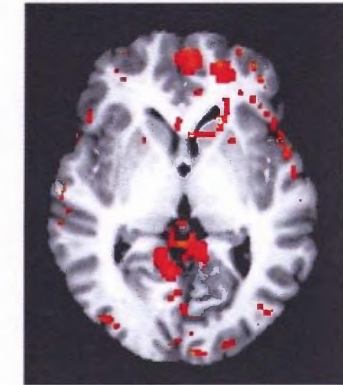
1-Activation BA 24 and 32 is observed in saccade 2 and saccade 3 trials, not in saccade 1 trial.



yelda4im67_sac1.jpg



yelda4im67_sac2.jpg

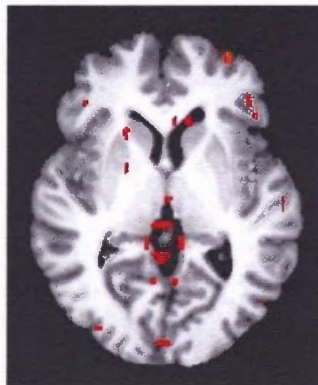


yelda4im67_sac3.jpg

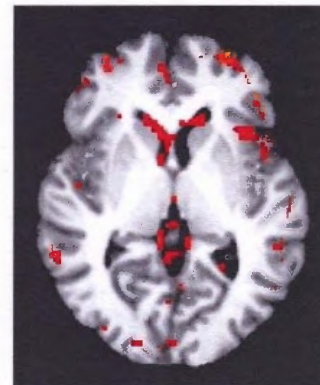
IMAGE#70

BA 6, BA 10, BA 13, BA 17, BA 18, BA 19, BA 21, BA 22, BA 24, BA 27, BA 29, BA 30, BA 37, BA 42, BA 44, BA 45, BA 46, BA 47

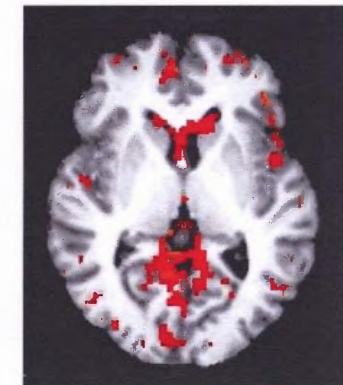
Caudate Putamen
Globus pallidus
Pulvinar



yelda4im70_sac1.jpg



yelda4im70_sac2.jpg



yelda4im70_sac3.jpg

P.S

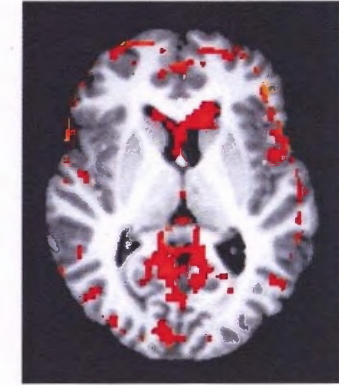
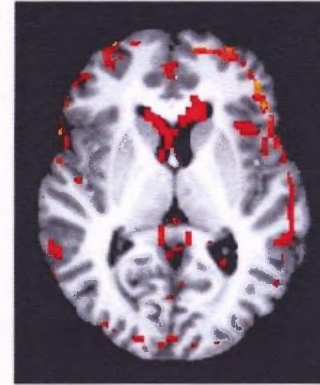
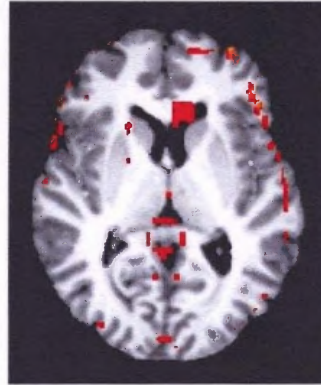
1-Activation on BA 23, 32, 41 is observed in saccade 2 and saccade 3 trials.
2-Activation on BA 25, 39, and, 43 is observed in just saccade 3 trial.

IMAGE#73

BA 6, BA 17, BA 18, BA 19, BA 21, BA 22, BA 23, BA 27, BA 29, BA 30, BA 39, BA 40, BA 41, BA 42, BA 43, BA 45, BA 46

P.S

1-Pulvinar is observed in saccade 2 and 3 trials.



yelda4im73_sac1.jpg

yelda4im73_sac2.jpg

yelda4im73_sac3.jpg

IMAGE#83

BA 1, BA 3, BA 4, BA 9, BA 13, BA 19, BA 22, BA 23, BA 29, BA 30, BA 39, BA 40, BA 41, BA 42, BA 44, BA 45

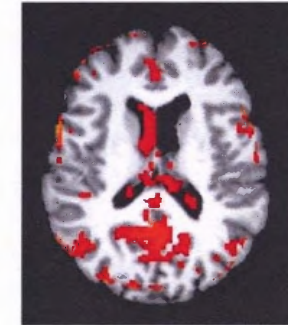
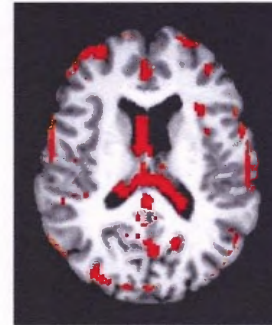
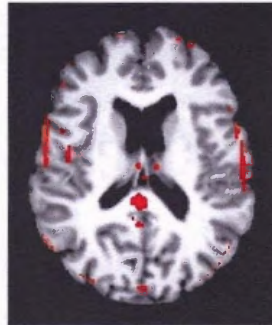
P.S

1-BA 2 is observed in saccade 1 and 2 trials.

2-BA 23 is observed in saccade 3 trial.

3-BA 24 is observed in saccade 1 and 3 trials.

4-BA 31 is observed in saccade 2 and saccade 3 trials.



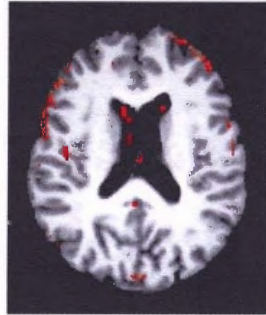
yelda4im83_sac1.jpg

yelda4im83_sac2.jpg

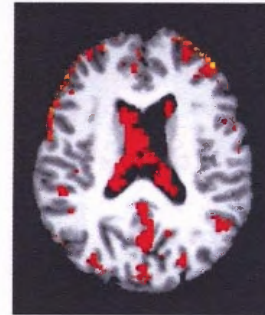
yelda4im83_sac3.jpg

IMAGE#86

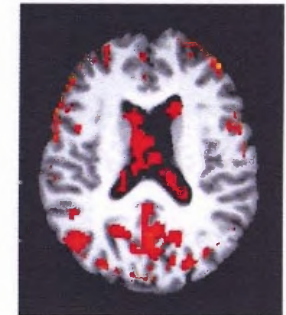
BA 1, BA 3, BA 4, BA 6,
BA 9, BA 10, BA 18, BA
23, BA 24, BA 29, BA 30,
BA 31, BA 32, BA 33, BA
40, BA 41, BA 42, BA 43,
BA 44, BA 45, BA 46



yelda4im86_sac1.jpg



yelda4im86_sac2.jpg



yelda4im86_sac3.jpg

P.S

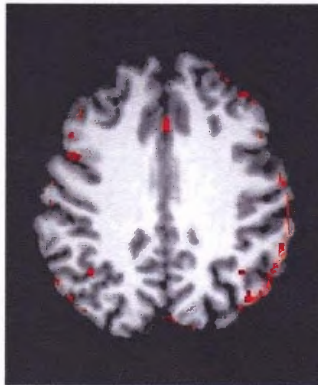
1-Activation BA 13, 19, 22, 39 is observed in saccade 2 and saccade 3 trials.

2-Activation on BA 2 is observed in saccade 3 trial.

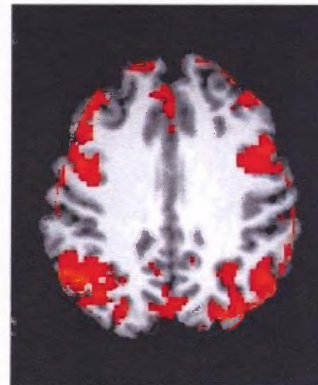
3-Activation on pulvinar is observed in saccade 2 and saccade 3 trials.

IMAGE#103

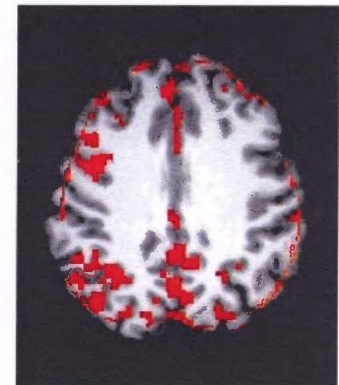
BA 1, BA 2, BA 3, BA 4,
BA 6, BA 7, BA 8, BA 9,
BA 19, BA BA 32, BA 39,
BA 40



yelda4im103_sac1.jpg



yelda4im103_sac2.jpg



yelda4im103_sac3.jpg

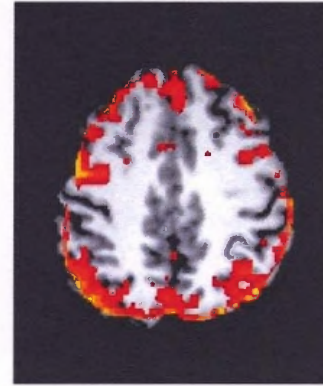
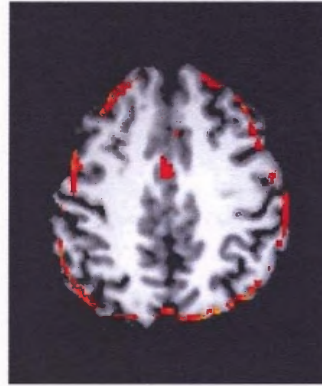
P.S

1-Activation on BA 31 is observed in saccade 2 and saccade 3 trials.

2-Activation on BA 24 is observed in saccade 1 and saccade 3 trials.

3- Activation on BA 23 is observed in saccade 3 trial.

IMAGE#110 This image is for observation of activation on SMA (supplementary motor area).

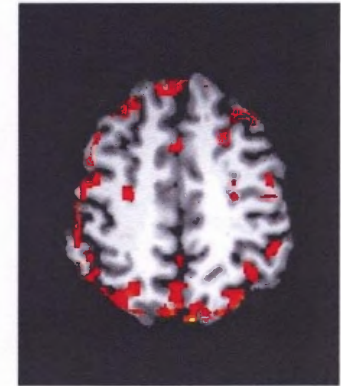
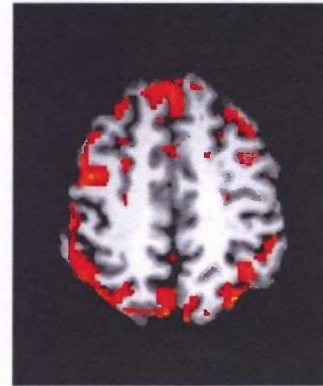
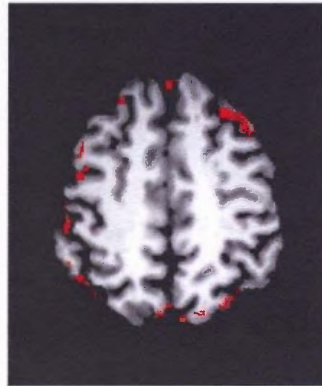


yelda4im110_sac1sma.jpg

yelda4im110_sac2sma.jpg

yelda4im110_sac3sma.jpg

IMAGE#114 BA 1, BA 2, BA 4, BA 6, BA 7, BA 8, BA 19, BA 39, BA 40
P.S
1-Activation on BA 3, 5, 24, 31, 32 and SMA is observed in saccade 2 and saccade 3 trials.

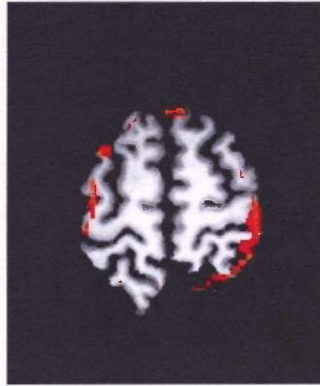


yelda4im114_sac1.jpg

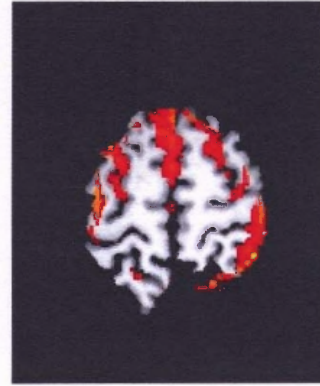
yelda4im114_sac2.jpg

yelda4im114_sac3.jpg

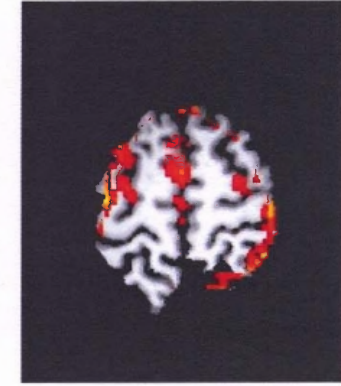
IMAGE#125 This image is for observation of activation on BA 5.



yelda4im125_sac1ba5.jpg



yelda4im125_sac2ba5.jpg



yelda4im125_sac3ba5.jpg

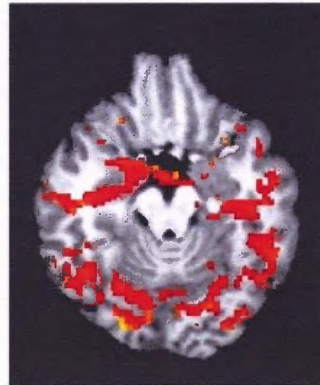
Part 2 Vergence Trials for Subject 6 (Data 7)

SUBJECT 6
 Threshold:
 0.0515
 IMAGE#48

OBSERVED
 ACTIVATED
 AREAS

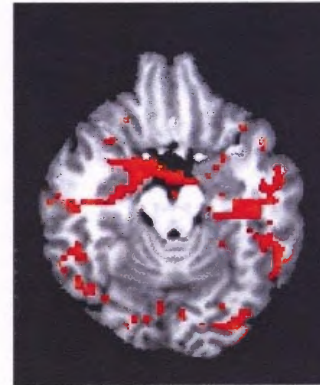
This image is for
 observation of
 activation on BA 28,
 BA 35, and BA 36.

