Functional Magnetic Resonance Study

eyeQ™

Study performed at Cal Tech Pasadena

Findings:

Functional MRI was used to measure activity in the human brain in response to reading words. We scanned the brain of a healthy young female whose native language was English. At first, we assessed the baseline activity of brain regions involved in word reading by presenting a series of words to the participant in the scanner while simultaneously scanning her brain. We found a typical network of brain areas involved in reading meaningful words, including **visual cortex and Broca's area**.

We then wanted to see how training with the EyeQ software changes the brain response to reading. To test this, we had the participant complete task # 2 of the EyeQ program inside the scanner. No brain activity was measured during this time. We then repeated the same word reading task as before, but using new words that were very similar in length and lexical frequency.

We found that the same network of brain areas was activated after training, however, brain activity now was significantly higher in visual cortex and Broca's area. The visual cortex processes complicated visual patterns and is essential for the fast recognition of visual symbols, such as written words. Increased activity in this area suggests that the brain now devoted more resources to the visual cortex, which explains why we see faster reading speeds after EyeQ training.

Broca's area is involved in the higher-level processing of language and words. It is a supermodal structure which processes language information from both the visual and auditory modalities. It is involved in the production and comprehension of speech. Increased brain activity in this cortical area suggests that EyeQ training might have positive effects on language comprehension.

We also found that EyeQ training balances activation in the cerebral hemispheres from a very dominant left-lateralization to a more evenly distributed processing across the hemispheres.

Therefore, the results from this functional neuroimaging studies supports the claim that EyeQ training facilitates both the sensory and cognitive processing of language during reading.

Methods:

Functional magnetic resonance imaging (fMRI) is the use of MRI to measure the haemodynamic response related to neural activity in the brain or spinal cord of humans or other animals. It is one of the most recently developed forms of neuroimaging.

Advantages of fMRI

It can noninvasively record brain signals (of humans and other animals) without risks of radiation inherent in other scanning methods, such as CT scans.

It can record on a spatial resolution in the region of 3-6 millimeters, but with relatively poor temporal resolution (in the order of seconds) compared with techniques such as EEG. However, this is mainly because of the phenomena being measured, not because of the technique. EEG measures electrical/neural activity while fMRI measures blood activity, which has a longer response. The MRI equipment used for fMRI can be used for high temporal resolution, if you measure different phenomena.

Subjects participating in a fMRI experiment are asked to lie still and are usually restrained with soft pads to prevent small motions from disturbing measurements. Some labs also employ bite bars to reduce motion, although these are unpopular as they can cause some discomfort to subjects. It is possible to correct for some amount of head movement with post-processing of the data, but large transient motion can render these attempts futile. Generally motion in excess of 3 millimeters will result in unusable data. The issue of motion is present for all populations, but most notably within populations that are not physically or emotionally equipped for even short MRI sessions (e.g., those with Alzheimer's Disease or schizophrenia, or young children). In these populations, various positive and negative reinforcement strategies can be employed in an attempt to attenuate motion artifacts, but in general the solution lies in designing a compatible paradigm with these populations.

An fMRI experiment usually lasts 1-2 hours. Depending on the purpose of study, subjects may view movies, hear sounds, smell odors, do cognitive tasks such as memorizing or imagination, or press a few buttons. Researchers are required to give detailed instructions and descriptions of the experiment plan to each subject, who must sign a consent form before the experiment.

these voxel time series with the task in order to produce maps of task-dependent activation.

fMRI data analysis

The ultimate goal of fMRI data analysis is to detect correlations between brain activation and the task the subject performs during the scan. The BOLD signature of activation is relatively weak, however, so other sources of noise in the acquired data must be carefully controlled. This means that a series of processing steps must be performed on the acquired images before the actual statistical search for activation can begin.

For a typical fMRI scan using an EPI pulse sequence the 3D volume of the subject's head is imaged every one or two seconds, producing a few hundred to a few thousand complete images per scanning session. The nature of MR imaging is such that these images are acquired in Fourier transform space, so they must be transformed back to image space to be useful. Because of practical limitations of the scanner the Fourier samples are not acquired on a grid, and scanner imperfections like thermal drift and spike noise introduce additional distortions. Small motions on the part of the subject and the subject's pulse and respiration will also effect the images.

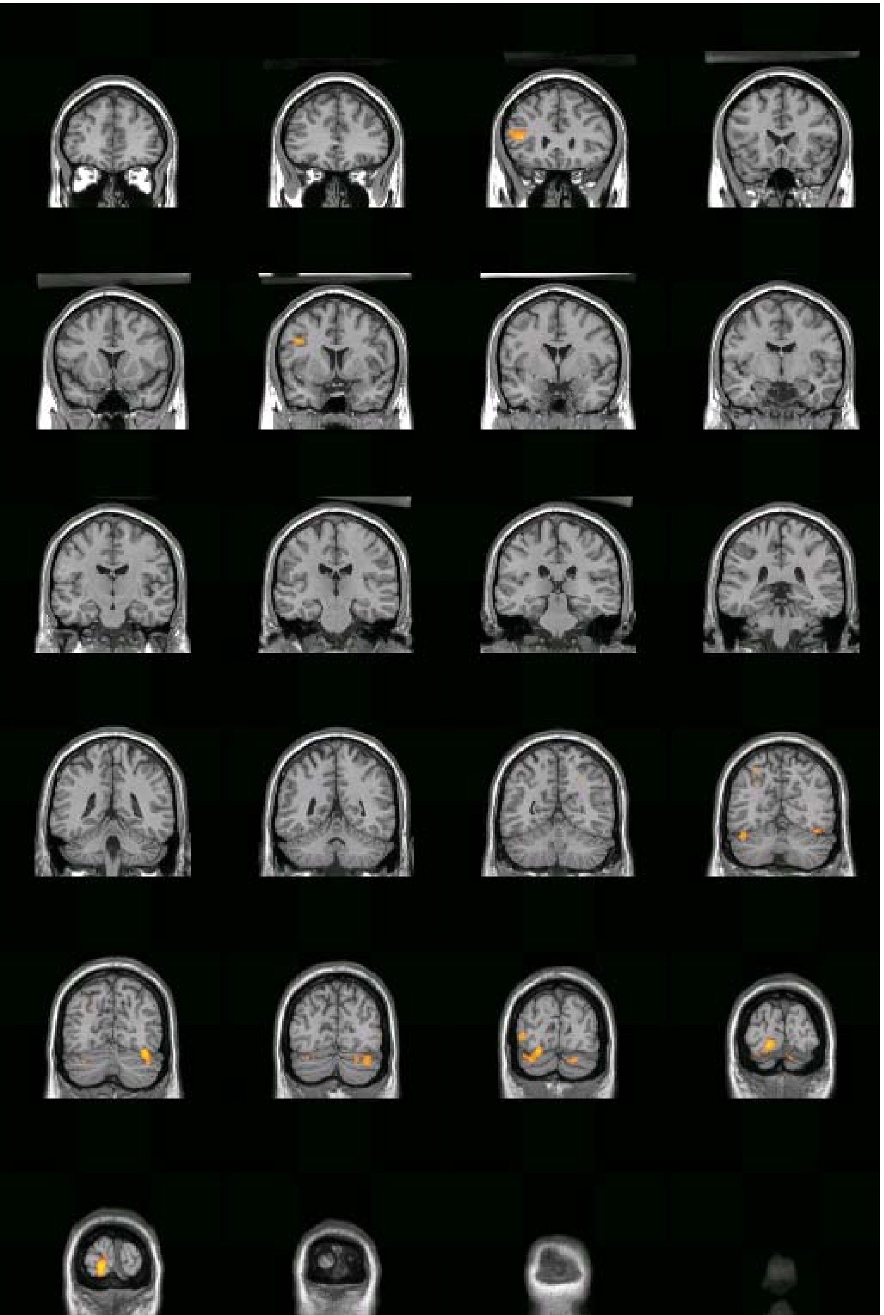
The most common situation is that the researcher uses a pulse sequence supplied by the scanner vendor, for example a boustrophedonic EPI sequence. Software in the scanner platform itself then performs the reconstruction of images from Fourier transform space. During this stage some information is lost (specifically the complex phase of the reconstructed signal). Some types of artifacts, for example spike noise, become more difficult to remove after reconstruction, but if the scanner is working well these artifacts are thought to be relatively unimportant. For pulse sequences not provided by the vendor, for example spiral EPI, reconstruction must be done by software running on a separate platform.

After reconstruction the output of the scanning session consists of a series of 3D images of the brain. The most common corrections performed on these images are motion correction and correction for physiological effects. Outlier correction and spatial and/or temporal filtering may also be performed. If the task performed by the subject is thought to produce bursts of activation which are short compared to the BOLD response time (on the order of 6 seconds), temporal filtering may be performed at this stage to attempt to deconvolve out the BOLD response and recover the temporal pattern of activation.

