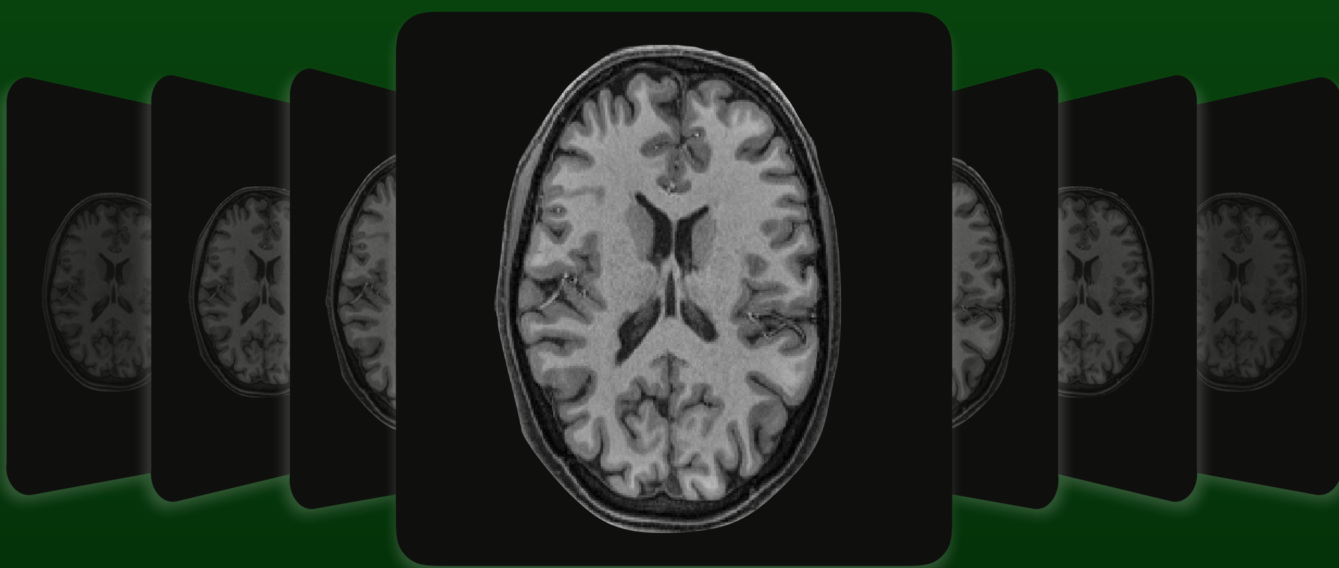
OXFORD NEUROIMAGING PRIMERS

Short introduction to

MRI Safety for Neuroimaging



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PRIMER APPENDIX

MRI Safety for Neuroimaging

Several aspects of MRI safety have already been touched upon in the experimental walkthrough in the main Primer text and in the MRI Physics appendix, but it is worth discussing safety in its own right as it is a very important aspect of MRI. To begin with it is worth stating that although there are some risks with MRI, it is entirely safe and does no tissue damage to the subject, provided that proper precautions are taken. This is different from X-ray, CT, PET or SPECT imaging, where following the proper procedures results in a safe scan, but nonetheless some tissue damage is done and repeated scans are typically advised against. This is not the case for MRI, where repeated scans are common, even in a research environment that comes with no clinical benefit to the subject.

There are some dangers with MRI scans though, and these are largely due to three things: metallic objects experiencing forces due to the magnetic fields present; heating that is induced by the RF fields; or hearing damage from the very noisy environment. We will briefly discuss each of these risks in turn, giving an understanding of their origin and ways to minimise the risks.

The most obvious danger related to MRI is due to the very large magnetic field that is ***always*** present. To get an idea of the strength of this field, the large electromagnets that are used to pick up cars in scrap yards are normally around 1T, whereas we typically use scanners with even stronger fields: from 1.5T to 7T. Hence these fields are easily capable of lifting large metallic objects, and there are reported incidents involving oxygen cylinders, medical trolleys, chairs and patient beds. If such an object gets too close to the scanner it will be very violently attracted to the scanner, well beyond the physical limits of any individual to hold it back, and if a subject is in the scanner at the time (or anywhere between the object and the scanner) they can be hit, pinned down or crushed. The force is easily enough to break bones and hence serious injuries and fatalities can happen from such mishaps. Therefore it is extremely important never to take anything into the scanner room that has not been approved as MR safe. Most facilities have a procedure for checking and labelling items, but if in any doubt whatsoever, do not take something into the scanner room. Instead check with the radiographer or scanner operator, who will have extensive safety training and experience. If the radiographer or operator is already in the scanner room, do not enter the room with any items in order to check with them, just signal for them to come to you. Similarly, all personnel involved with an MRI experiment need to follow these rules, including subjects, assistants, nurses, senior investigators, etc. There is no exception as the danger here is very real.

