Functional Magnetic Resonance Imaging

Functional Magnetic Resonance Imaging (fMRI) is a modern brain-imaging technique that measures the blood-flow to different parts of the brain. This allows researchers to study which parts of the brain are more active (and therefore require more blood) during different psychological and behavioral tasks.

The technique has been used world-wide for more than 20 years and is safe, provided that certain guidelines are followed and experimental participants are adequately prepared. The following information provide an introduction to the technique and answer some general questions that you might have.

**Q: How does fMRI work?**

**A:** fMRI was developed by physicists from the technique of Nuclear Magnetic Resonance (NMR). The 'Nuclear' in this phrase does not refer to the way the machines are powered(!), but to the fact that it is the nucleus of individual atoms that 'resonates' when placed into a magnetic field, and stimulated with radio-waves. Since different atoms behave differently in these magnetic fields, physicists can work out which atoms are present in a substance, and what they’re doing. Medical physiologists now use the technique (renamed Magnetic Resonance Imaging, with machines adapted to fit humans in a comfortable position) to image the human body. Bone, fat, blood, muscle and other bodily tissues produce different signals inside the magnetic field. These signals can be detected and analyzed to create a 3-D image of the body and the brain. Neurologists and Neuroscientists typically study just the brain, but the technique can be used for many aspects of medical imaging.

The underlying principle of functional Magnetic Resonance Imaging is that the brain depends on a very high flow of blood to cope with its high demands for oxygen and glucose. Fortunately for neuroscience, changes in the regional distribution of blood flow are quite tightly related to changes in the activity of different parts of the brain. When looking at pictures on a screen, for example, visual regions of the brain require relatively more blood than the rest of the brain. When listening to music, the auditory regions require relatively more blood. This increase of blood flow into the brain is accompanied by an increase of haemoglobin (the iron-rich molecule that carries oxygen within red-blood-cells). fMRI measures the relative amount of oxygenated-haemoglobin to deoxygenated-haemoglobin in the blood. This measurement is called the Blood Oxygenation Level Dependent (or BOLD) signal, and produces the lovely
colourful 'maps' of the brain's activation associated with different tasks. The actual change in blood flow is quite small – a large change is only a 1 – 3 % increase, while the smallest reliable change might be ten times lower than this!

**Q: Why do we need fMRI?**

**A:** Functional Magnetic Resonance Imaging provides a sensitive measurement of the different parts of the brain involved in different psychological and behavioral functions. Understanding how different parts of the brain respond to external stimuli, process information, and make decisions and responses, is a central aim of neuroscience and can be of enormous help clinically, for patients with brain lesions (e.g. stroke), degenerative brain disease (e.g. dementias, cognitive impairments that cannot be explained) or mental illness (e.g. schizophrenia). For patients information gained from neuro-imaging techniques, however, needs to be compared to information gained from other disciplines and other techniques – including the results of rehabilitation (e.g. occupational therapy, cognitive retraining), effect of pharmaceutical interventions, etc.

The future will be even more complex, we will be able to combine different techniques that together reveal the spatio-temporal orchestration of the human brain processes. While fMRI, for example, has a good spatial resolution (it can detect differences in activity across brain areas separated by only a few millimetres), it has quite poor temporal resolution (the BOLD response takes about 5 seconds to build up in the brain – we can tell quite easily if a part of the brain is involved in a task, but not so easily when it was involved, or what the individual neurons are doing). These limitations mean that fMRI must be used and interpreted in conjunction with other kinds of evidence, such as MEG. Technology and mathematical analysis techniques are always being improved, however, and the temporal and spatial resolution of fMRI will get better, allowing us to ask more fine-grained questions about brain function in the future. Technology will allow to easily combine EEG and fMRI, or MEG and fMRI so that temporal and spatial aspects of brain processing can be integrated.

**Q: Who should NOT have a scan?**

**A:** This imaging technique involves strong, rapidly changing magnetic fields (about 10–20,000 times stronger than the earth's magnetic field!), and exposure to radio-waves. The strong magnetic fields would cause any metal in/near the scanner to accelerate, while the radio waves would cause the metal to heat up. For these reasons, anyone with any metal in their body MUST NOT take part. The following list provides some examples of people who are
EXCLUDED, but it is not exhaustive: You will undergo an interview before your scan.