At this point the data provides a time series of samples for each voxel in the scanned volume. A variety of methods are used to correlate

Brain Images

Reading before training



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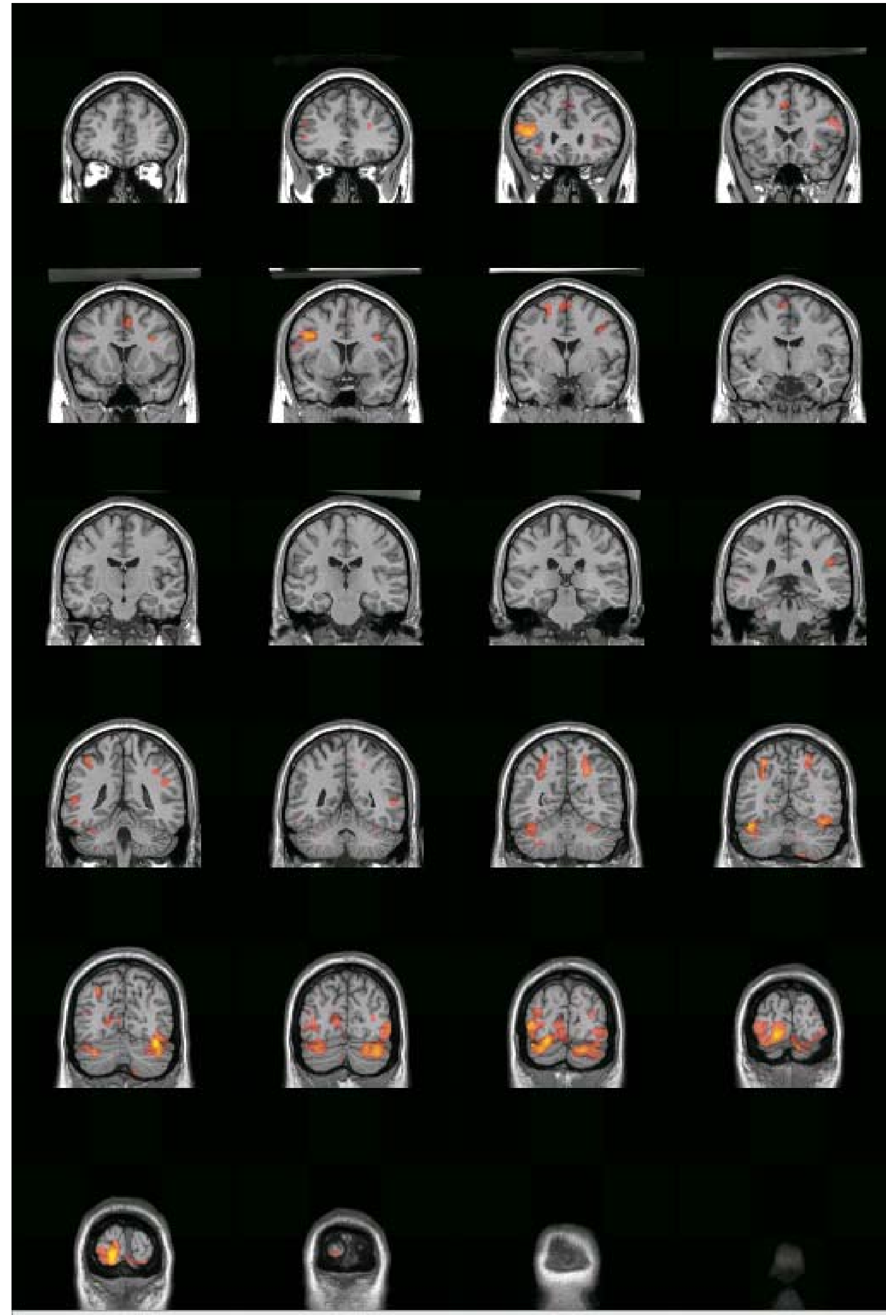

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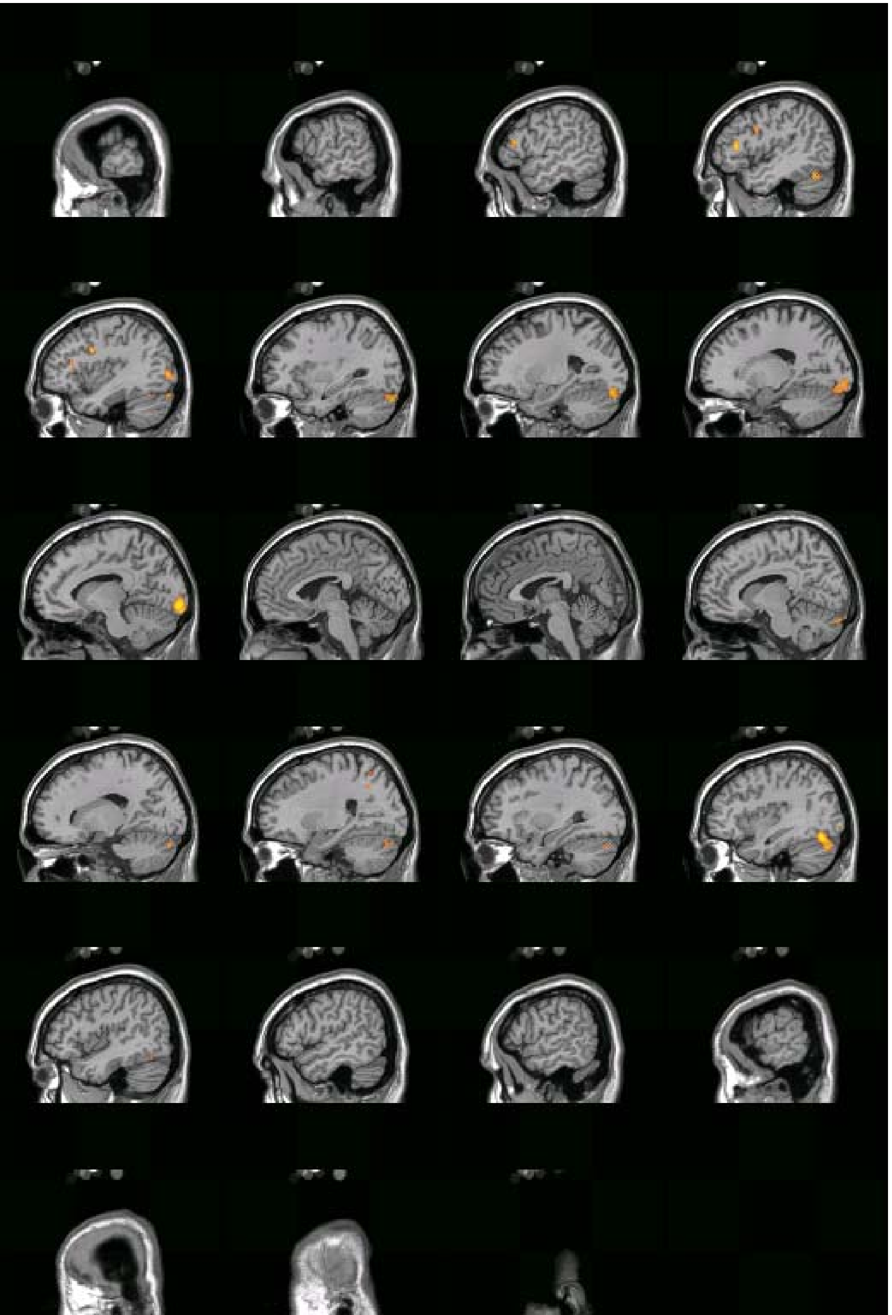

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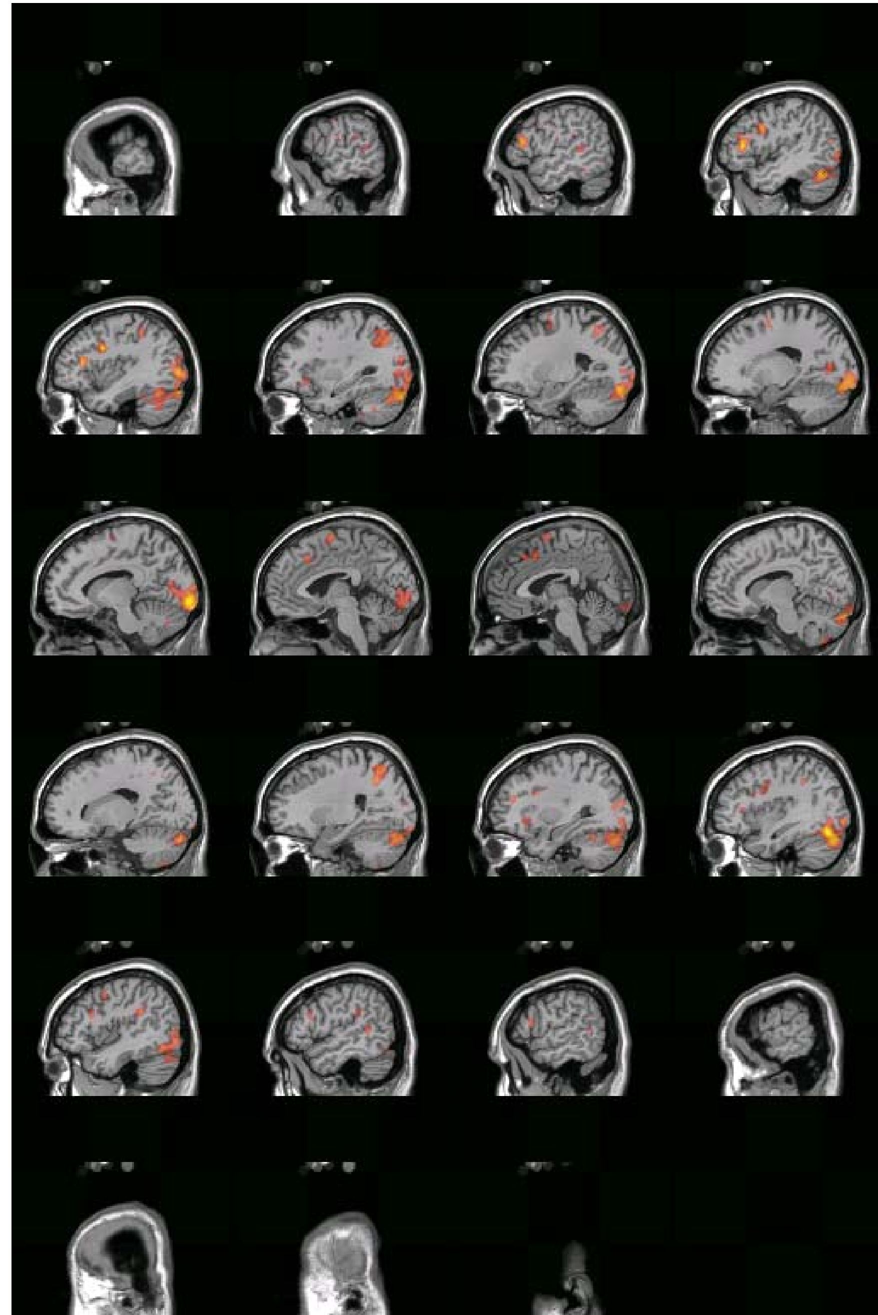