TRIAL2
 (VERG1)



yelda4im48_verg1.jpg

TRIAL4
 (VERG2)



yelda4im48_verg2.jpg

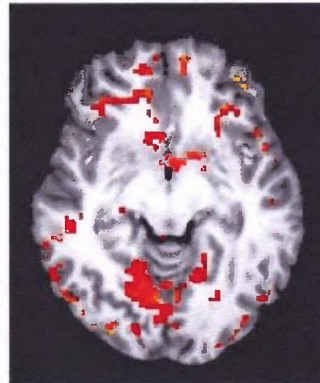
TRIAL6
 (VERG3)



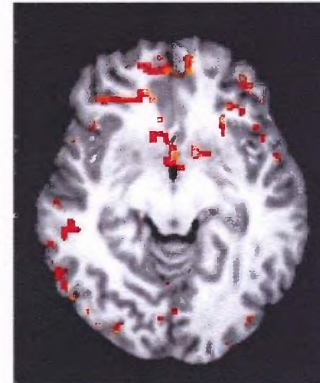
yelda4im48_verg3.jpg

IMAGE#58

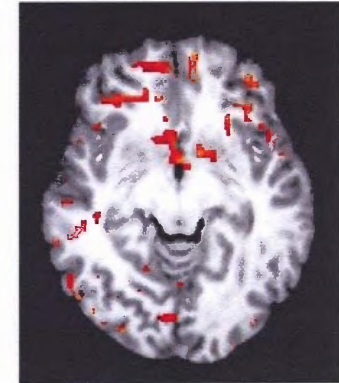
BA 10, BA11, BA 13,
 BA 17, BA 18, BA
 19, BA 20, BA 21,
 BA 22, BA24, BA 25,
 BA 32, BA 34, BA
 37, BA 38, BA 47
 Caudate
 Putamen
 Globus pallidus



yelda4im58_verg1.jpg



yelda4im58_verg2.jpg



yelda4im58_verg3.jpg

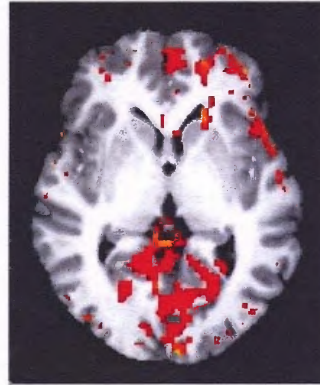
PS.1-Activation on BA 27, 28, 30, 35, 36 is observed in vergence trials 1 and 3, not in vergence 2 trial.

IMAGE#67

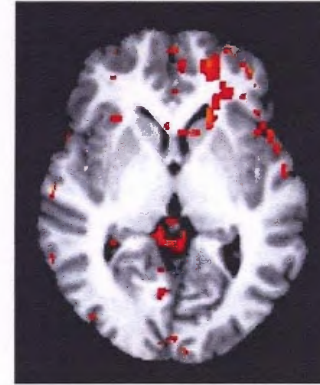
BA 6, BA 10, BA 13,
BA 21, BA 22, BA
24, BA 25, BA 27,
BA 30, BA 44, BA 47

P.S

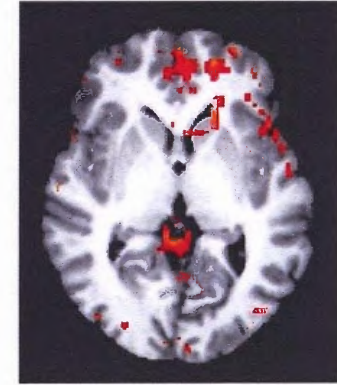
1-Activation on BA
41 is observed in
vergence 1 and
vergence 2 trials.



yelda4im67_verg1.jpg



yelda4im67_verg2.jpg



yelda4im67_verg3.jpg

IMAGE#70

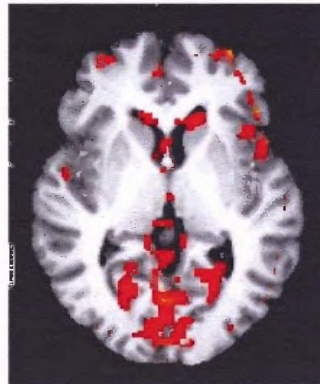
BA 6, BA 10,
BA 13, BA 17, BA
18, BA 19, BA 21,
BA 22, BA 23, BA
24, BA 25, BA 27,
BA 29, BA 30, BA
32, BA 37,
BA 39, BA 41, BA
42, BA 43, BA 44, BA
45, BA 46, BA 47,
Caudate
Pulvinar

P.S

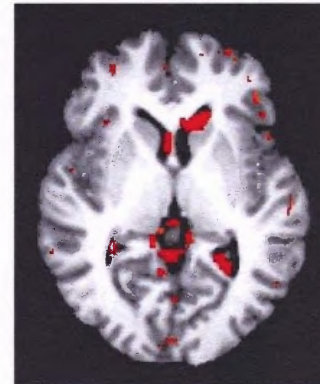
1-Activation on BA 37 is observed in vergence 1 trial.

2-Activation on putamen, BA 23, 41, 42, and 43 is observed in vergence 1 and vergence 2 trials.

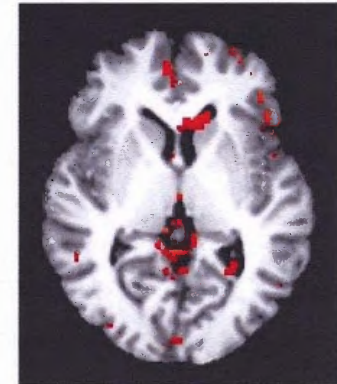
3-Activation on globus pallidus is observed in vergence 1 and vergence 3 trials.



yelda4im70_verg1.jpg



yelda4im70_verg2.jpg



yelda4im70_verg3.jpg

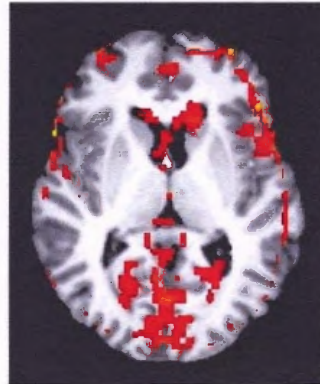
IMAGE#73

BA 6, BA 13, BA 17,
BA 18, BA 19, BA
21, BA 22, BA 23,
BA 27, BA 29, BA
30, BA 39, BA 40,
BA 42, BA 43, BA
44, BA 45, BA 46

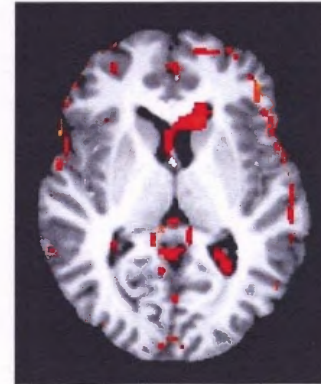
Pulvinar

P.S

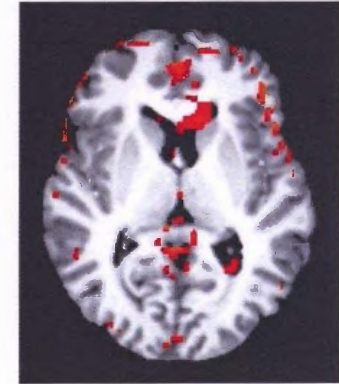
1-Activation BA
31 and 41 is observed
in vergence 1 and
vergence 2 trials.



yelda4im73_verg1.jpg



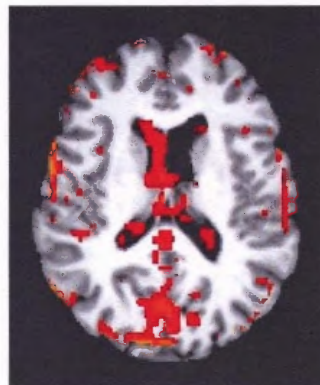
yelda4im73_verg2.jpg



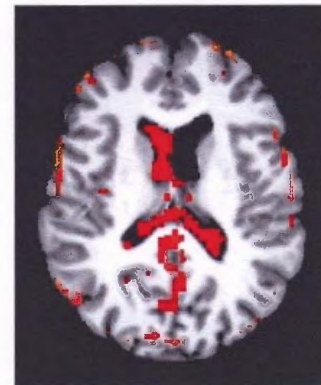
yelda4im73_verg3.jpg

IMAGE#83

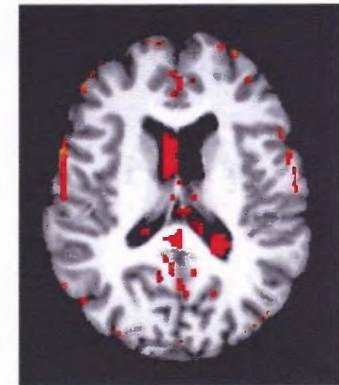
BA 1, BA 3, BA 4,
BA 9, BA 17, BA 18,
BA 19, BA 22, BA
23, BA 24, BA 29,
BA 30, BA 31, BA
32, BA 33, BA 39,
BA 40, BA 41, BA
42, BA 43, BA 44,
BA 45



yelda4im83_verg1.jpg



yelda4im83_verg2.jpg



yelda4im83_verg3.jpg

P.S

1-Activation on BA 2 is observed in vergence 1 and vergence 2 trials.

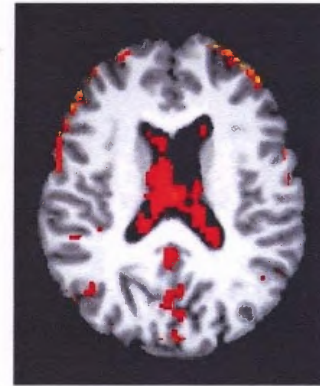
2-Activation on BA 13 is observed in vergence 1 and 2 trials.

IMAGE#86

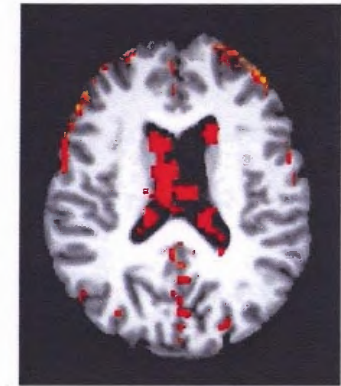
BA 1, BA 3, BA 4,
BA 6, BA 9, BA 10,
BA 13, BA 17, BA
18, BA 19, BA 23,
BA 24, BA 29, BA
30, BA 31, BA 32,
BA 33, BA 39, BA
40, BA 41, BA 42,
BA 43, BA 44, BA
45, BA 46
Pulvinar



yelda4im86_verg1.jpg



yelda4im86_verg2.jpg

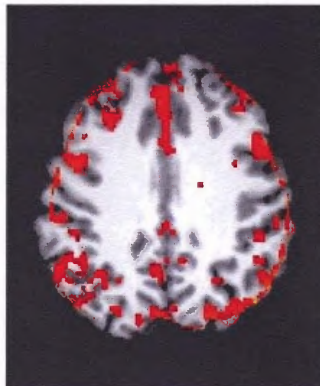


yelda4im86_verg3.jpg

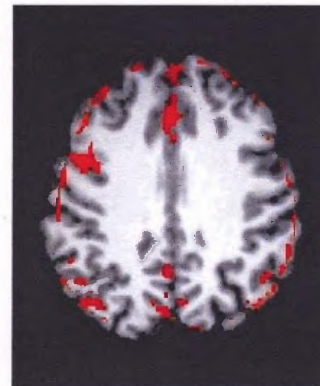
P.S 1-Activation on BA 22 is observed in vergence 1 and vergence 2 trials.

IMAGE#103

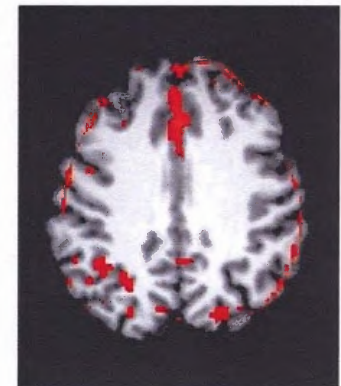
BA 1, BA 2, BA 3,
BA 4, BA 6, BA 7,
BA 8, BA 9, BA 19,
BA 24, BA 31, BA
32, BA 39, BA 40



yelda4im103_verg1.jpg



yelda4im103_verg2.jpg



yelda4im103_verg3.jpg

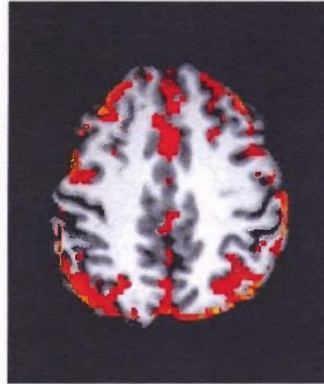
P.S

1-Activation on SMA (supplementary motor area) is observed in vergence 1 and vergence 3 trials.