SOME MRI EXCLUSION CRITERIA:


IF YOU HAVE WORKED AS A METAL GRINDER, WELDER, or HAVE BEEN EXPOSED TO ANY METALLIC FLAKES, or suffered a METALLIC INJURY, and have not since had an X-ray showing you have no metal embedded in your head or body, then you cannot have a scan.

IF YOU ARE PREGNANT, or there is a possibility that YOU MAY BE PREGNANT, you cannot have a scan.

IF YOU ARE CLAUSTROPHOBIC (afraid / uncomfortable in small, enclosed spaces) you SHOULD NOT PARTICIPATE.

IF YOU WEAR GLASSES, PLEASE USE CONTACT LENSES INSTEAD (unless this would cause irritation or you are not used to wearing them). IF YOU ARE SHORT-SIGHTED, WE HAVE A LIMITED RANGE OF NON-METALLIC CORRECTION GLASSES TO WEAR. FOR OTHER VISUAL DEFECTS – PLEASE ENQUIRE BEFORE THE SCAN – you need to be able to read the computer screen in the scanning room to perform the experiments properly.

When you arrive at the scanner, you will be asked, several times and by different people, to remove all metal objects from your body and clothing. This includes (from the top): Hair Bands/Clips, Glasses, Earrings, Dental-Braces, Face- and Body-Piercings, Necklaces, Wired-Bras, Belts, Money, Credit Cards, Watches, Bracelets, and any other metal objects not listed above. If you wear glasses for short-sight, please have the prescription strength number with you (measured in diopters, normally between 1 and 7). We have a range of non-metallic glasses which you can wear. If you normally wear an under-wired bra, please refrain from doing so on the day of the experiment – use a non-wired bra.

PLEASE NOTE: For most experiments, participants with normal, healthy brains are required. During or after the scan, there is a very small possibility that the radiologist will detect an abnormality in your brain that you may not have been aware of. In the unlikely event of this happening, the radiologist will inform you or your doctor, and advise you to visit your doctor for a proper examination.
Research scans are NOT medical diagnostic scans, and we will not be able to tell you if there is anything to be concerned about. If you think you may have a neurological problem, you should visit your doctor and not participate in this research.

Q: How long does it take?

A: Most experiments last around two hours. There are several parts to the scan itself, once you are in position and comfortable: First, a few brief scans check your position and make a map of the magnetic field around your body and head (every person distorts the magnetic field in a different way, due to differences in size, weight, lung capacity, etc). This initial registration process may take 5 minutes or so. The main experimental Functional Scan might take 15 – 45 minutes, depending on the specific experiment. This time should be broken up into blocks of trials – you will get a break between blocks, the radiologist will check that you are OK, and the experimenter will give you appropriate instructions. Additionally, a Structural Scan will take a high-resolution image of the structure of your brain. This will take a further 10–20 minutes.

In the case we also acquire clinical sequences, the scan will be longer. Every patient participating will have a clinical sequence.

You will be asked to arrive at least 15 minutes before your scheduled scanning time. Additionally, depending on the experiment, you may be asked to do some behavioral training sessions before the scan, perhaps on a different day – either in a laboratory at the NeuroVisual Clinic, or in the hospital itself.

Q: Is it uncomfortable or noisy?

A: During the scan, you will be laying down on a bed within the scanner. The examiners will try to ensure that you are as comfortable as possible, and they have a variety of blankets, and padding to do this. The scanner room is quite cool, but we will make sure that you will be as comfortable as possible. We have blankets, cushions, all to make you feel good. The scanner tube itself is less than a meter in diameter, and your head will also be surrounded by additional support and a smaller tube. On your first experience, it feels quite small in there! – people with claustrophobia or potential claustrophobia should definitely not participate.

When in the scanner, you need to lie very still (any slight movements distort the magnetic fields, and we will lose some important and expensive data!), in particular, keeping your head still. The computer software can correct for very small movements, but the larger the movement, the worse the data recording is.
You may be asked to try to control your eye-blinking during certain stages of the experiment. In addition, you should try to stay as relaxed as possible, keep your breathing as regular and normal as possible, try not to tense or move any parts of your body, except for those movements required for the experiment (e.g. pressing a button). [Some things (yawning, sneezing, etc) may be unavoidable, but if you think you might have a strong cold on the day of the scan, for example, it might be best to withdraw as early as possible, so we can cancel the scan without penalty.]

The scanner makes a lot of strange bleeping and whirring noises, some of which are quite loud (around 100 dB). You will be provided with ear-plugs to diminish the sound of the scanner machine itself, but you will be able to hear any instructions clearly through the microphone associated with the control panel in the room where the examiners are running the study.