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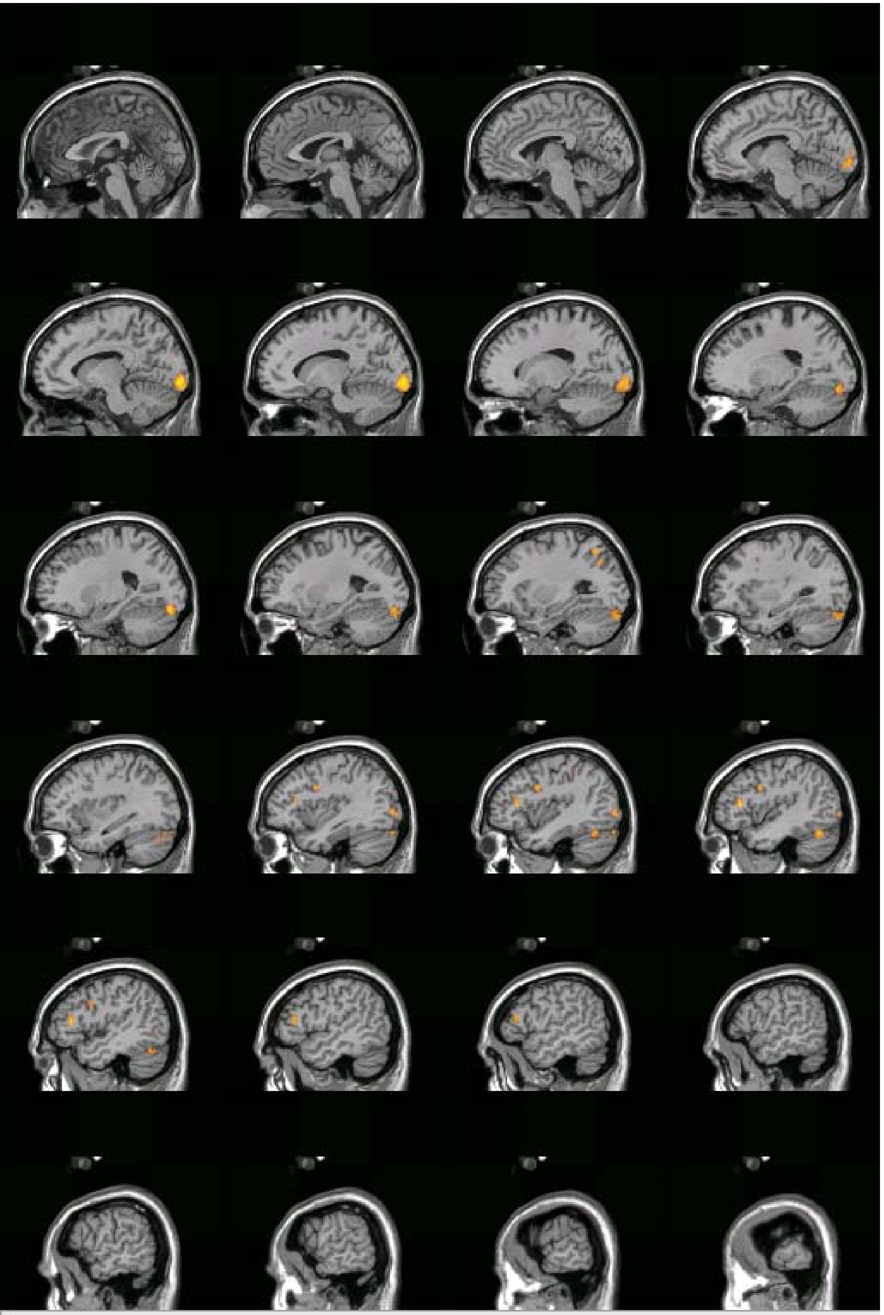

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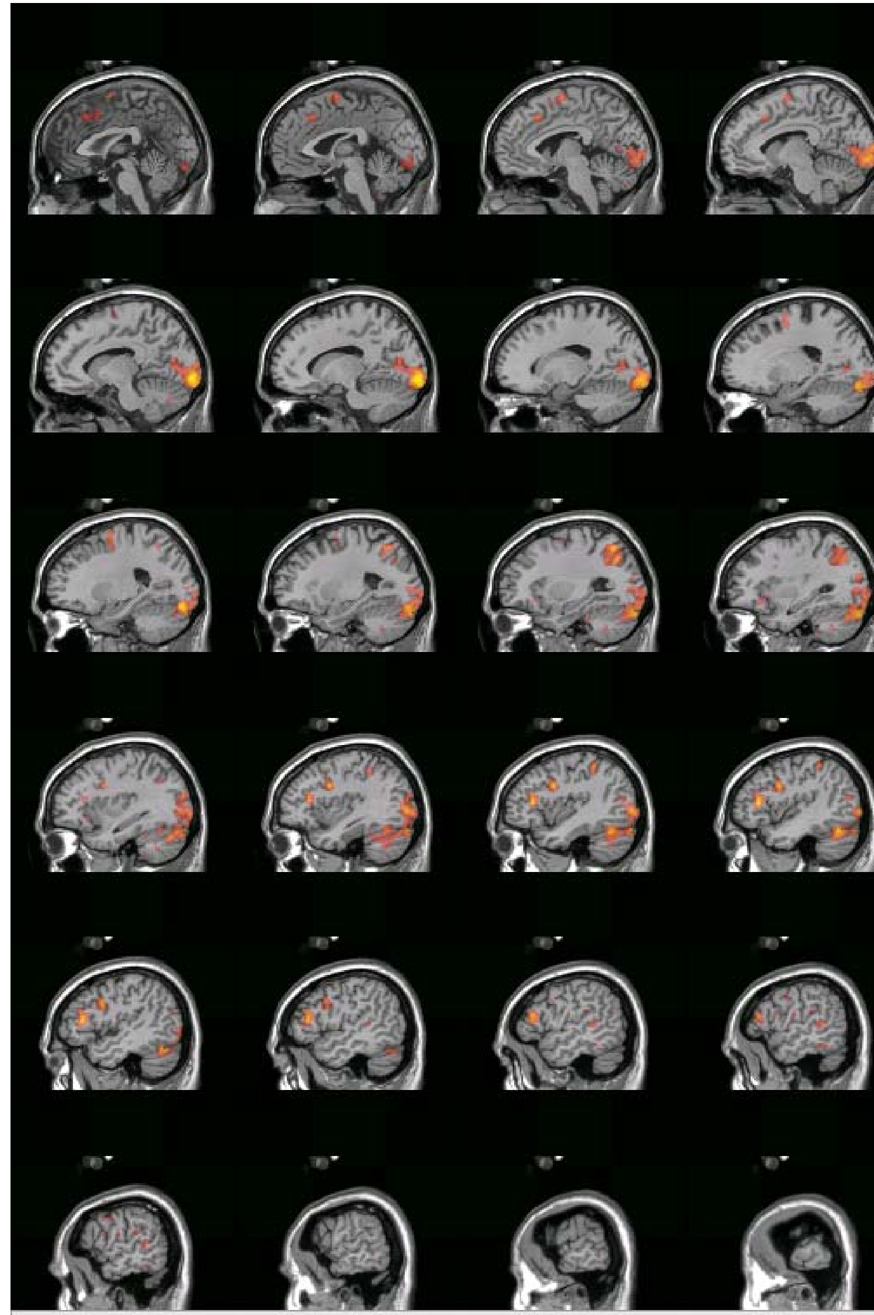