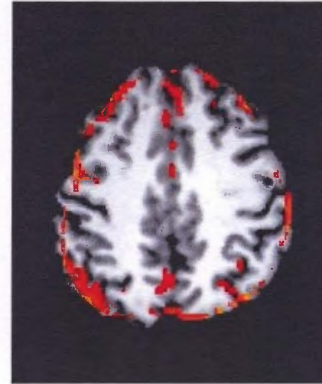
2-Activation on BA 23 is observed in vergence 1 trial

IMAGE#110

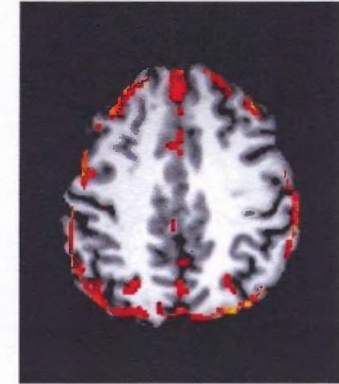
This image is for observation of activation on SMA (supplementary motor area).



yelda4im110_verg1sma.jpg



yelda4im110_verg2sma.jpg



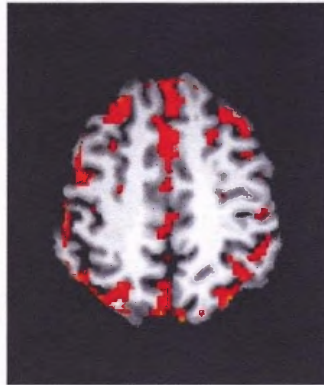
yelda4im110_verg3sma.jpg

IMAGE#114

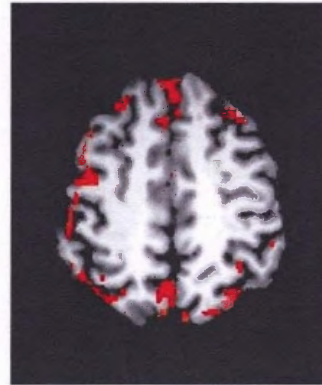
BA 1, BA 2, BA 3, BA 4, BA 6, BA 7, BA 8, BA 19, BA 24, BA 32, BA 39, BA 40 SMA

P.S

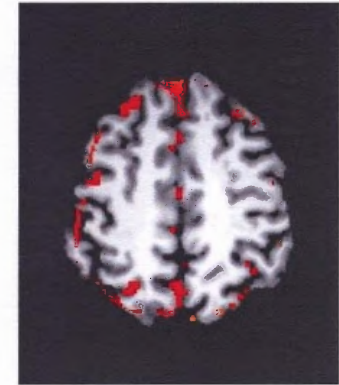
1-Activation on BA 5 and 31 is observed in vergence 1 and vergence 3 trials.



yelda4im114_verg1.jpg



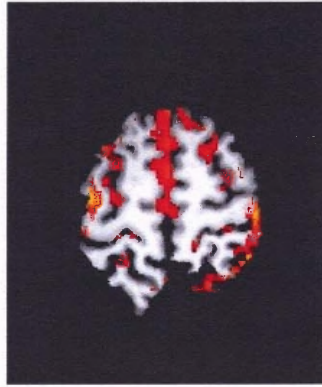
yelda4im114_verg2.jpg



yelda4im114_verg3.jpg

IMAGE#125

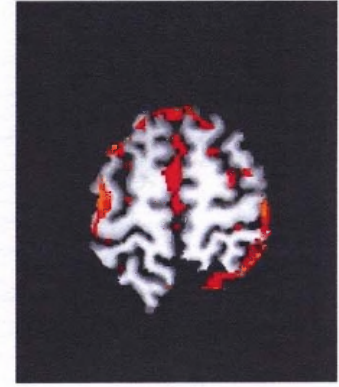
This image is for
observation of
activation on BA 5.



yelda4im125_verg1ba5.jpg



yelda4im125_verg2ba5.jpg



yelda4im125_verg3ba5.jpg

APPENDIX G

ACTIVATED REGIONS OF SUBJECT 7 FOR SACCADE AND VERGENCE TRIALS

The Appendix G includes the activated regions that belongs to the saccadic and vergence trials for subject 7. The different image numbers are used for clear observation of cortical activation..

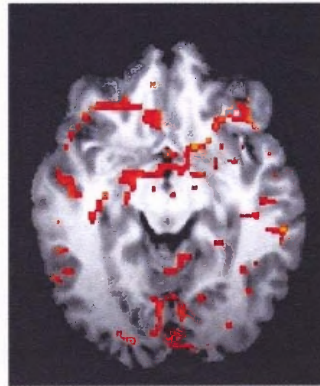
Part 1 Saccade Trials for Subject 7 (Data 5)

SUBJECT 7
Threshold:
0.0515
IMAGE#55

OBSERVED
ACTIVATED AREAS

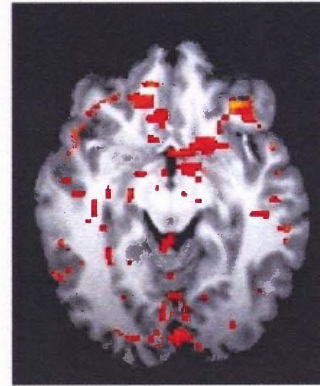
This observation on areas is done for observing clearly activation on BA 28, BA 34, BA 35, and BA 36.

TRIAL1
(SAC1)



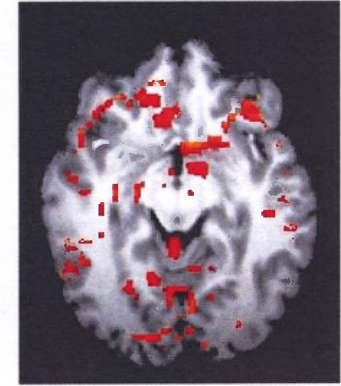
yelda5im55_sac1.jpg

TRIAL3
(SAC2)



yelda5im55_sac2.jpg

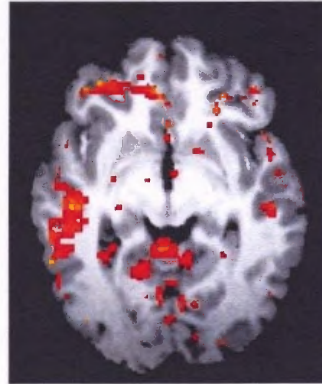
TRIAL5
(SAC3)



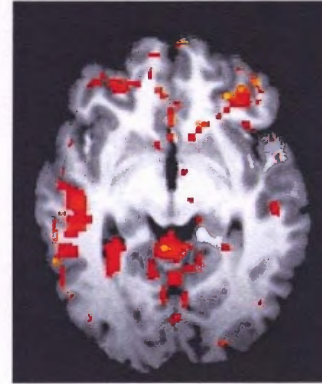
yelda5im55_sac3.jpg

IMAGE#58

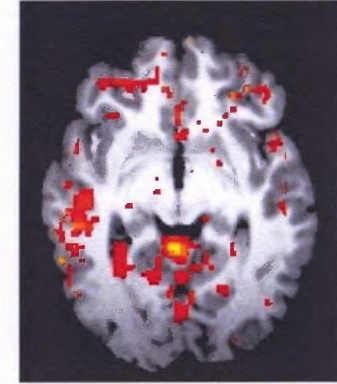
BA 10, BA 11, BA 13,
BA 17, BA 18, BA 19,
BA 20, BA 21, BA 22,
BA 24, BA 25, BA 27,
BA 28, BA 30, BA 32,
BA 34, BA 35, BA 36,
BA 37, BA 38, BA 47
Caudate
Putamen
Globus pallidus



yelda5im58_sac1.jpg



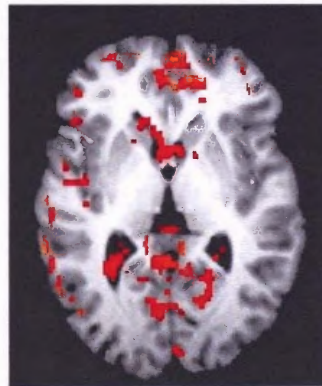
yelda5im58_sac2.jpg



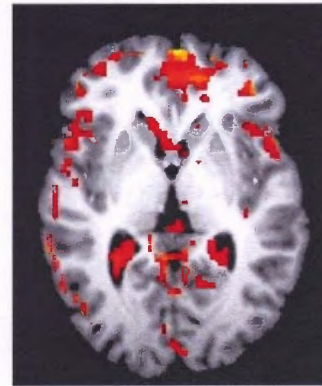
yelda5im58_sac3.jpg

IMAGE#67

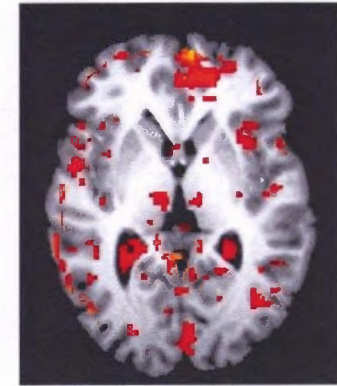
This image is for
observation of activation
on BA 27.



yelda5im67_sac1ba27.jpg



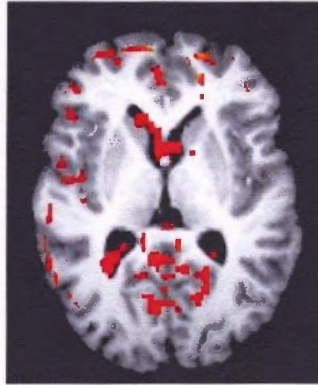
yelda5im67_sac2ba27.jpg



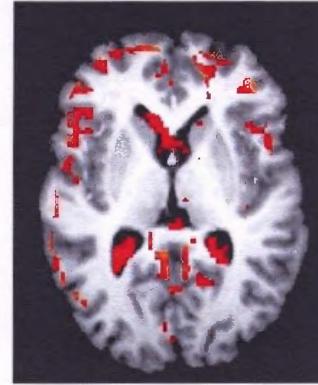
yelda5im67_sac3ba27.jpg

IMAGE#70

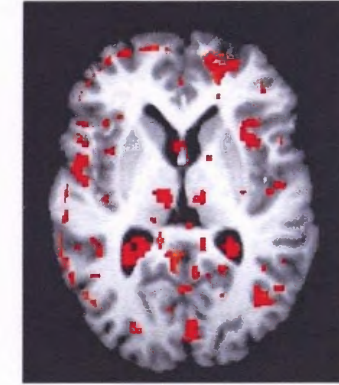
BA 6, BA 10, BA 13,
BA 17, BA 18, BA 19,
BA 21, BA 22, BA 24,
BA 27, BA 29, BA 30,
BA 32, BA 37, BA 39,
BA 41, BA 42, BA 43
BA 44, BA 45, BA 46,
BA 47
Caudate
Putamen
Globus pallidus
Pulvinar



yelda5im70_sac1.jpg



yelda5im70_sac2.jpg

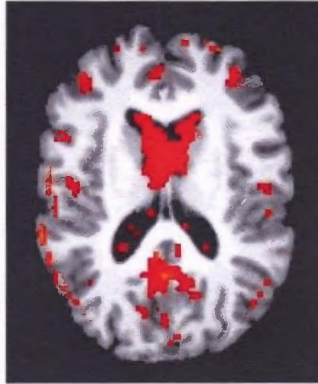


yelda5im70_sac3.jpg

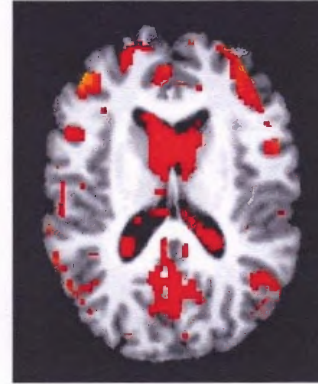
P.S 1-Activation on BA 23 and 25 observed in saccade 1 and saccade 3 trials.

IMAGE#80

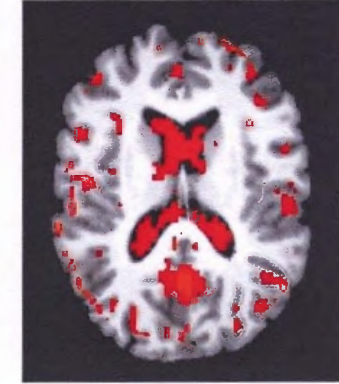
This image is for
observation of activation
on BA 33.