There is a possibility that you will FEEL SLEEPY during the scan! This would obviously be a problem for the reliability of the examination and data acquired—blocks of trials will be kept as short as possible, and you will be kept as active as is possible to prevent this happening.

**Q: Can I withdraw before or during the scan?**

**A:** As a volunteer, you are always entitled to withdraw at any stage of any experiment or scan without having to give a reason, and you will be reimbursed for your time and expenses. While in the scanner, you are provided with a 'panic button' which you can squeeze to alert us, and you can talk to us at any time.

*Before participating, you should think carefully about the experiment and the scanning process — if you have any doubts at all, then you should not participate. If you have any questions at any stage, you should contact any member of our team.*

For being able to do the scanning, we require from you commitment and willingness to lie very still within the scanner and to concentrate on the functional tasks as much as possible. Scanning is very expensive (around $600 per hour!) and getting the data and analyzing it is very labor-intensive, so we need to get it right first time. Preparation and concentration is very important to get good results — unhappy or uncomfortable participants will not be concentrating on the behavioral task itself, and the results will be affected and hence of little use.
Information for First-Time fMRI Subjects

The day of the scan:

* If applicable, remember to wear contact lenses instead of glasses. Have the prescription with you, if you want to wear glasses. We will fit you with plastic, magnet compatible glasses.
* Do not drink excessive amounts of liquid, especially caffeine (a diuretic -- an fMRI session seems much longer with a full bladder!).
* Do not wear any shirts with metal around the head (e.g., pullovers with zippers). Metal buttons and zippers on pants are okay. In general though we will ask you to change in the hospital clothes.
* Do not use any hairclips and be prepared to remove jewelry.
* For women, if possible, do not wear an underwire bra (the metal can throw off the magnetic field). Sports bras are usually good and we keep a baggy sweater around if you want to wear it. The clasps on the back of a regular bra are not a problem, but avoid wearing bras that have metal parts on the straps.
* Avoid mascara (can contain metal flakes), hair gel (can throw off magnet signal) and wet hair.
* Make sure you know where you are going to meet us and what time you are expected to show up. See directions of the Martinos Biomedical Imaging Center: www.nmr.mgh.harvard.edu/martinos/contact/directions.php
* If anything comes up such that you cannot make your scheduled time, please notify us as soon as possible. Scan time costs regardless of whether or not the subject shows up.

While in the magnet:

* If you notice anything vaguely uncomfortable before you get rolled into the magnet, tell us. Things that are slightly uncomfortable at the start become excruciating by the end. Please keep in mind that once you are in place, you will maintain that exact position for a couple hours.
* As the bed is moving into the center of the bore, moving through the magnetic field may play tricks on your vestibular system and some people feel a bit dizzy. This is normal, and will subside shortly after the bed stops moving.
* Try not to change head or body position during a scan (while the magnet is beeping). If the head moves, it creates artifacts that are usually difficult if not impossible to fix. The position of body parts in the magnetic field distorts it. So if you cross your legs, scratch your head, open your mouth, yawn (inhale deeply), or shift your posture, it can lead to artifacts even if your brain doesn’t move. We try to keep runs as short as possible (ideally 5 minutes) so that you can stay in the same position the whole time.
* **Swallowing can lead to head motion artifacts.** If you can avoid swallowing during a scan, the data quality will be better. If trying not to swallow makes you gag or swallow suddenly, then it's best to just swallow normally.

* Between scans (when the magnet is not beeping), you can swallow freely, however you still can not change your body position or scratch, etc. If you absolutely can't stand it, then it is better to do those things between scans, but is highly discouraged. If it happens frequently, the session will be a waste. Millimeters matter; do your best not to do anything that will move your head from its original position.

* If you have your nose stuffed, you will have hard time breathing and that would cause significant head motion which will compromise the image.

* Try to stay relaxed throughout the session. If you tense up at the beginning of a scan, your head can drift as you settle down and that caused a change in position and motion artifacts.

* If you notice anything weird with the stimuli (e.g., they're upside down or you can't see the display or the screen saver comes on partway through a scan) or have problems with the task (e.g., make mistakes, fall asleep), be sure to tell us after the scan in which it happened.

* You will be given a squeeze ball in case you need to stop the scan midway. You can use this if something goes wrong with the stimuli or if you need to stop immediately. Also the experimenter will communicate with you frequently and you will respond by squeezing the ball.