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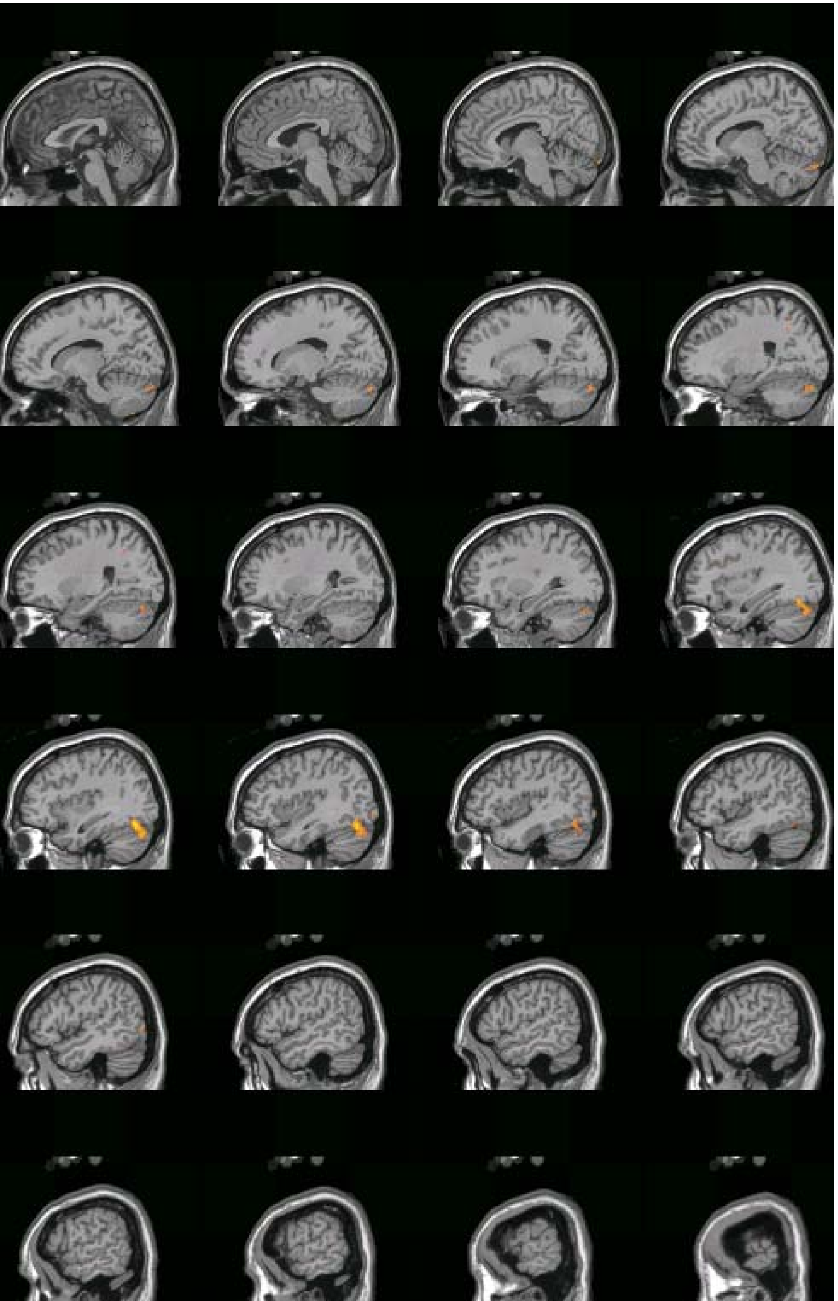

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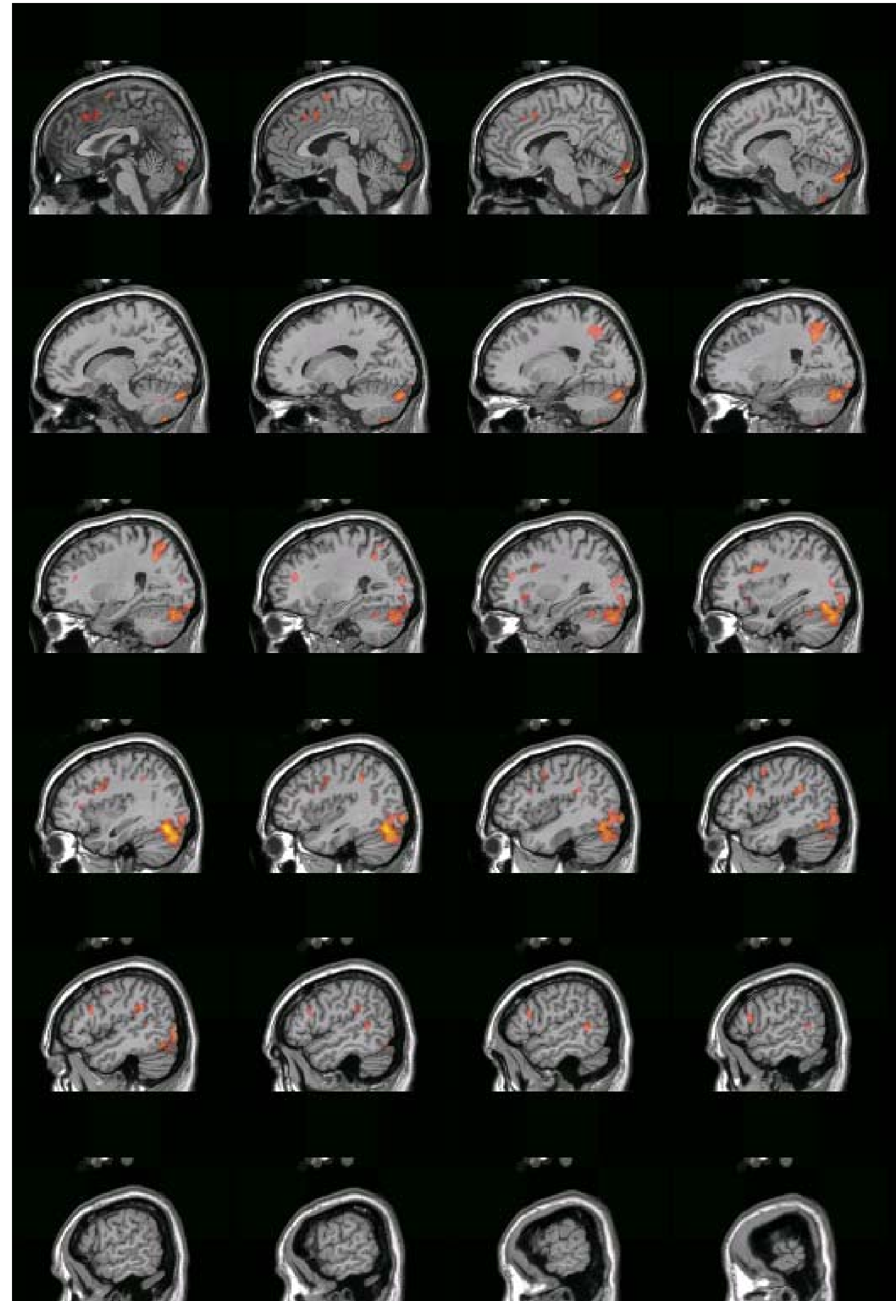

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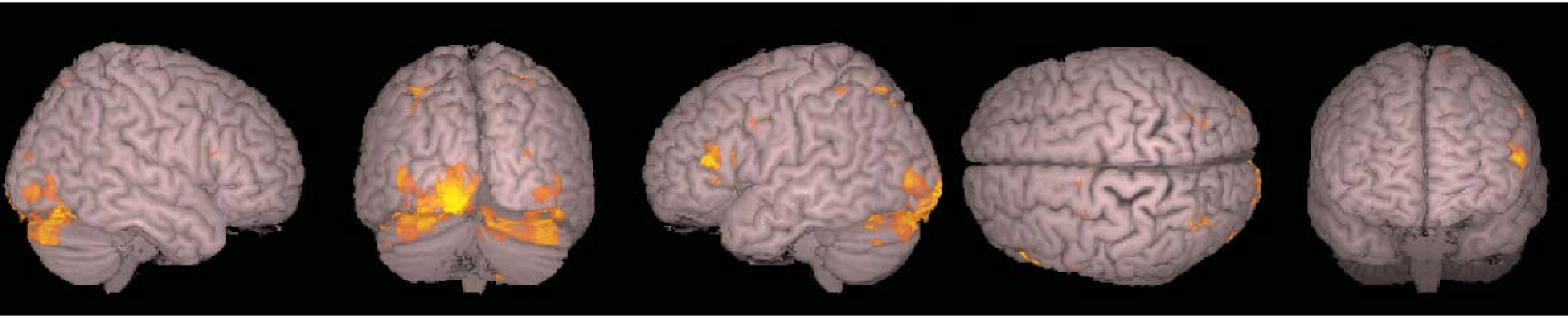