yelda5im80_sac1ba33.jpg



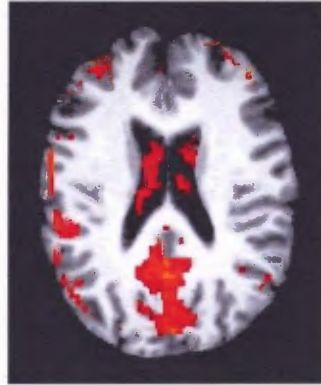
yelda5im80_sac2ba33.jpg



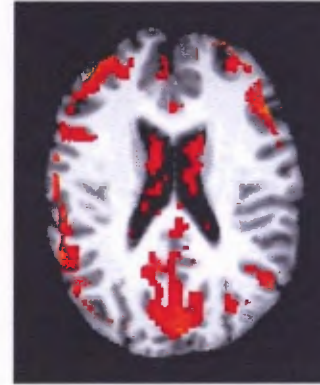
yelda5im80_sac3ba33.jpg

IMAGE#86

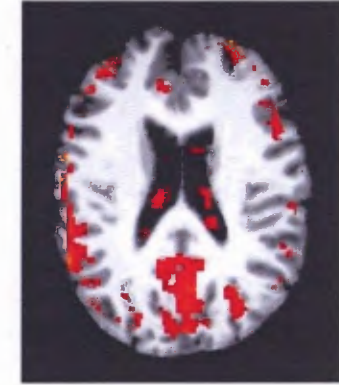
BA 1, BA 2, BA 3, BA 4, BA 6, BA 9, BA 10, BA 13, BA 17, BA 18, BA 19, BA 22, BA 23, BA 24, BA 29, BA 30, BA 31, BA 32, BA 33, BA 39, BA 40, BA 41, BA 42, BA 43, BA 44, BA 45, BA 46
Pulvinar



yelda5im86_sac1.jpg



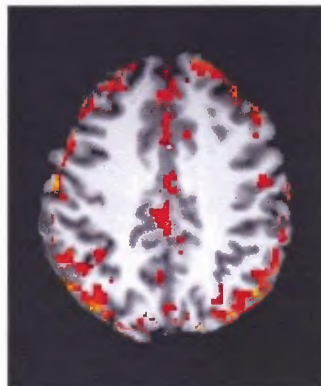
yelda5im86_sac2.jpg



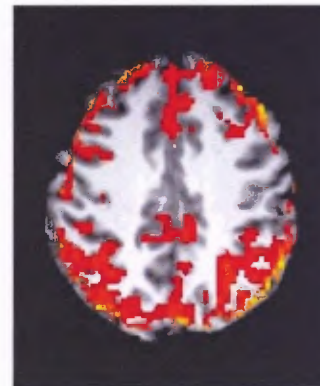
yelda5im86_sac3.jpg

IMAGE#103

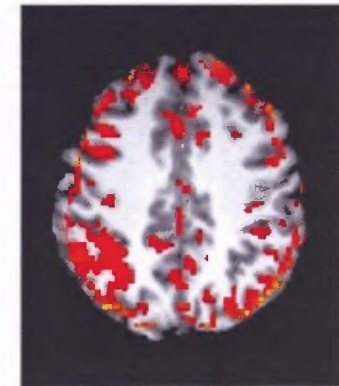
BA 1, BA 2, BA 3, BA 4, BA 6, BA 7, BA 8, BA 9, BA 19, BA 23, BA 24, BA 31, BA 32, BA 39, BA 40
SMA



yelda5im103_sac1.jpg



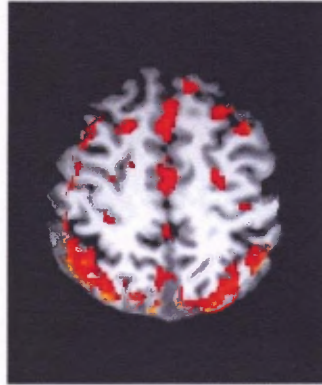
yelda5im103_sac2.jpg



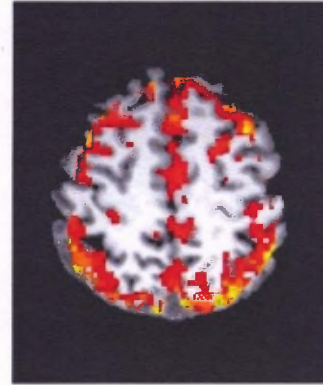
yelda5im103_sac3.jpg

IMAGE#114

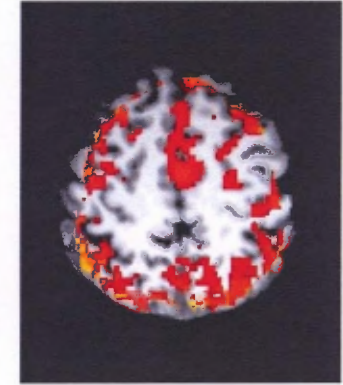
BA 1, BA 2, BA 3, BA 4,
BA 5, BA 6, BA 7,
BA 8, BA 19, BA 24,
BA 31, BA 32, BA 39,
BA 40
SMA



yelda5im114_sac1.jpg



yelda5im114_sac2.jpg



yelda5im114_sac3.jpg

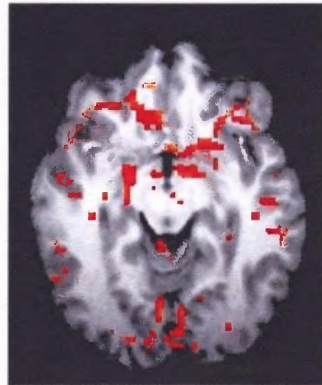
Part 2 Vergence Trials for Subject 7 (Data 5)

SUBJECT 7
 Threshold:
 0.0515
 IMAGE#55

OBSERVED
 ACTIVATED
 AREAS

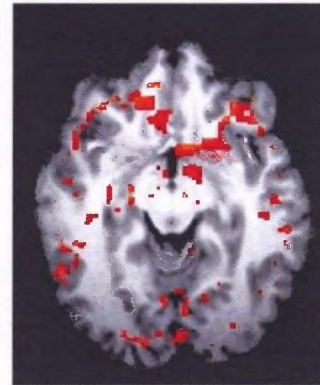
This observation on
 areas is done for
 observing clearly
 activation on BA 28,
 BA 34, BA 35,
 and BA 36.

TRIAL2
 (VERG1)



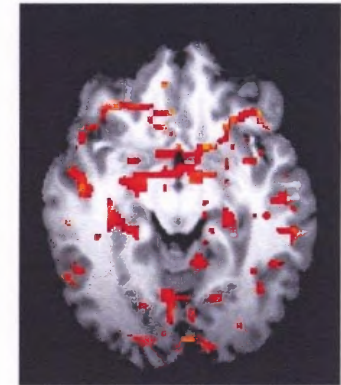
yelda5im55_verg1.jpg

TRIAL4
 (VERG2)



yelda5im55_verg2.jpg

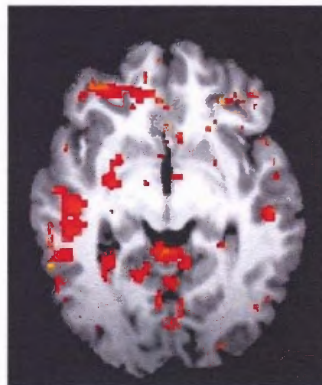
TRIAL6
 (VERG3)



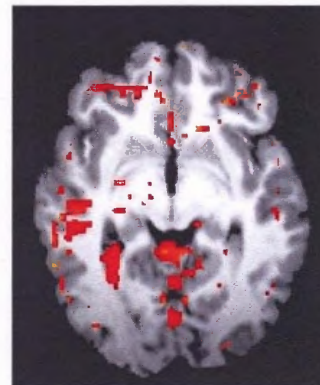
yelda5im55_verg3.jpg

IMAGE#58

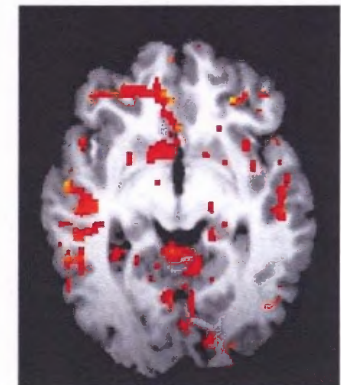
BA 10, BA 11, BA
 13, BA 17, BA 18,
 BA 19, BA 20, BA
 21, BA 22, BA 24,
 BA 25, BA 27, BA
 28, BA 30, BA 32,
 BA 35, BA 36, BA
 37, BA 38, BA 47
 Caudate, Putamen
 Globus pallidus



yelda5im58_verg1.jpg



yelda5im58_verg2.jpg

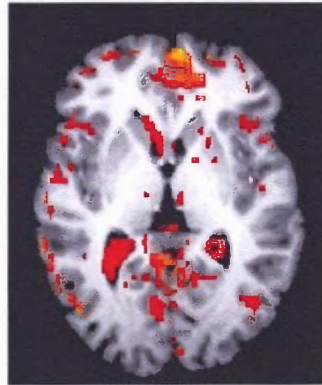


yelda5im58_verg3.jpg

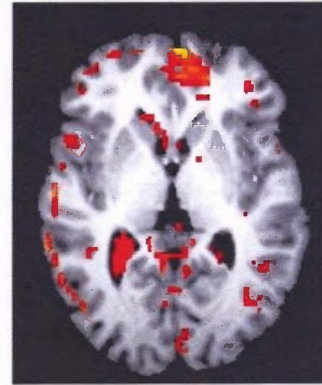
P.S 1-Activation on BA 34 is observed in vergence 1 and vergence 3 trials.

IMAGE#67

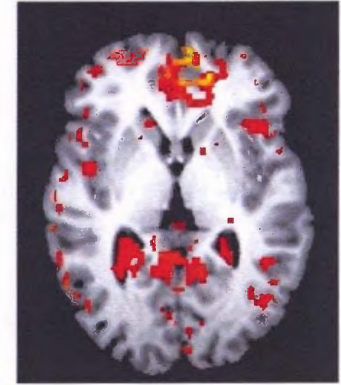
This image is for observation of activation on BA 27.



yelda5im67_verg1ba27.jpg



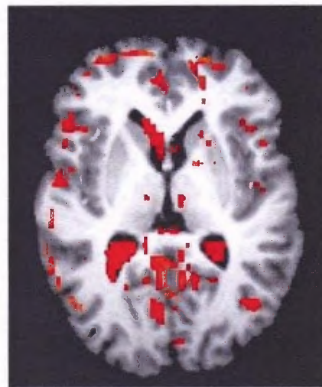
yelda5im67_verg2ba27.jpg



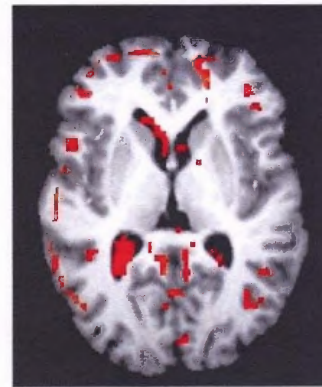
yelda5im67_verg3ba27.jpg

IMAGE#70

BA 6, BA 10, BA 13,
BA 17, BA 18, BA
19, BA 21, BA 22,
BA 23, BA 24, BA
25, BA 27, BA 29,
BA 30, BA 32, BA
37, BA 39, BA 41,
BA 42, BA 43 BA
44, BA 45, BA 46,
BA 47
Caudate
Putamen
Globus pallidus
Pulvinar



yelda5im70_verg1.jpg



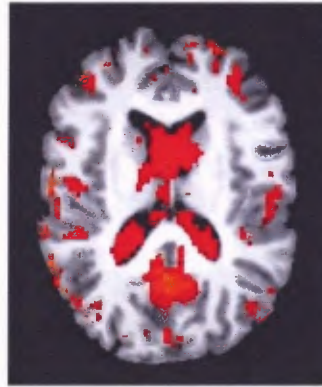
yelda5im70_verg2.jpg



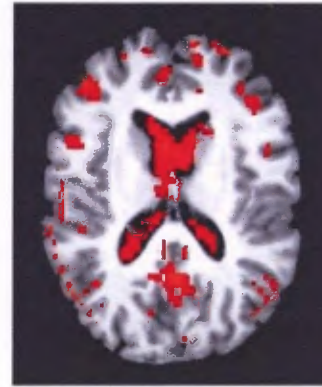
yelda5im70_verg3.jpg

IMAGE#80

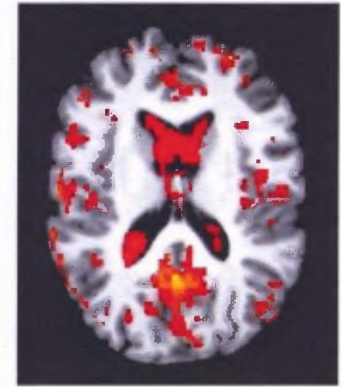
This image is for observation of activation on BA 33.



yelda5im80_verg1ba33.jpg



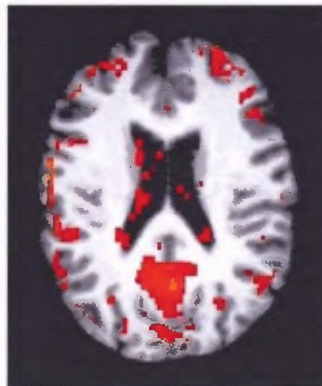
yelda5im80_verg2ba33.jpg



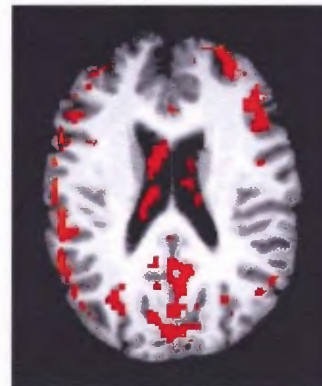
yelda5im80_verg3ba33.jpg

IMAGE#86

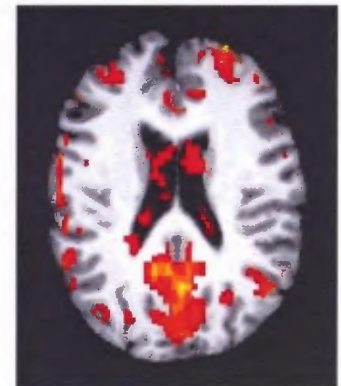
BA 1, BA 2, BA 3,
BA 4, BA 6, BA 9,
BA 10, BA 13, BA
17, BA 18, BA 19,
BA 22, BA 23, BA
24, BA 29, BA 30,
BA 31, BA 32, BA
33, BA 39, BA 40,
BA 41, BA 42, BA
43, BA 44, BA 45,
BA 46
Pulvinar



yelda5im86_verg1.jpg



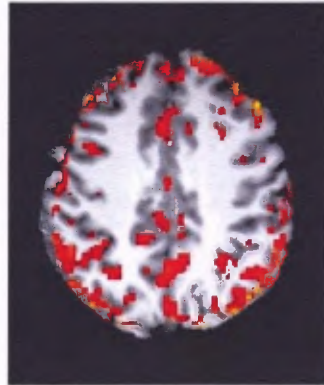
yelda5im86_verg2.jpg



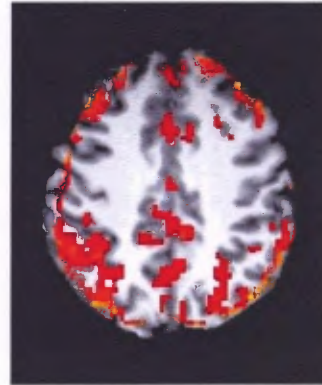
yelda5im86_verg3.jpg

IMAGE#103

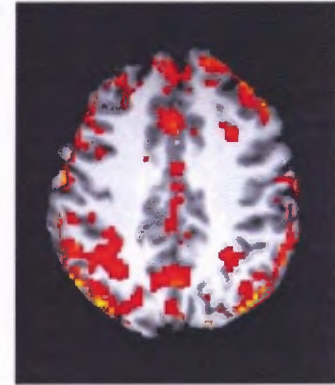
BA 1, BA 2, BA 3,
BA 4, BA 6, BA 7,
BA 8, BA 9, BA 19,
BA 23 BA 24, BA
31, BA 32, BA 39,
BA 40
SMA