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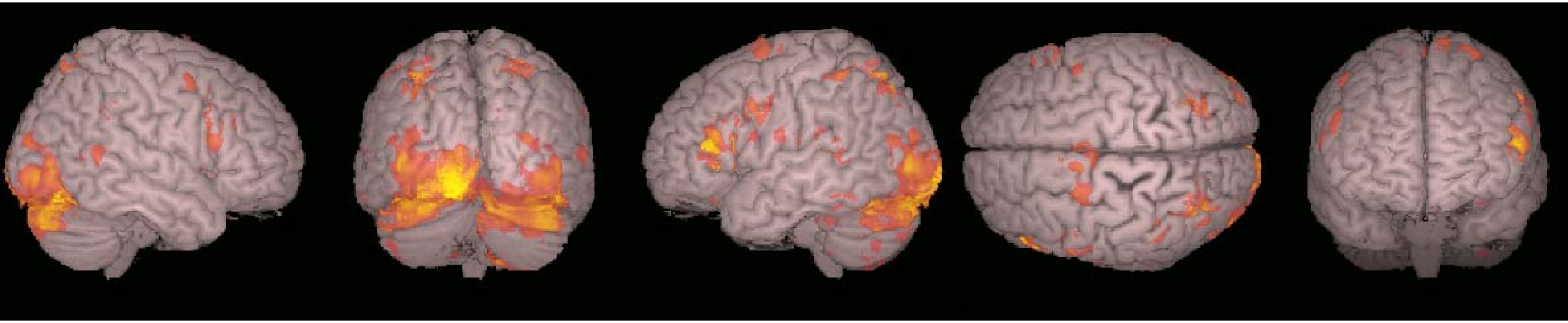
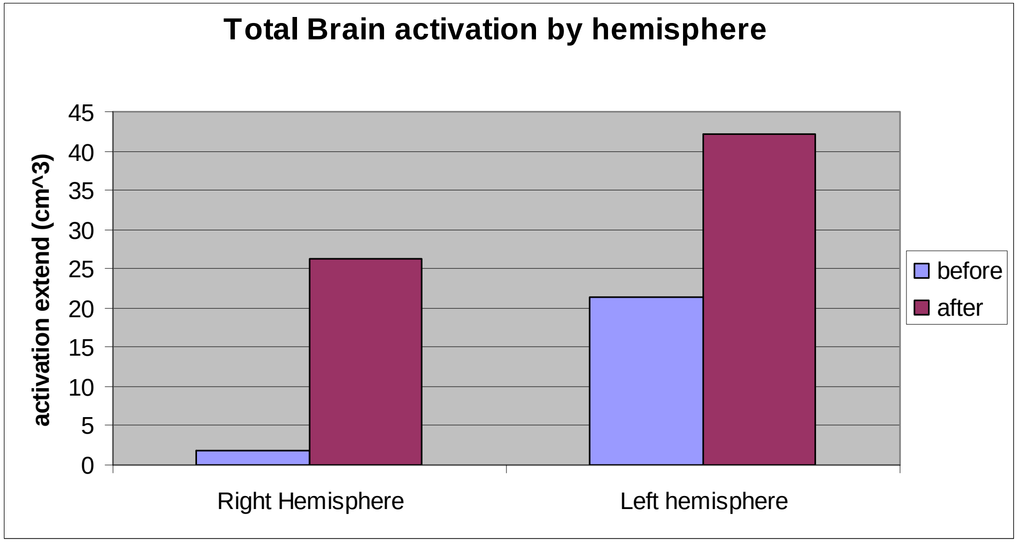
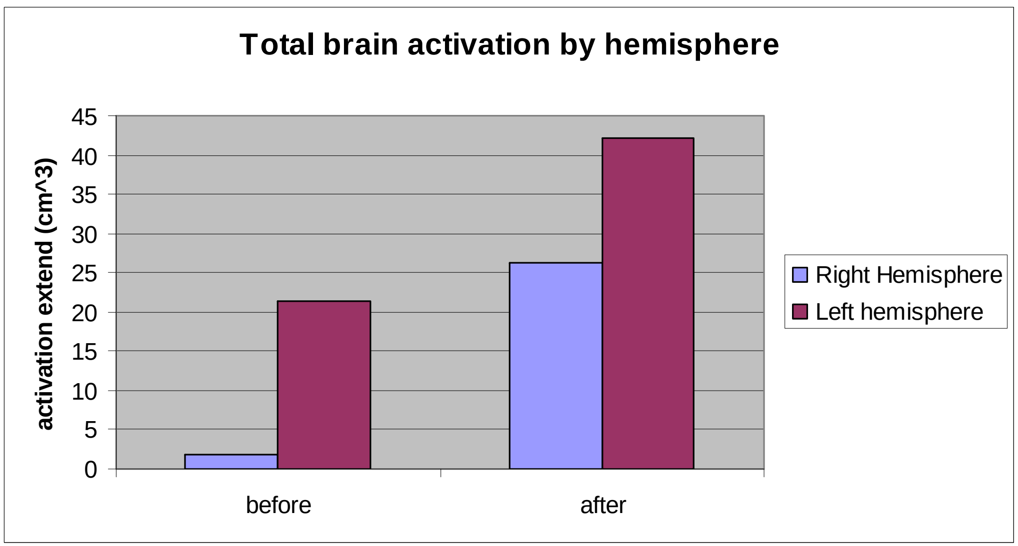




These graphs show that word reading activates the left hemisphere more than the right. This is consistent with previous findings on hemispheric specialization of language.
From the bottom graph we can see that brain activity after EyeQ training is more balanced across the hemisphere.

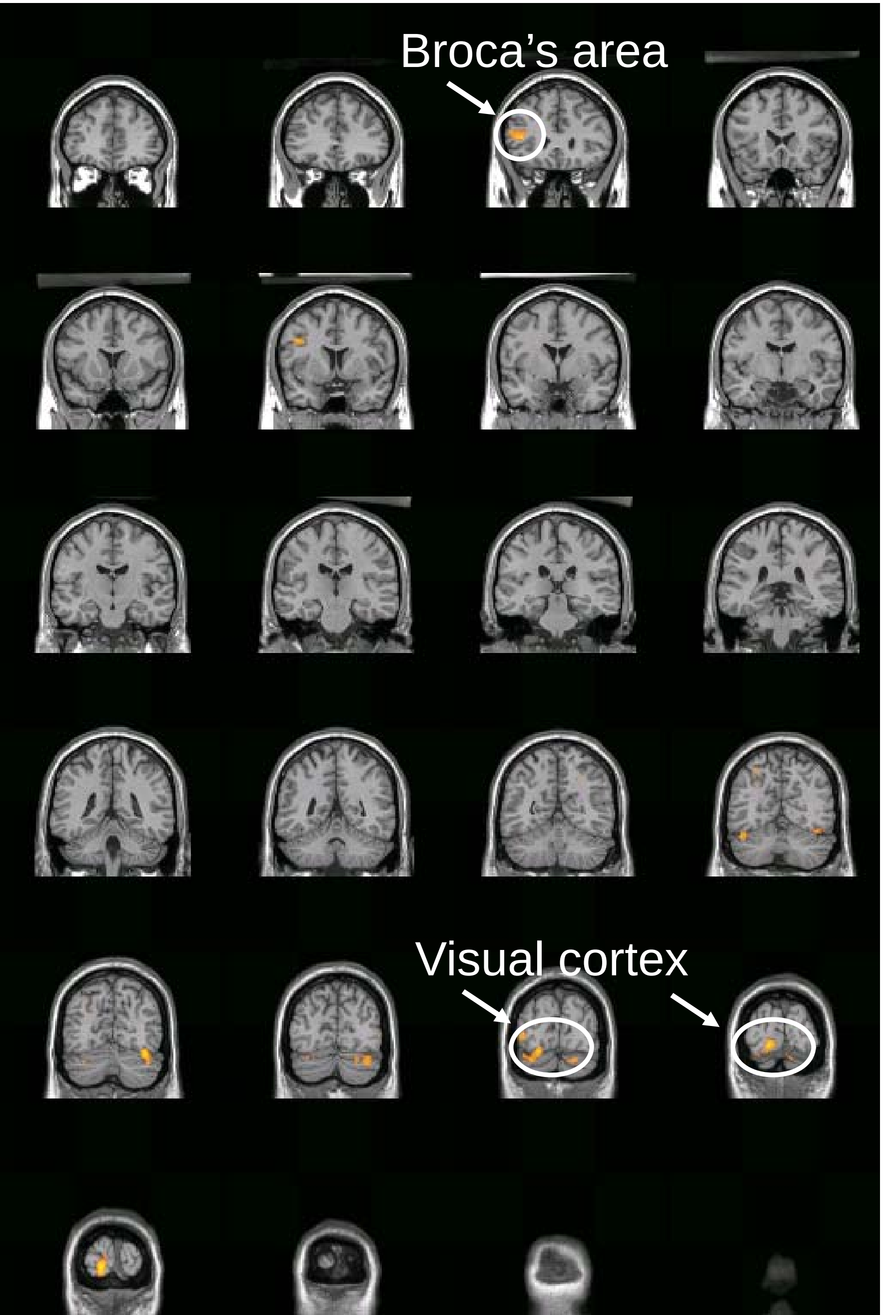


Raw data for further graphs:

	Right Hemisphere	Left hemisphere
before	1.76	21.43
after	26.36	42.12

Annotated Brain Images showing Visual Cortex and Broca's Area where significant changes were found between pre- and post-training.