yelda5im103_verg1.jpg



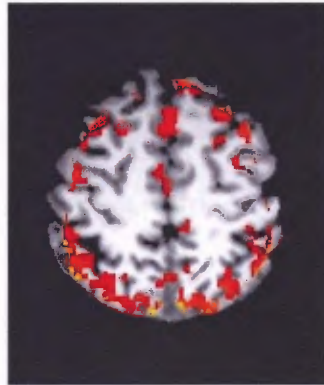
yelda5im103_verg2.jpg



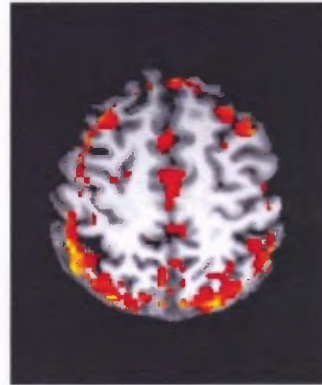
yelda5im103_verg3.jpg

IMAGE#114

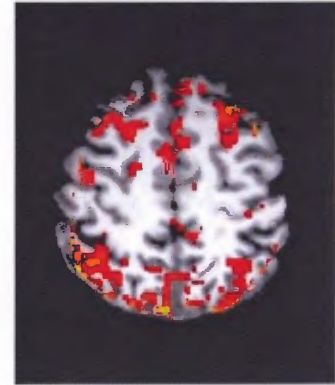
BA 1, BA 2, BA 3,
BA 4, BA 5, BA 6,
BA 7, BA 8, BA 19,
BA 24, BA 31, BA
32, BA 39, BA 40
SMA



yelda5im114_verg1.jpg



yelda5im114_verg2.jpg



yelda5im114_verg3.jpg

APPENDIX H

ACTIVATED REGIONS OF SUBJECT 8 FOR SACCADE AND VERGENCE TRIALS

The Appendix H includes the activated regions that belongs to the saccadic and vergence trials for subject 8. The different image numbers are used for clear observation of cortical activation..

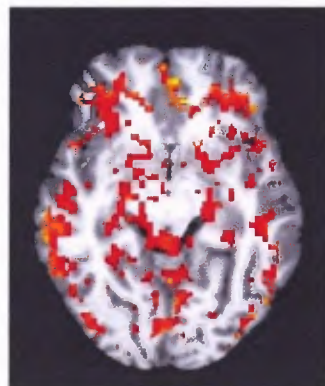
Part 1 Saccade Trials for Subject 8

SUBJECT 8
 Threshold:
 0.0515
 IMAGE#58

OBSERVED
 ACTIVATION AREAS

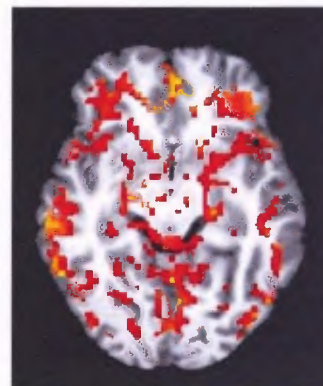
BA 10, BA11, BA 13, BA
 17, BA 18, BA 19, BA 20,
 BA 21, BA 22, BA 24,
 BA 25, BA 27, BA 28,
 BA 30, BA 32, BA 34,
 BA 35, BA 36, BA 37,
 BA 38, BA 47
 Caudate,
 Putamen,
 Globus pallidus

TRIAL1
 (SAC1)



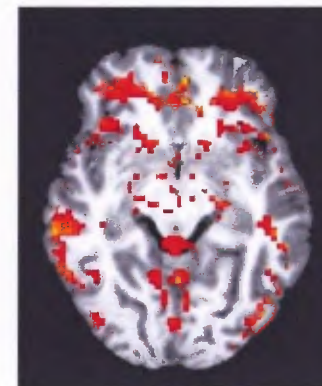
yelda8im58_sac1.jpg

TRIAL3
 (SAC2)



yelda8im58_sac2.jpg

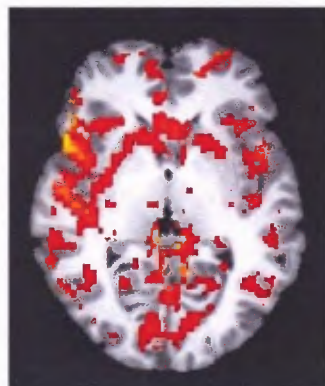
TRIAL5
 (SAC3)



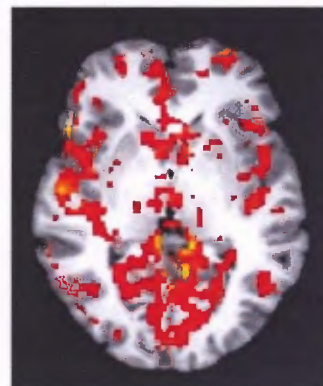
yelda8im58_sac3.jpg

IMAGE#70

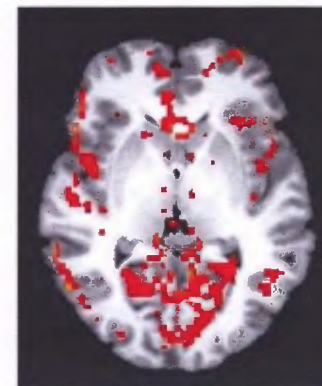
BA 6, BA 10, BA 13, BA
 17, BA 18, BA 19, BA 21,
 BA 22, BA 23, BA 24,
 BA 25, BA 27, BA 29,
 BA 30, BA 32, BA 37,
 BA 39, BA 41, BA 42,
 BA 43, BA 44, BA 45,
 BA 47
 Caudate
 Putamen
 Globus pallidus
 Pulvinar



yelda8im70_sac1.jpg



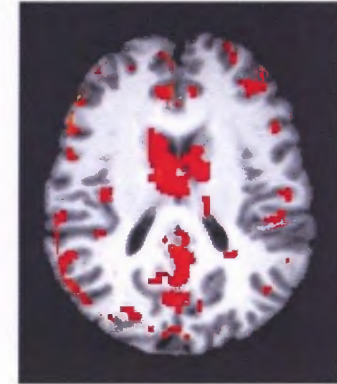
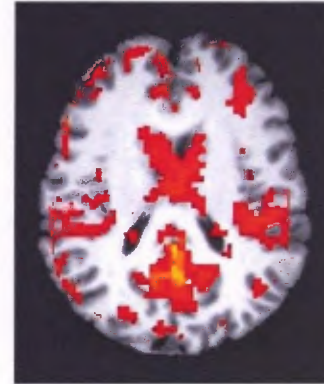
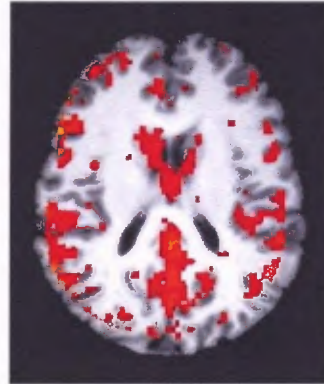
yelda8im70_sac2.jpg



yelda8im70_sac3.jpg

IMAGE#86

BA 1, BA 2, BA 3, BA 4,
BA 6, BA 9, BA 10, BA
13, BA 17, BA 18, BA 19,
BA 22, BA 23, BA 24,
BA 29, BA 30, BA 31,
BA 32, BA 33, BA 39,
BA 40, BA 41, BA 42,
BA 44, BA 45, BA 46
Pulvinar



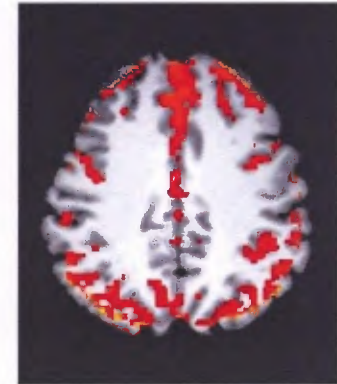
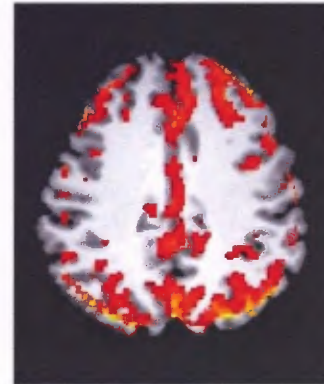
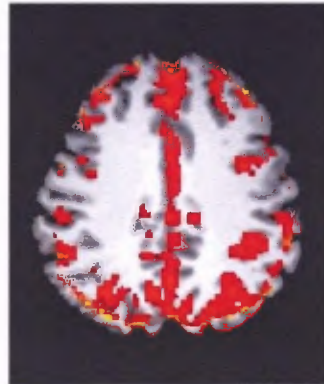
yelda8im86_sac1.jpg

yelda8im86_sac2.jpg

yelda8im86_sac3.jpg

IMAGE#103

BA 1, BA 2, BA 3, BA 4,
BA 6, BA 7, BA 8, BA 9,
BA 19, BA 23, BA 24,
BA 31, BA 32, BA 39,
BA 40
SMA (supplementary
motor area)



yelda8im103_sac1.jpg

yelda8im103_sac2.jpg

yelda8im103_sac3.jpg

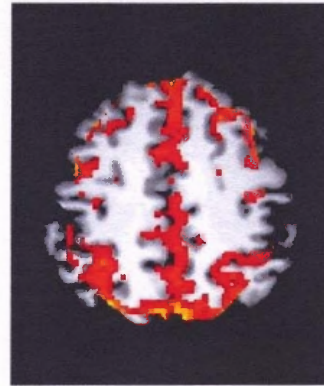
IMAGE#114

BA 3, BA 4, BA 5, BA 6,
BA 7, BA 8, BA 19, BA
24, BA 31, BA 32, BA 39,
BA 40

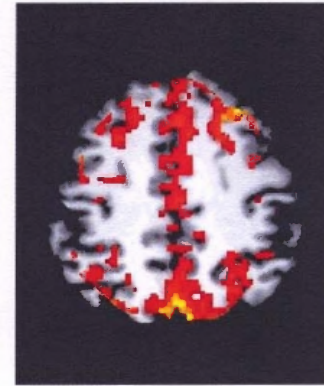
P.S

1-Activation on BA 1 is
observed in saccade 1
trial.

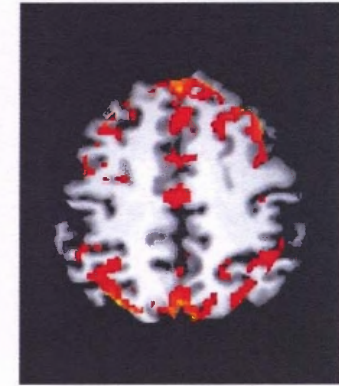
2-Activation on BA 2 is
observed in saccade 1 and
saccade 2 trials.



yelda8im114_sac1.jpg



yelda8im114_sac2.jpg



yelda8im114_sac3.jpg

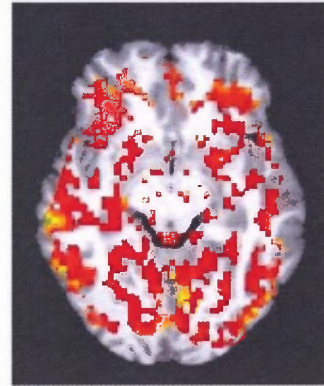
Part 2 Vergence Trials for Subject 8

SUBJECT 8
Threshold:
0.0515
IMAGE#58

OBSERVED
ACTIVATED AREAS

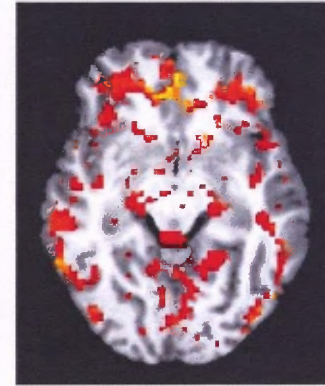
BA 10, BA11, BA 13,
BA 17, BA 18, BA 19,
BA 20, BA 21, BA 22,
BA 25, BA 27, BA 28,
BA 30, BA 34, BA 35,
BA 36, BA 37, BA 38,
BA 47
Caudate,
Putamen,
Globus pallidus

TRIAL 2
(VERG 1)



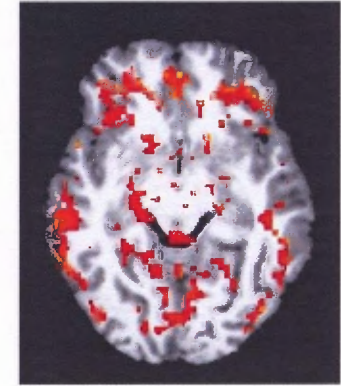
yelda8im58_verg1.jpg

TRIAL 4
(VERG2)



yelda8im58_verg2.jpg

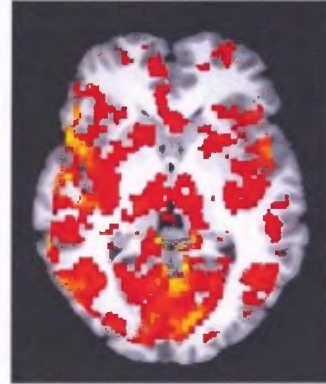
TRIAL 6
(VERG3)



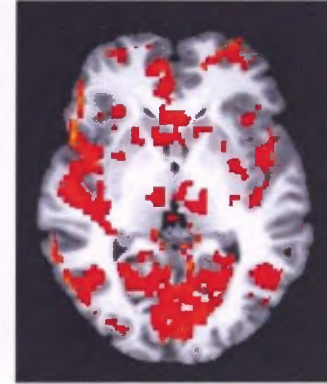
yelda8im58_verg3.jpg

IMAGE#70

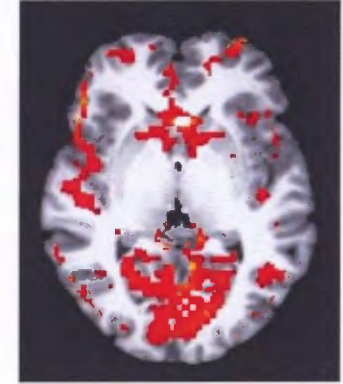
BA 6, BA 10, BA 13, BA 17, BA 18, BA 19, BA 21, BA 22, BA 23, BA 24, BA 25, BA 27, BA 29, BA 30, BA 32, BA 37, BA 39, BA 41, BA 42, BA 43, BA 44, BA 45, BA 47
Caudate,
Putamen,
Globus pallidus
Pulvinar



yelda8im70_verg1.jpg



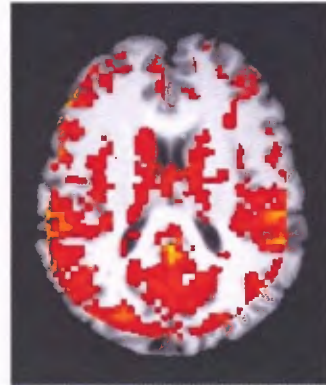
yelda8im70_verg2.jpg



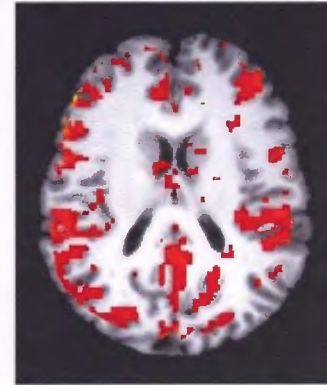
yelda8im70_verg3.jpg

IMAGE#86

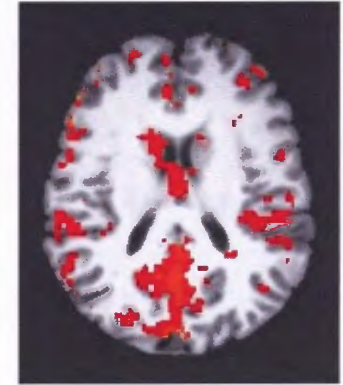
BA 1, BA 2, BA 3, BA 4, BA 6, BA 9, BA 10, BA 13, BA 17, BA 18, BA 19, BA 22, BA 23, BA 24, BA 29, BA 30, BA 31, BA 32, BA 33, BA 39, BA 40, BA 41, BA 42, BA 43, BA 44, BA 45, BA 46



yelda8im86_verg1.jpg



yelda8im86_verg2.jpg

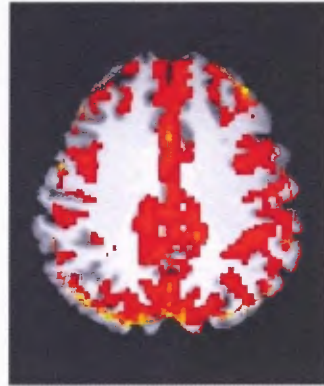


yelda8im86_verg3.jpg

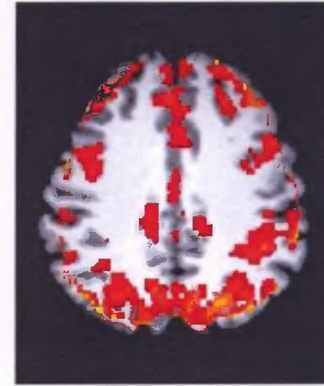
P.S 1-Activation on pulvinar is observed in vergence 1 and vergence 2 trials.

IMAGE#103

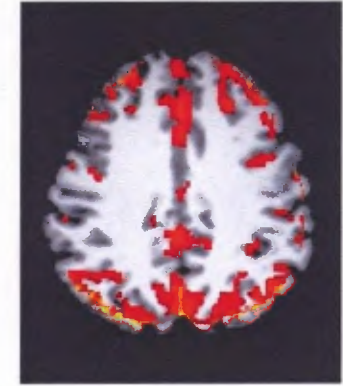
BA 1, BA 2, BA 3, BA 4,
BA 6, BA 7, BA 8, BA 9,
BA 19, BA 23, BA 24,
BA 31, BA 32, BA 39,
BA 40
SMA (supplementary
motor area)



yelda8im103_verg1.jpg



yelda8im103_verg2.jpg



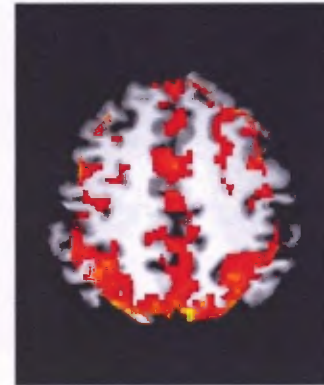
yelda8im103_verg3.jpg

IMAGE#114

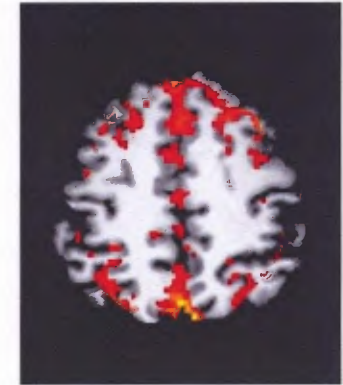
BA 3, BA 4, BA 5, BA 6,
BA 7, BA 8, BA 19, BA
24, BA 31, BA 32, BA
39, BA 40
SMA
P.S
1-Activation on BA 1 and
BA 2 is observed in
vergence1 and vergence 2
trials.



yelda8im114_verg1.jpg



yelda8im114_verg2.jpg



yelda8im114_verg3.jpg

APPENDIX I

BASIC COMMAND LINES FROM AFNI

PART 1

Example command line used in analysis of subject's eight data just for trial 1

```
to3d -time:zt 80 1 2s alt+z MPrage/Image000*
```

```
to3d -geoparent ANAT+orig -prefix MPRAGE -time:zt 80 1 2s Mprage/Image000*
```

```
to3d -geoparent ANAT+orig. -prefix sub8data8 -time:zt 32 70 2s alt+z  
TRIAL1/Image000*
```

```
cd TRIAL 1
```

```
to3d -time:zt 32 70 2s alt+z Image000*
```

After this point, motion correction is applied by going from Define Datamode to Plugins and from there to 3dRegistration, lastly motion corrected file is formed.

```
3dDetrend -prefix DMC-sub8may31data8sac1 -polort 2 MC-sub8may31data8sac1+orig
```

```
3dcalc -a MC-sub8may31data8sac1+orig[0] -expr '(step(a-300))' -prefix  
Masksub8may31datasac1
```

```
3dTotalMean -input DMC-sub8may31data8sac1+orig -p_thr 0.1 -delB 4 -zfirst 0 -zlast  
31 -mask Masksub8may31data8sac1+orig. -bucket AMasksub8may31dat8sac1+orig -  
out All
```

Talairach Transformation

```
3dSkullStrip -input MPRAGE+orig -o_ply NewMprage
```

```
@auto_tlrc -base TT_N27+tlrc -input NewMprage+orig
```

```
@auto_tlrc -apar NewMprage_at+tlrc -input AMasksub8may31dat8sac1+orig
```

MASKING PART

```
3dcalc -a ../cut1im140sub1may15+tlrc -b AMasksub8may31dat8sac1_at+tlrc -expr  
'(a*b)' -prefix denememaskedsac1_data8
```

PART 2**Example average calculations of saccadic trials for eight subjects**

```
3dcalc -a avge8_sac1+tlrc -expr '(a/8)' -prefix meanavge8_sac1
```

```
3dcalc -a avge8_sac2+tlrc -expr '(a/8)' -prefix meanavge8_sac2
```

```
3dcalc -a avge8_sac3+tlrc -expr '(a/8)' -prefix meanavge8_sac3
```

```
3dcalc -a meanavge8_sac1+tlrc -b meanavge8_sac2+tlrc -c meanavge8_sac3+tlrc -expr '(a+b+c)/3' -prefix meanavge8_totalsac
```

PART 3**Example of Boolean Algebra for saccadic trials (AND GATE)**

```
3dcalc -a meanavge8_totsac+tlrc -b meanavge8_totverg+tlrc -expr '(and(a,b))' -prefix ANDofmeanavge_sacVSverg
```

Example of Boolean Algebra for saccadic trials (OR GATE)

```
3dcalc -a meanavge8_totsac+tlrc -b meanavge8_totverg+tlrc -expr '(or(a,b))' -prefix ORofmeanavge_sacVSverg
```

The command line for observing activated regions just for saccades

```
3dcalc -a meanavge8_totsac+tlrc -b meanavge8_totverg+tlrc -expr '(step(a-0.10)-and(step(a-0.10), step(b-0.10)))' -prefix SAC-ANDofmeanavge_sacVSvergT10
```

Example of Command Line for Summation of saccade trials

```
3dcalc -a meanavge8_sac1+tlrc -b meanavge8_sac2+tlrc -c meanavge8_sac3+tlrc -expr '(and(step(a-0.05), step(b-0.05), step(c-0.05)))' -prefix ANDsacAVGt05
```

Two other optional ways of Boolean Algebra for saccades**AND GATE**

```
3dcalc -a meanavge8_totalsac+tlrc -b meanavge8_totalverg+tlrc -expr '(and(step(a-0.05), step(b-0.05)))' -prefix ANDofmeanavge8_totalsacVSvergT05
```

Saccades only

```
3dcalc -a meanavge8_totalsac+tlrc -b meanavge8_totalverg+tlrc -expr '(step(a-0.05)-  
and(step(a-0.05), step(b-0.05)))' -prefix SAC-ANDofmeanavge8_totalsacVSvergT05
```

APPENDIX J

CODE FOR MATLAB SECTION OF THE THESIS

Part 1 Calculation of pixel value for cropped area

```
threshold=0.58;
FMRI = imread('yelda7im55_sac3.jpg');
figure(1), imshow(FMRI), title('fabric');

trial_1=FMRI;
%trial_1=totsac_data8_barea4_axial;
%imshow(trial_1);
cform=makecform('srgb2lab');
lab_trial=applycform(trial_1,cform);

%imshow(lab_trial);
a=lab_trial(:,:,2);
%imshow(a);

%-----change to binary image-----
level = graythresh(a);
BW = im2bw(a,threshold);
figure
imshow(BW);

%-----calaulate the area-----
[X Y]=ginput(1);
X1=floor(X);
Y1=floor(Y);
seed=[X1 Y1]
region_th=0;
stopn=1000;
I_image=BW;

[my_map,area]=regiongrow_you(I_image,seed,region_th,stopn);
hold on
plot(my_map(:,2),my_map(:,1),'r.')

Xmax=max(my_map(:,2));
Xmin=min(my_map(:,2));
Ymax=max(my_map(:,1));
Ymin=min(my_map(:,1));
```

```
Boundary=BW(Ymin:Ymax,Xmin:Xmax);
```

```
figure
imshow(Boundary)
area
area_total=length(find(Boundary==1))
```

Part 2 Region Growing Technique (Tracing of Boundaries)

```
function [my_map,area]=regiongrow(I_image,seed,region_th,stopn)

O_image = I_image;
% put seed into queue
[row,col]=size(O_image)
xseed = seed(1);
yseed = seed(2);
pixel_seed = I_image(yseed,xseed);
queue = [yseed xseed];
top = 1;
my_index = 0;
area = 1;

region_matrix = ones(row,col);
region_matrix(yseed,xseed) = 0; % if region_matrix is the same, mark 1 else mark 0

% search the area
region_count = 1; % manufacture a convergence region
while top~=0 % when queue label has no label, stop loop
    % find the bottom label from queue
    row_bottom = queue(1,1); %yseed
    col_bottom = queue(1,2); %xseed
    pixel_bottom = O_image(row_bottom,col_bottom);
    % according this label as seed, judge pixel that arround the image belong the same
    region
    regionedge = 0;
    % assume a judge regionedge
    for i=-1:1
        for j=-1:1
```

```

    if row_bottom+i<=row & row_bottom+i>0 & col_bottom+j<=col &
col_bottom+j>0 %the click point is within the range of the image

        if abs(I_image(row_bottom+i,col_bottom+j)-pixel_bottom) == region_th &
region_matrix(row_bottom+i,col_bottom+j)~=0
            % if the interval between pixel = region_th, it's the same region
            top = top+1;
            area = area+1;

            queue(top,:) = [row_bottom+i col_bottom+j];
            region_matrix(row_bottom+i,col_bottom+j) = 0;
            O_image(row_bottom+i,col_bottom+j) = 1;
        end

        if region_matrix(row_bottom+i,col_bottom+j) == 1

            regionedge = 1;

            if my_index == 0
                my_map = [row_bottom+i col_bottom+j];
                my_index = my_index+1;

            else
                my_map=[my_map;row_bottom+i col_bottom+j];
                my_index = my_index+1;

            end
        end
    else
        regionedge = 1; % judge regionedge
        if my_index == 0
            my_map = [row_bottom+i col_bottom+j];
            my_index = my_index+1;
        else
            my_map=[my_map;row_bottom+i col_bottom+j];
            my_index = my_index+1;
        end
    end

end

end
end

if regionedge~=1

```

```
    O_image(row_bottom,col_bottom) = I_image(yseed,xseed);  
end  
  
% delete the finish convergence label from queue  
  
queue = queue(2:top,:);  
top = top-1;  
end  
% O_image(yseed,xseed) = 0.5; % set seed pixel 0.5
```