Reading before training



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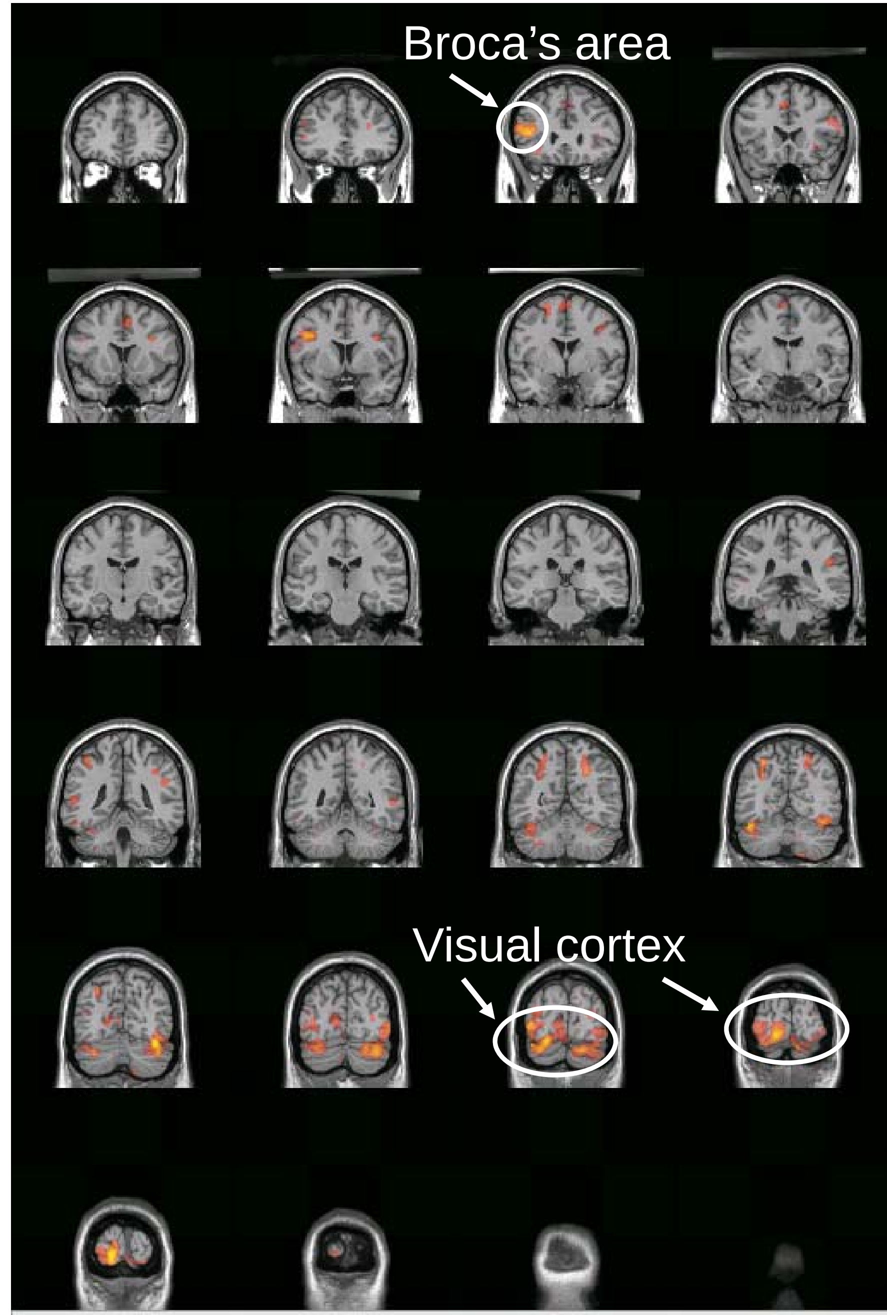

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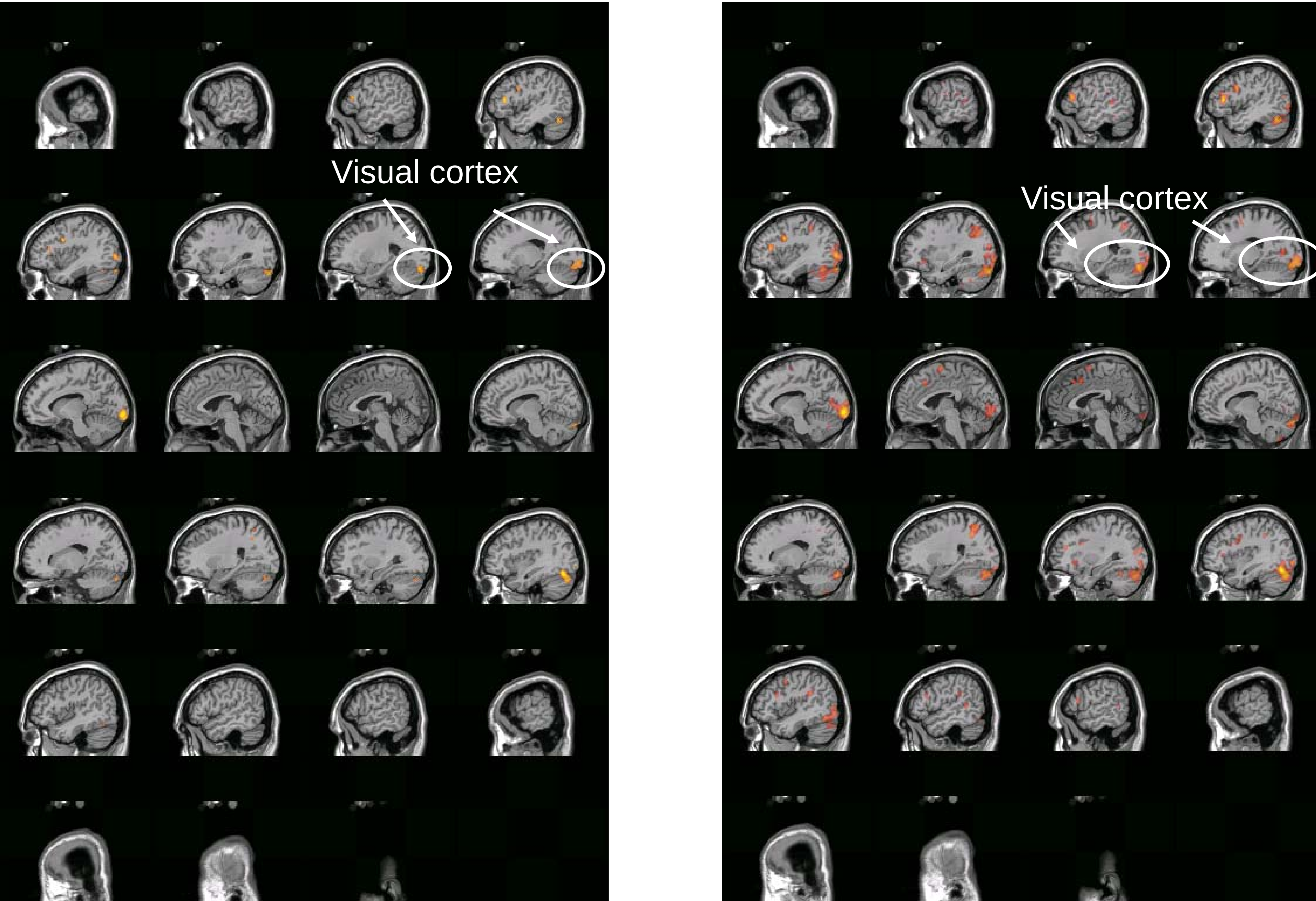

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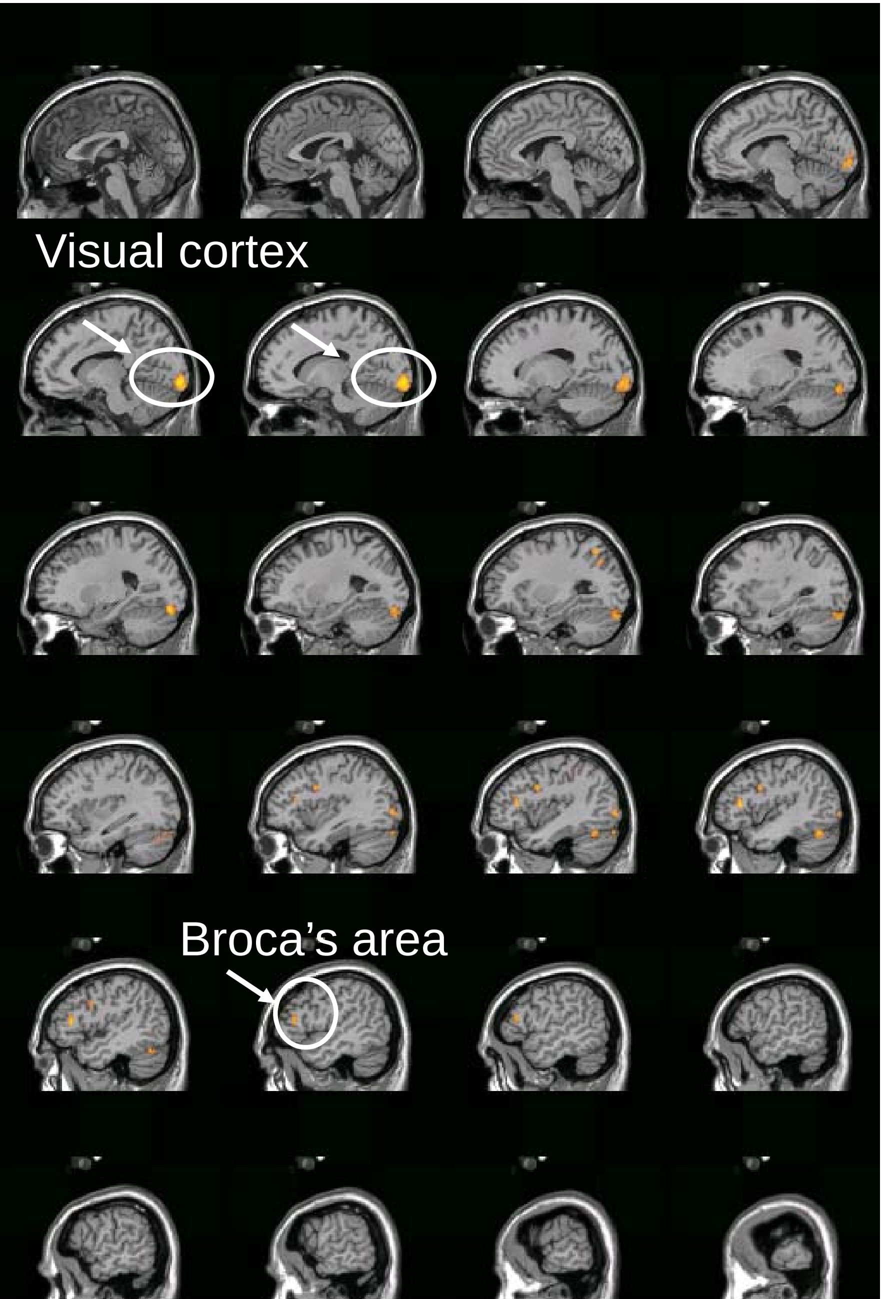

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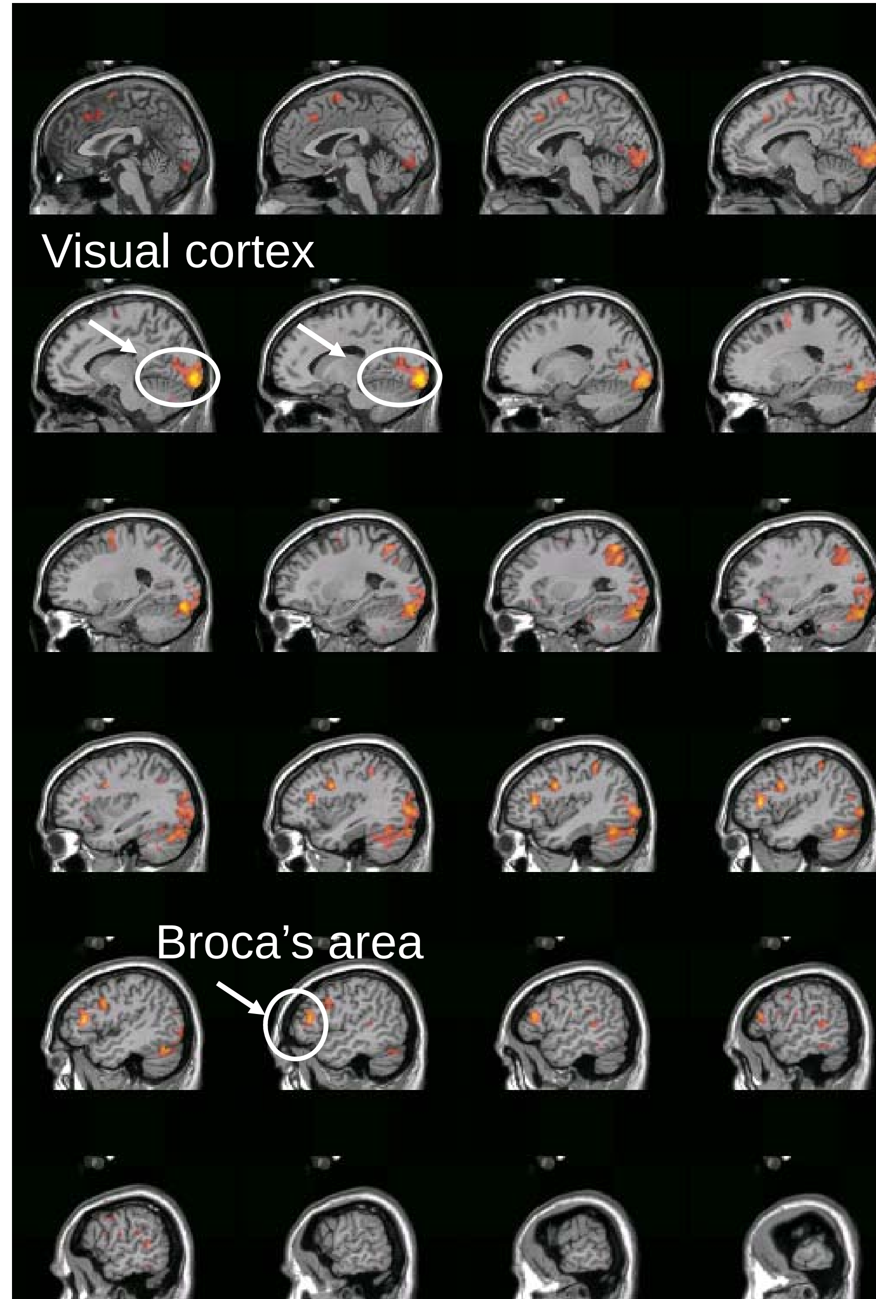

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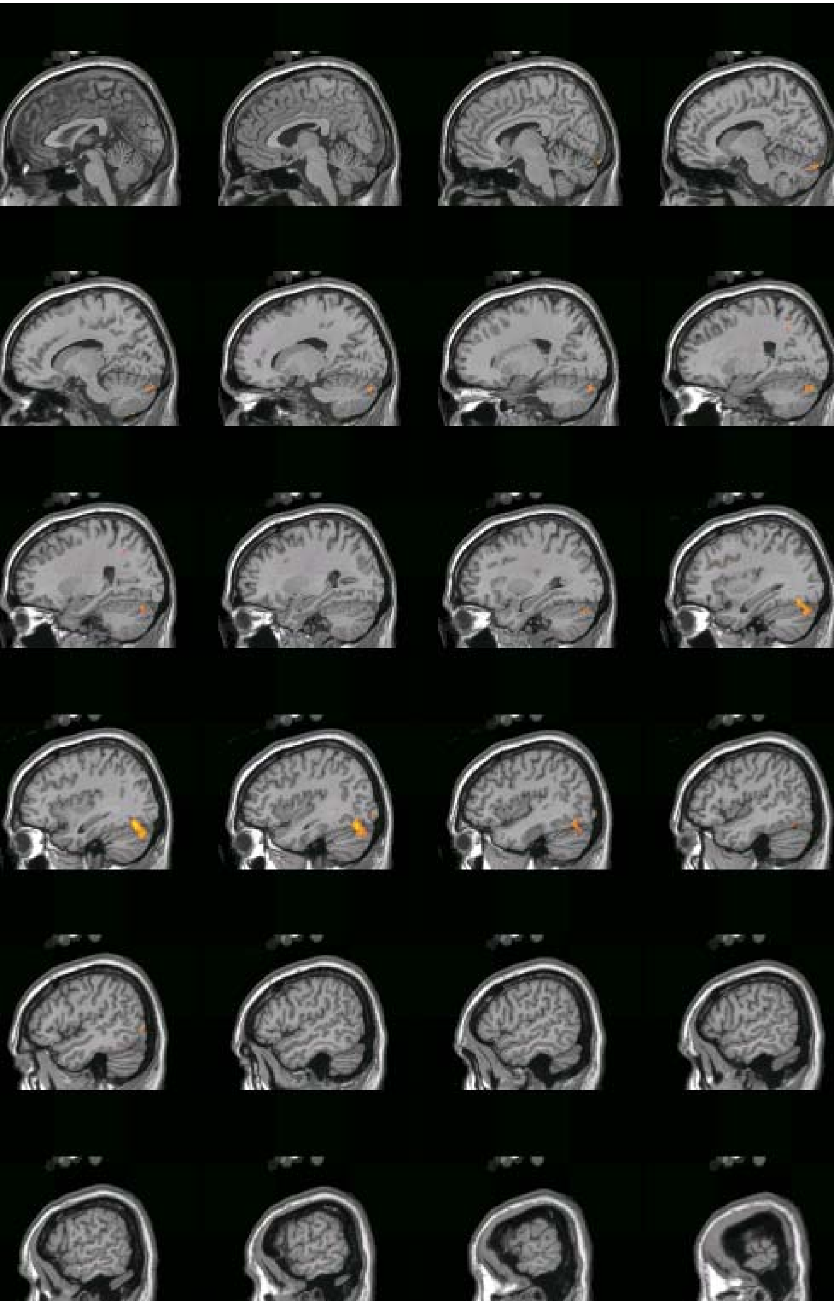

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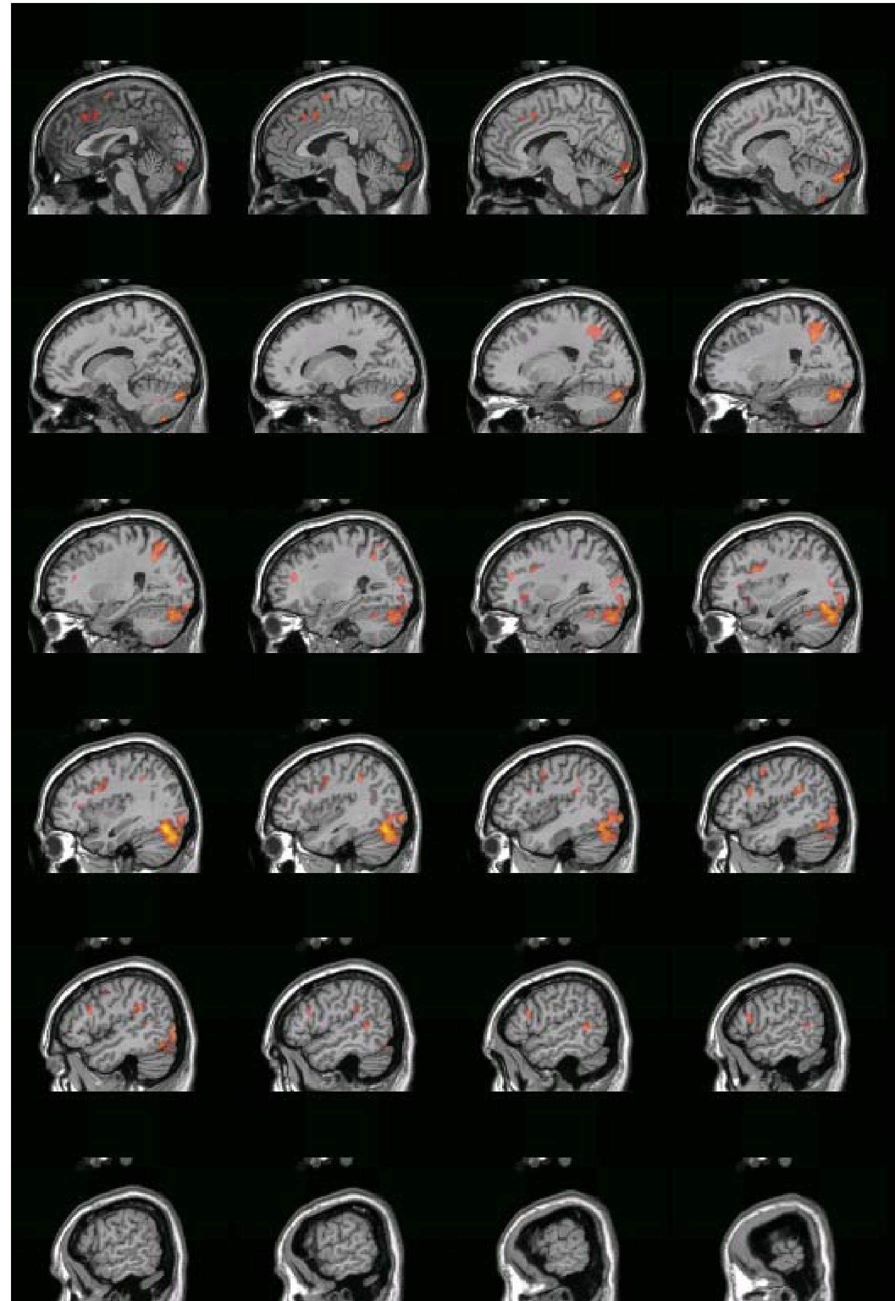