REFERENCES

- Anatomy of the Human Eye, (2001). Retrieved October 2007, from <http://teachhealthk-12.uthscsa.edu/curriculum/vision-hearing/pa06pdf/0601LSN.pdf>
- Anderson, A., Richard, Snyder, H., Lawrence, Bradley, C., David, Xing, Jing, (1997). Multimodal Representation of Space in the Posterior Parietal Cortex and its use in planning movements, *Annual Review of Neuroscience*, 20, 303-330.
- Anderson, J. T., Jenkins, I. H., J. D., Brooks, Hawken, B. M., Frackowiak, J. S. R., Kennard, C., (1994). Cortical control of saccades and fixation in man A PET study, *Brain*, 117, 1073-1084.
- An Eye Into Vision: Anatomy and Eye. Retrieved October 2007, from <http://library.thinkquest.org/27940/anatomy/>
- Aphasia. Retrieved September 2007, from <http://en.wikipedia.org/wiki/Aphasia>
- Berthoz, Alain, (1997). Parietal and hippocampal contribution to topokinetic and topographic memory, *The Royal Society Biological Sciences*, 352, 1437-1448.
- Binkofski, F., Fink, G. R., Geyer, S., Buccino, G., Gruber, O., Shah, J. N., Taylor, G. J., Seitz, J. R., Zilles, K., Freund, J. H., (2002). Neural Activity in Human Primary Motor Cortex Areas 4a and 4p Is Modulated Differentially by Attention to Action, *The Journal of Neurophysiology*, 88, 514-519.8.
- Bremner, Douglas, J., Vythilingam, Meena, Vermetten, Eric, Nazeer, Ahsan, Adil, Jahangir, Khan, Sarfraz, Staib, H., Lawrence, Charney, S., Dennis, (2002). Reduced volume of orbitofrontal cortex in major depression, *Biological Psychiatry*, 51, 273-279.
- Brodmann area 10. Retrieved September 2007, from http://en.wikipedia.org/wiki/Brodmann_area_10
- Brodmann area 11. Retrieved September 2007, from http://en.wikipedia.org/wiki/Brodmann_area_11
- Brodmann area 22. Retrieved September 2007 from http://en.wikipedia.org/wiki/Brodmann_area_22
- Brodmann's area 25. Retrieved September 2007, from http://www.sylvius.com/index/b/brodmann_s_area_25.html
- Brodmann's area 33. Retrieved September 2007, from http://www.sylvius.com/index/b/brodmann_s_area_33.html

- Brodmann area 35. Retrieved September 2007, from http://en.wikipedia.org/wiki/Brodmann_area_35
- Brodmann area 36. Retrieved September 2007, from http://en.wikipedia.org/wiki/Brodmann_area_36
- Brodmann's area 38. Retrieved September 2007, from http://www.sylvius.com/index/b/brodmann_s_area_38.html
- Brodmann's area 39. Retrieved September 2007, from http://www.sylvius.com/index/b/brodmann_s_area_39.html
- Brodmann area 39. Retrieved September 2007, from http://en.wikipedia.org/wiki/Brodmann_area_39
- Brodmann area 40. Retrieved September 2007, from http://en.wikipedia.org/wiki/Brodmann_area_40
- Brodmann's area 40. Retrieved September 2007, from http://www.sylvius.com/index/b/brodmann_s_area_40.html
- Brodmann's area 41. Retrieved September 2007, from http://www.sylvius.com/index/b/brodmann_s_area_41.html
- Brodmann's area 42. Retrieved September 2007, from http://www.sylvius.com/index/b/brodmann_s_area_42.html
- Bushara, O., Khalafalla, Weeks, A., Robert, Ishii, Kenji, Catalan, Jose-Maria, Tian, Biao, Rauschecker, P., Josef, Hallett, Mark, (1999). Modality-specific frontal and parietal areas for auditory and visual spatial localization in humans, *Nature Neuroscience*, 2, 759-766.
- Cassin, B. and Solomon, S., Dictionary of Eye Terminology. Ciliary Body. Retrieved October 2007, from http://en.wikipedia.org/wiki/Ciliary_body
- Castelli, Fulvia, Happé Francesca, Frith, Uta, Frith, Chris, (2000). Movement and Mind: A Functional Imaging Study of Perception and Interpretation of Complex Intentional Movement Patterns, *NeuroImage*, 12, 314-325.
- Colby, L., Carroll, Olson, R., Carl (2003). In Spatial Cognition. In Squire, R., Larry, Bloom, E., Floyd, McConnell, K., Susan, Roberts, L., James, Spitzer, C., Nicholas, Zigmond, J., Michael (Eds.), *Fundamental Neuroscience* (2nd ed.), (pp. 1229-1246). Academic Press, San Diego, California
- Corneal Limbus. Retrieved October 2007, from http://en.wikipedia.org/wiki/Corneal_limbus

- Courtney, M., Susan, Ungerleider, G., Leslie, (1997). What fMRI has taught us about human vision, *Current Opinion in Neurobiology*, 7, 554-561.
- Crane, Joelle, Milner, Brenda, (2005). What went where? Impaired object-location learning in patients with right hippocampal lesions, *Hippocampus*, 15, 216-231
- Culham, Jody, fMRI for newbies. Retrieved August 2007, from <http://psychology.uwo.ca/fmri4newbies/>
- Daftari, A.P., Alvarez, T.L., Chua, F.B. Semmlow, J.L., Pedrono, C, (2004). A LabVIEW Program for the Stimulation of a Vergence Open-Loop Response. Bioengineering Conference, proceedings of the IEEE 30 th Annual Northeast.
- Denis, Michel, Logie, H., Robert, Cornoldi, Cesare, Vega de, Manuel, Engelkamp, Johannes, (2001). Imagery, Language, and Visuo-Spatial Thinking. Retrieved September 2007, from http://www.limsi.fr/Individu/denis/I_L_et_VS_Think_2001_8.htm
- Deseilligny-Pierrot, Charles, Müri, M., Nyffeler, T., Milea, Dan, (2005). The role of the human dorsolateral prefrontal cortex in ocular motor behavior, *Annals of the New York Academy of Sciences*, 1039, 239-251.
- Deseilligny-Pierrot, C., Müri, M. R., Ploner, J. C., Gaymard, B., Demeret, S., Rivaud-Péchoux, S., (2003). Decisional Role of the dorsolateral prefrontal cortex in ocular motor behaviour, *Brain*, 126, 1-14
- Deseilligny-Pierrot, C., Israël, I., Berthoz, A., Rivaud, S., Gaymard, B., (1993). Role of the different frontal lobe areas in the control of the horizontal component of memory-guided saccades in man, *Experimental Brain Research*, 95(1), 166-171.
- Deseilligny-Pierrot, Charles, Müri, M., René, Rivaud-Pechoux, Sophie, Gaymard, Bertrand, Ploner, J., Christoph (2002). Cortical Control of Spatial Memory in Humans : The visuoculomotor Model. *Annals of Neurology*, 52, 10-19.
- Deseilligny-Pierrot, C., Milea, Dan, Müri, M., René, (2004). Eye movement control by the cerebral cortex, *Current Opinion in Neurology*, 17, 17-25.
- Dorland's Illustrated Medical Dictionary (30th ed.), (2000), p. 806. Saunders, Philadelphia, PA 19106
- Dreher, Claude-Jean, Grafman, Jordan, (2002). The roles of the cerebellum and basal ganglia in timing and error prediction, *European Journal of Neuroscience*, 16, 1609-1619.

- Ettinger U., Kumari V., Chitnis X.A., Corr P.J., Sumich A.L., Rabe-Hesketh S., Crawford T.J., Sharma T, (2002). Relationship between brain structure and saccadic eye movements in healthy humans, *Neuroscience Letters*, 328, 225-228.
- Forss, Nina, Jousmäki, Veikko, (1998). Sensorimotor integration in human primary and secondary somatosensory cortices, *Brain Research*, 781, 259-267.
- Galuske, W. A., Ralf, Schlote, Wolfgang, Bratzke, Hansjürgen, Singer, Wolf, (2000). Interhemispheric Asymmetries of the Modular Structure in Human Temporal Cortex, *Science*, 289, 1946-1949.
- Gamlin, P., Paul, Yoon, Kyunghye, (2000). An area for vergence eye movement in primate frontal cortex, *Nature*, 407, 1003-1007.
- Garey, J., Laurence, (2006). Brodmann's localization in the cerebral cortex (3rd ed.), (pp 105-126). Springer Science and Business Media, New York
- Gaymard, B., Ploner, J. C., Rivaud-Péchoix, S., Pierrot-Deseilligny, C., (1999). The frontal eye field is involved in spatial short-term memory but not in reflexive saccade inhibition, *Experimental Brain Research*, 129(2), 288-301.
- Glimcher, W., Paul. (2003). Eye Movements. In Squire, R., Larry, Bloom, E., Floyd, McConnell, K., Susan, Roberts, L., James, Spitzer, C., Nicholas, Zigmond, J., Michael (Eds.), *Fundamental Neuroscience* (2nd ed.), (pp. 873-892). Academic Press, San Diego, California
- Goebel, Rainer, Muckli, Lars & Kim, Dae-shik (2004). Visual System. In Paxinos, George, Mai, K., Jürgen (Eds.), *The Human Nervous System* (2nd ed.), (pp. 1280-1305). San Diego, California: Elsevier Academic Press.
- Grézes, J., Decety, J., (2002). Does visual perception of object afford action? Evidence from aneuroimaging study, *Neuropsychologia*, 40, 212-222.
- Hagen, C., Matthew, Franzén, Ove, McGlone, Francis, Essick, Greg, Dancer, Christopher, Pardo, V., José, (2002). Tactile motion activates the human middle temporal/V5 (MT/V5) complex, *European Journal of Neuroscience*, 16, 957-964.
- Hampson, Michelle CA, Olson, Ingrid R., Leung, Hoi-Chung, Skudlarski, Pawel, Gore, John C., (2004). Changes in functional connectivity of human MT/V5 with visual motion input, *Neuroreport*, 15, 1315-1319.
- Hanakawa, Takashi, Immisch, Ilka, Toma, Keisichiro, Dimyan, A., Michael, Gelderen, Van Peter, Hallett, Mark, (2002). Functional Properties of Brain Areas Associated with Motor Execution and Imagery, *Journal of Neurophysiology*, 89, 989-1002.

- Hari, R., Forss, N., Avikainen, S., Kirveskari, E., Salenius, S., Rizzolatti, G., (1998). Activation of human primary motor cortex during action observation: A neuromagnetic study, *Neurobiology*, 95, 15061-15065.
- Hikosaka, Okihide, Takikawa, Yoriko, Kawagoe, Reiko, (2000). Role of the Basal Ganglia in the Control of Purposive Saccadic Eye Movements, *Physiological Reviews*, 80, 953-978.
- Holdstock, S. J., Dr., (2005). The role of the human medial temporal lobe in object recognition and object discrimination, *The Quarterly Journal of Experimental Psychology Section B*, 58, 326-339.
- Horizontal Cells. Retrieved October 2007, from <http://www.answers.com/topic/horizontal-cell>
- Horwitz, Barry, Tagamets, M-A., McIntosh, Randal, Anthony, (1999). Neural modeling, functional brain imaging, and cognition, *Trends in Cognitive Sciences*, 3, 91-98.
- Howstuffworks, Extraocular muscles. Retrieved October 2007, from <http://static.howstuffworks.com/gif/vision3.gif>
- Huettel, A., Scott, Song, W., Allen, McCarthy, Gregory, (2004). Functional Magnetic Resonance Imaging, Sinauer Associates, Inc.
- Husain, Masut, Christopher, Kennard, (1996). Visual neglect associated with frontal lobe infarction, *Journal of Neurology*, 243, 652-657.
- Iacoboni, Marco, Woods, P., Roger, Lenzi, Luigi, Gian, Mazziotta, C., John (1997). Merging of oculomotor and somatomotor space coding in the human right precentral gyrus, *Brain*, 120, 1635-1645.
- Ivry, B., Richard, Spencer, MC., Spencer, (2004). The neural representation of time, *Current Opinion in Neurobiology*, 14, 225-232.
- Jancke, L., Mirzazade, S., Joni, Shah, N., (1999). Attention modulates activity in the primary and the secondary auditory cortex: a functional magnetic resonance imaging study in human subjects, *Neuroscience Letters*, 266, 125-128.
- Jueptner, J., Jueptner, M., Jenkins, H. I., Brooks, J. D., Frackowiak, J. S. R., Passingham, E. R., (1996). The sensory guidance of movement: a comparison of the cerebellum and basal ganglia, *Experimental Brain Research*, 112, 462-474.
- Kaas, H., Jon (2004). Somatosensory System. In Paxinos, George, Mai, K., Jürgen, The Human Nervous System (pp. 1059-1092). San Diego, California: Elsevier Academic Press

- Kalaska, F., John, Scott, H., Stephen, Cisek, Paul, Sergio, E., Lauren, (1997). Cortical control of reaching movements, *Current Opinion in Neurobiology*, 7, 849-859.
- Káldy, Zsuzsa, Sigala, Natasha, (2004). The neural mechanisms of object working memory: what is where in the infant brain?, *Neuroscience and Biobehavioral Reviews*, 28, 113-121.
- Kandel, R., Eric, Schwartz, H., James, Jessel, M., Thomas (2000). Principles of Neural Science (4th ed.). McGraw-Hill Companies
- Keenan, M., Kyle, (2007). Visual Pathway. Retrieved October 2007, from <http://artsci.shu.edu/biology/Student%20Pages/Kyle%20Keenan/eye/optpthway.html>
- Knox, C., Paul, (2007). The parameters of eye movements. Retrieved October 2007, from <http://www.liv.ac.uk/~pcknox/teaching/Eymovs/params.htm>
- Kwong, K., Kenneth, Belliveau, W., John, Chesler, A., David, Goldberg, E., Inna, Weisskoff, M., Robert, Pancelet, P., Brigitte, Kennedy, N., David, Hoppel, E., Bernica, Cohen, S., Mark, Turner, Robert, Cheng, Ming-Hong, Brady, J., Thomas, Rosen, R., Bruce, (1992). Dynamic Magnetic resonance imaging of human brain activity during primary sensory stimulation, *Neurobiology*, 89, 5675-5679.
- Lamm, Clauss, Windischberger, Christian, Leodolter, Ulrich, Moser, Ewald, Bauer, Herbert (2001). Evidence for Premotor Cortex Activity during Dynamic Visuospatial Imagery from Single-Trial Functional Magnetic Resonance Imaging and Event-Related Slow Cortical Potentials, *NeuroImage*, 14, 268-283
- Lee, C. H., Andy, Bandelow, Stephen, Schwarzbauer, Henson, A. N., Richard, Graham, S., Kim, (2006). Perirhinal cortex activity during visual object discrimination: An event-related fMRI study, *NeuroImage*, 33, 362-373.
- Lewis, W., James, Beauchamp, S., Michael, De Yoe, A., Edgar, (2000). A Comparison of Visual and Auditory Motion Processing in Human Cerebral Cortex, *Cerebral Cortex*, 10, 873-888.
- MacDonald, W., Angus, Cohen, D., Jonathan, Stenger, Andrew, V., Carter, S., Cameron, (2000). Dissociating the Role of the Dorsolateral Prefrontal and Anterior Cingulate Cortex in Cognitive Control, *Science*, 288, 1835-1838
- Maddock, J. R., Garret, S. A., Buonocore, H. M., (2001). Remembering familiar people: The posterior cingulate cortex and autobiographical memory retrieval, *Neuroscience*, 104, 667-676.

- Malmivuo, Jaakko, Plonsey, Robert, (1995). The electric signal originating in the eye (Chapter 28). In *Principles and Application of Bioelectric and Biomagnetic Fields* Oxford University Press. Retrived October 2007, from <http://butler.cc.tut.fi/~malmivuo/bem/bembook/>
- Martinez, A., Anllo-Vento, L., Sereno, I. M., Frank, R. L., Buxton, B. R., Dubowitz, J. D., Wong, C. E., Hincrichs, H., Heinze, J. H., Hillyard, A. S., (1999). Involvement of striate and extrastriate visual cortical areas in spatial attention, *Nature Neuroscience* , 2, 364-369.
- Melcher, David, Morrone, Conetta, M, (2003). Spatiotopic temporal integration of visual motion across saccadic eye movements, *Nature Neuroscience*, 6, 877-881.
- Milea, Dan, Label, Elie, Lehericy, Stéphane, Deseilligny-Pierrot, Charles, Berthoz, Alain, (2005). Cortical Mechanisms of Saccade Generation from Execution to Decision. *Annals of the New York Academy of Sciences*, 1039, 232-238.
- Miller, K., Earl, Wallis, Jonathan (2003). *In The Prefrontal Cortex and Executive Brain Functions*. In Squire, R., Larry, Bloom, E., Floyd, McConnell, K., Susan, Roberts, L., James, Spitzer, C., Nicholas, Zigmond, J., Michael.Eds.), *Fundamental Neuroscience* (2nd ed.), (pp. 1353-1376). Academic Press, San Diego, California
- Mima, Tatsuya, Nagamina, Takashi, Nakamura, Kaori, Shibasaki, Hiroshi, (1998). Attention Modulates Both Primary and Second Somatosensory Cortical Activities in Humans: A Magnetoencephalographic Study, *The Journal of Neurophysiology*, 80, 2215-2221.
- Mink, W., Jonathan. (2003). The Basal Ganglia. *In Squire, R., Larry, Bloom, E., Floyd, McConnell, K., Susan, Roberts, L., James, Spitzer, C., Nicholas, Zigmond, J., Michael. (Eds.), Fundamental Neuroscience* (2nd ed.), (pp. 816-839). Academic Press, San Diego, California
- Miyashita, Yasushi, Hayashi, Toshihiro, (2000). Neural representation of visual objects: encoding and top-down activation, *Current Opinion in Neurobiology*, 10, 187-194.
- Montgomery, M., Ted. *Anatomy, Physiology and Pathology of The Human Eye- The extra ocular Muscles*. Retrieved October 2007, from http://www.tedmontgomery.com/the_eye/eom.html
- Morris, Renée,& Petrides, Michael, & Pandya, N., Deepak, (1999). Architecture and connections of retrosplenial area 30 in the rhesus monkey (macaca mulatta), *European Journal of Neuroscience*, 11, 2506-2518.

- Mottaghy, M. F., Gangitano, M., Sparing, R., Krause, J. B., Leone-Pascual, A., (2002). Segregation of Areas Related to Visual Working Memory in the Prefrontal Cortex Revealed by rTMS, *Cerebral Cortex*, 12, 369-375.
- Munoz, P., Semmlow, J.L., Alvarez, T.L., Weihong Yuan, (1997). Short -Term Adaptation in disparity vergence-eye movements. Engineering in Medicine and Biology Society, proceedings of the 19 th Annual International Conference of the IEEE, 6, 2803-2806
- Murray, A., Elisabeth, Richmond, J., Barry, (2001). Role of perirhinal cortex in object perception, memory, and associations, *Current Opinion in Neurobiology*, 11, 188-193.
- Nelson, Ralph. Visual Responses of Ganglion Cells. Retrieved October 2007, from <http://webvision.med.utah.edu/GCPHYS1.HTM>
- Nolte, John (2002). *The Human Brain* (5th ed.). Mosby, Inc. An affiliate of Elsevier, St. Louis, Missouri 63146
- Okuda J.; Fujii T.; Yamadori A.; Kawashima R.; Tsukiura T.; Fukatsu R.; Suzuki K.; Ito M.; Fukuda H., (1998). Participation of the prefrontal cortices in prospective memory: evidence from a PET study in humans, *Neuroscience Letters*, 253, 127-130.
- Oliver, T., Robyn, Schill-Thompson, L., Sharon, (2003). Dorsal stream activation during retrieval of object size and shape, *Cognitive, Affective, & Behavioral Neuroscience*, 3, 309-322.
- Olk, Bettina, Chang, Erik, Kingstone, Alan, Ro, Tony, (2006). Modulation of Antisaccades by Transcranial Magnetic Stimulation of the Human Frontal Eye Field. *Cerebral Cortex*, 16(1), 76-82.
- Parry, A., Matthews, M. P. Functional magnetic resonance imaging (fMRI): A “window” into the brain, The Oxford University.
- Paulus, P., Martin, Feinstein, S., Justin, Leland, David, Alan, N., Simmons, (2005). Superior temporal gyrus and insula provide response and outcome-dependent information during assessment and action selection in a decision-making situation, *NeuroImage*, 2005, 25, 607-615.
- Perry, J. R., Zeki, S., (2000). The neurology of saccades and covert shifts on spatial attention: an event-related fMRI study, *Brain*, 123, 2273-2288.
- Petit, Laurent, Orssaud, Christophe, Tzourio, Nathalie, Crivello, Fabrice, Berthoz, Alain, Mazoyer, Bernard, (1996). Functional Anatomy of a Prelearned Sequence of Horizontal Saccades in Humans, *The Journal of Neuroscience*, 16, 3714-3726.

- Petrides, Michael, & Pandya, N., Deepak (2004). The Frontal Cortex. In Paxinos, George, Mai, K., Jürgen (Eds.), *The Human Nervous System* (pp. 950-972). San Diego, California: Elsevier Academic Press
- Philipps, L., Mary, Drevets, C., Wayne, Rauch, L., Scott, Lane, Richard, (2003). Neurobiology of emotion perception I: the neural basis of normal emotion perception, *Biological Psychiatry*, 54, 504-514.
- Ranpura, Ashish. The Anatomy of Vision. Retrieved October 2007, from <http://www.brainconnection.com/topics/?main=anat/vision-anat>
- Reiss-Werner, Uri, Kelly, A., Kristin, Trause, S., Amanda, Underhill, M., Abigail, Groh, M., Jennifer, (2003). Eye Position Affects Activity in Primary Auditory Cortex of Primates, *Current Biology*, 13, 554-562.
- Riečanský, I., (2004). Extrastriate area V5 (MT) and its role in the processing of visual motion, *Cekoslovenska fysiologie*, 53, 17-22.
- Rizzolatti G., Fogassi L., Gallese V., (2002). Motor and cognitive functions of the ventral premotor cortex, *Current Opinion in Neurology*, 12, 149-154
- Rodman, R., Hillary, Pessoa Luiz, Ungerlieder, G., Leslie. (2003). Visual Perception of objects. In Squire, R., Larry, Bloom, E., Floyd, McConnell, K., Susan, Roberts, L., James, Spitzer, C., Nicholas, Zigmond, J., Michael. (Eds.), *Fundamental Neuroscience* (2nd ed.), (pp. 1201-1227). Academic Press, San Diego, California
- Rogers, D., Robert, Ramnani, Narender, Mackay, Clare, Wilson, L., James, Jezzard, Peter, Carter, S., Cameron, Smith, S., Stephen, (2004). Distinct portions of anterior cingulate cortex and medial prefrontal cortex are activated by reward processing in separable phases of decision-making cognition, *Biological Psychiatry*, 55, 594-602
- Rolls, T., Edmund, Inoue, Kazue, Browning, Andrew, (2003). Activity of Primate Subgenual Cingulate Cortex Neurons Is Related to Sleep, *Journal of Neuropysiology*, 90, 134-142
- Ryan, Lee, Nadel, Lynn, Keil, Katrina, Putnam, Karen, Schnyer, David, Trouard, Theodore, Moscovitch, Morris, (2001). Hippocampal complex and retrieval of recent and very remote autobiographical memories: Evidence from functional magnetic resonance imaging in neurologically intact people, *Hippocampus*, 11, 707-714.
- Sanes, N., & Donoghue, P., John, (2000). Plasticity and Primary Motor Cortex, *Annual Review of Neuroscience*, 23, 393-415

- Savoy, L., Robert. Functional Magnetic Resonance Imaging (fMRI). Encyclopedia of the Brain.
- Schall, D., Jeffrey, (2001). Neural Basis of Deciding Choosing and Acting, *Nature Reviews Neuroscience*, 2, 33-42.
- Schmahmann, D., Jeremy, Sherman, C., Janet, (1998). The cerebellar cognitive affective syndrome, *Brain*, 121, 561-579.
- Semendeferi, Katerina, Armstrong, Este, Schleicher, Axel, Zilles, Karl, Hoesen, Van, W., Gary, (2001). Prefrontal cortex in humans and apes: A comparative study of area 10, *American Journal of Physical Anthropology*, 114, 224-241.
- Sharpe, A., James (1998). Cortical Control of eye movements. *Current Opinion in Neurology*, 11(1), 31-38.
- Shulin, Chen, Xia, Weiwei, Lingjiang, Li, Lui, He, Zhong, Zhang, Zishu, Yan, Lirong, Zhang, Jinli, Hu, Dewen, (2005). Gray matter density reduction in the insula in fire survivors with posttraumatic stress disorder: A voxel-based morphometric study, *Psychiatry Research: NeuroImaging*, 146, 65-72.
- Smith, E., Edward, Jonides John. (2003). In Executive Control and Thought. In Squire, R., Larry, Bloom, E., Floyd, McConnell, K., Susan, Roberts, L., James, Spitzer, C., Nicholas, Zigmond, J., Michael. (Eds.), *Fundamental Neuroscience* (2nd ed.), (pp. 1353-1376). Academic Press, San Diego, California
- Straka, H., Dieringer N., (2004). Vestibulo ocular reflex. Retrieved October 2007, from http://en.wikipedia.org/wiki/Vestibulo-ocular_reflex
- Suzuki, A., Wendy, Miller, K., Earl, Desimone, Robert, (1997). Object and Place Memory in the Macaque Entorhinal Cortex, *The Journal of Neurophysiology*, 78, 1062-1081.
- Swanson, W., Larry. (2003). In The Architecture of the Nervous System. In Squire, R., Larry, Bloom, E., Floyd, McConnell, K., Susan, Roberts, L., James, Spitzer, C., Nicholas, Zigmond, J., Michael. (Eds.), *Fundamental Neuroscience* (2nd ed.), (pp. 15-44). Academic Press, San Diego, California
- Takagi, M., Tamargo, R., Zee, DS., (2003). Effects of lesions of the cerebellar oculomotor vermis on eye movements in primate: binocular control, *Progress in brain research*, 142, 19-33.
- Talairach, Jean, Tounoux, Pierre, (1988). *Co-Planar Stereotaxic Atlas of the Human Brain*. Thieme Medical Publishers, Inc. New York

- Tanji, Jun, (2001). Sequential Organization of Multiple Movements: Involvement of Cortical Motor Areas, *Annual Review of Neuroscience*, 24, 631-651.
- The Eye: Visual System. Retrieved October 2007, from <http://www.webschoolsolutions.com/patts/systems/eye.htm>
- The Oculomotor System: Anatomy and Physiology. Retrieved October 2007, from <http://brain.phgy.queensu.ca/pare/assets/Oculomotor%20handout.pdf>
- Thinkquest, The rods and cones. Retrived October 2007, from <http://library.thinkquest.org/27066/theeye/rodcone.gif>
- Underleider, G., Leslie, Haxby, V., James, (1994). 'What' and 'where' in the human brain, *Current Opinion in Neurobiology*, 4, 157-165.
- Wikimedia, Schematic *diagram of the human eye*. Retrived October 2007, from http://upload.wikimedia.org/wikipedia/en/f/f8/Schematic_diagram_of_the_human_eye.png
- Vaina, M., Lucia, Solomon, Jeffrey, Chowdhury, Sanjida, Sinha, Pawan, Belliveau, W., John, (2001). Functional neuroanatomy of biological motion perception in humans, *Neurobiology*, 98, 11656-11661.
- Zilles, Karl (2004). Architecture of the Human Cerebral Cortex; Regional and Laminar Organization. In Paxinos, George, Mai, K., Jürgen (Eds.), *The Human Nervous System* (pp. 997-1055). San Diego, California: Elsevier Academic Press