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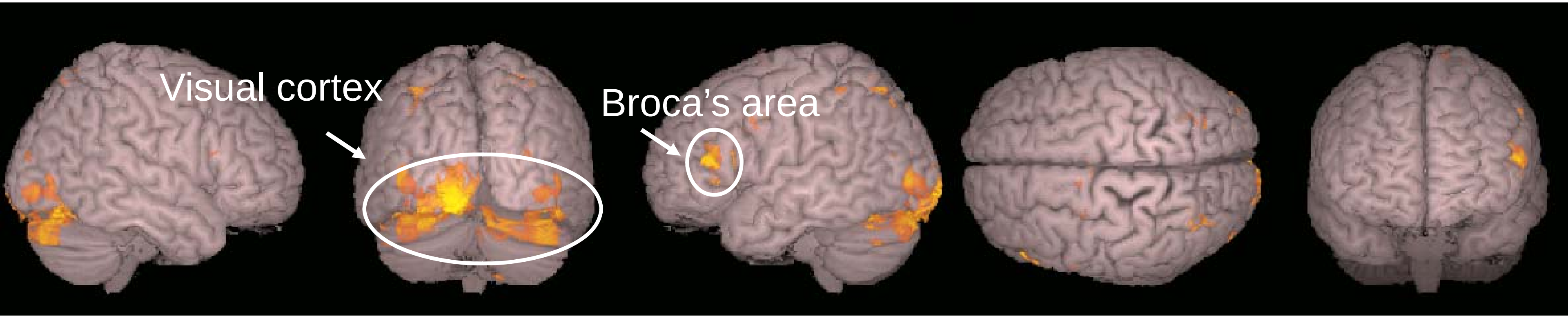

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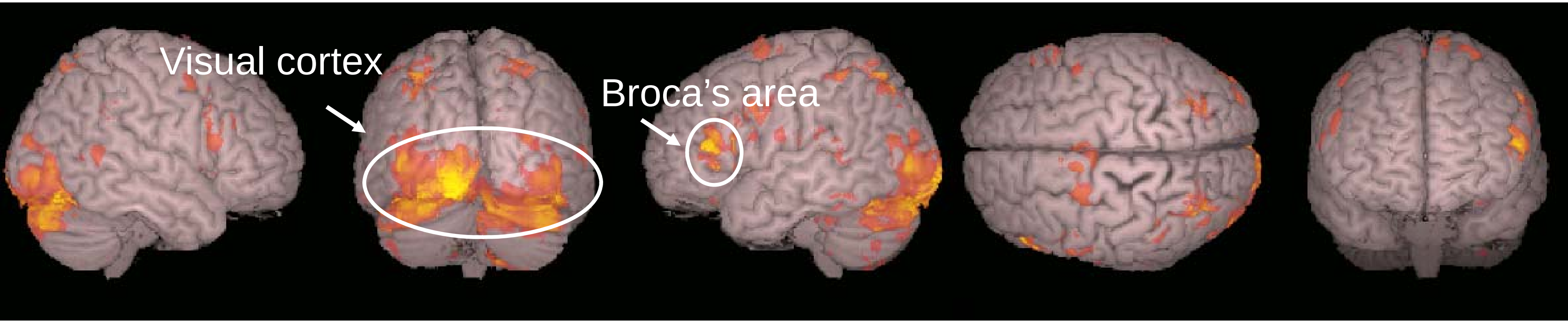
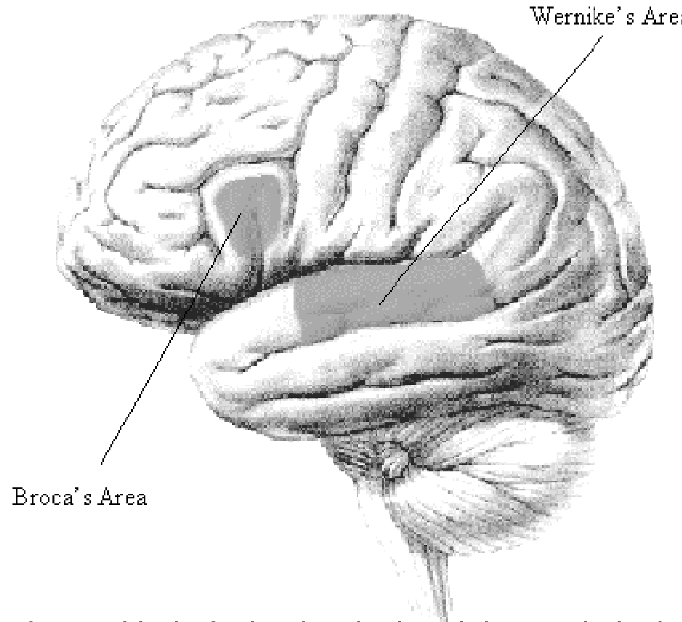


Broca's area is the section of the human brain (in the opercular and triangular sections of the inferior frontal gyrus of the frontal lobe of the cortex) that is involved in language processing, speech production and comprehension. It is involved in processing both heard and written language.



It can also be described as Brodmann's Area 44, and 45 and is connected to Wernicke's area by a neural pathway called the arcuate fasciculus.

Broca's area is named after Pierre Paul Broca, who first described it in 1861, after conducting a post mortem study on a speech-impaired patient.

There are two main parts of Broca's area, which express different roles during language comprehension and production:

Pars triangularis (anterior), which is thought to support the interpretation of various 'modes' of stimuli (plurimodal association) and the programming of verbal conducts

Pars opercularis (posterior), which is thought to support the management of only one kind of stimulus (unimodal association) and the coordination of the speech organs for the actual production of language, given its favorable position close to motor-related areas.

People suffering from damage to this area may show a condition called Broca's aphasia (sometimes known as expressive aphasia, motor aphasia, or nonfluent aphasia), which makes them unable to create grammatically-complex sentences: their speech is often described as telegraphic and contains little but content words. Comprehension in Broca's aphasia is relatively normal, although many studies have demonstrated that Broca's aphasics have trouble understanding certain kinds of syntactically complex sentences.1

This type of aphasia can be contrasted with Wernicke's aphasia, named for Karl Wernicke, which is characterized by damage to more posterior regions of the left hemisphere (in the superior temporal lobe). Wernicke's aphasia manifests as a more pronounced impairment in comprehension, and speech that seems normal grammatically but is often roundabout, vague or meaningless.

For example, in the following passage, a Broca's aphasic patient is trying to explain how he came to the hospital for dental surgery.

"Yes... ah... Monday... er... Dad and Peter H... (his own name), and Dad.... er... hospital... and ah... Wednesday... Wednesday, nine o'clock... and oh... Thursday... ten o'clock, ah doctors... two... an' doctors... and er... teeth... yah."2.

PET and functional MRI have found decreases in activity in the Broca's area in stuttering.

Visual cortex is the term applied to both the primary visual cortex (also known as striate cortex or "V1") and upstream visual cortical areas also known as extrastriate cortical areas (V2, V3, V4, V5). The primary visual cortex is anatomically equivalent to Brodmann area 17, or BA17.

The visual cortex occupies about one third of the surface of the cerebral cortex in humans. It is thought to be divided into as many as thirty interconnected visual areas, but at the present time there is good evidence for only 4 of these areas, V1, V2, V3 and MT (aka V5). The first cortical visual area, the one that receives information directly from the lateral geniculate nucleus, is the Primary Visual Cortex, or V1.

The primary visual cortex is the best studied visual area in the brain. It is the part of the cerebral cortex that is responsible for processing visual stimuli. It is the simplest, earliest cortical visual area. It is highly specialized for processing information about static and moving objects and is excellent in pattern recognition (such as written words). The visual cortex is the pattern recognition unit that is required to identify written words.