It is not only large objects that are a problem. Small items such as coins, pens, watches, scissors, tools, needles, jewellery and so forth can all be attracted to the magnet if they contain ferromagnetic materials, and it is hard to know exactly what a lot of things are made of, so never assume that they do not contain ferromagnetic metals. Such small items can be accelerated to very high velocities when approaching the centre of the scanner bore, and can also pass through the other side and return back, causing repeated injuries. Again, there is a substantial risk of serious or fatal injury if such objects are brought into the scanner room, and so it is imperative that anyone entering the room empties their pockets and checks that no such items are on or about their person. It is not uncommon to have subjects change into scrubs or other clothing in order to avoid the potential for them to have things in their pockets. In addition, it is crucial that they are checked to make sure that they don't have hairpins or other items on them. Some items, including certain piercings, can be left in but these must be explicitly tested, screened and approved by the radiographer or operator. Never make an assumption about these yourself, even if the subject reports that they have been scanned with these in before, as it may have been a different type of scanner, or a different part of the body, and the dangers may be quite different.

Related to the last point is the fact that it is not only ferromagnetic materials (those attracted to magnets) that can cause problems. Any metal will interact in some way with the strong magnetic fields. For instance, aluminium is a non-ferromagnetic material but if you try to move a piece of aluminium around in the scanner then it experiences forces on it due to currents that are induced within the metal and these result in a force that resists changes in magnetic field, such as being moved around. Consequently, metal implants within subjects may experience forces on them when the subject is moved into the centre of the scanner (they will also happen even before this, when the subject enters the room, but they are much stronger when closer to the centre of the bore). If the implants are well restrained (such as certain orthopaedic implants and dental work) then they can be safe for the subject, but otherwise they can represent potentially serious risks (e.g., clips on blood vessels can move and rupture the vessels). Therefore it is vitally important that all subjects (and experimenters and other staff) are carefully screened before going into the scanner room. Only trained professionals (e.g., radiographers) are able to determine what implants are safe or not, and in a research setting, where there is no clinical benefit or medical need for the scans, it is common to play it safe and just not scan subjects that have implants. The extreme example of an implant that is not MRI safe is a pacemaker. People with pacemakers are often not even allowed into MRI facilities as any field over 5 gauss (50 micro tesla) is potentially lethal.

Another risk for MRI participants is associated with burns due to RF fields and induced currents. These most often occur when a large conductive loop is present, such as if subjects cross their legs or arms, or when conductive materials are present near or in the skin. Although the body is not highly conductive it is still possible for the strong magnetic fields in MRI to induce some currents, and if a large loop is present the currents will be bigger and have more potential to cause skin burns. These are quite uncommon though, and easily avoided by making sure that the subject does not cross their arms or legs, and this includes avoiding touching fingers, thighs, calves, ankles or feet together. Placing some clothing over the legs, or putting a pillow in between, in sufficient to stop this being a problem. Other risks for burns include materials that contain metallic fibres (and antibacterial silver fibres are becoming more commonplace in clothing, though far from obvious) and metallic pigments in either clothing or tattoos. Again, decisions related to such things should be made by the trained radiographers or operators.

Finally, there is also a lot of noise when the MRI scanner is running. This is because of the large forces exerted on the gradient coils when they are switching fields, as they behave much like the coils in a speaker cone. Consequently they vibrate and certain frequencies are mechanically amplified by the scanner and result in noises as loud as a jet engine. Therefore it is crucial that subjects wear hearing protection, either ear defenders/headphones or earplugs or both. It is important that these are fitted well, as badly fitted ones do not reduce the noise levels sufficiently and can result in hearing damage. However, only the people who will be in the scanner room during the actual scanning (normally only the subject, but can also include nurses, experimenters or guardians/partners, depending on the experiment) need to have this protection, since when the scanner is idle the gradient coils are not used. The main B_0 field is still on, as it is created by the superconducting coil and is never turned off, but the gradients are not used during idle periods and so when positioning subjects in the scanner room the radiographers, operators, experimenters, etc., do not need to have hearing protection, though they always need to be vigilant about the other risks.

Although the preceding paragraphs elaborate some concerning risks, MRI is actually a very safe imaging modality. It is very important to be aware of the risks and able to work safely, in the same way that you need to be if you drive a car or use the roads, but that should not discourage you from using MRI. The safety record of MRI is extremely good and those that work with MRI (e.g., radiographers, operators, physicists) are very well trained, though everyone involved needs to appreciate risks and act appropriately. With respect to the subject, no known harmful effects of MRI are known and so it is one of the best modalities for research studies, because of the large flexibility but also because it can be used on a wide range of subjects, including even babies and pregnant women.

The aim of this appendix is to introduce you to the issues related to MRI safety. You should not consider this a proper training in MR safety, merely something to introduce you to the topic. Every MRI centre should conduct MRI safety training and experimenters should not be allowed to scan, or certainly not allowed into the room with the scanner, unless they have done the MR safety training that the facility mandates. This is very important and is often a condition of even entering such a facility, as careless actions can easily and very quickly lead to serious injuries or even fatalities. Thankfully such incidents are very uncommon in MRI, but that is largely due to everyone being suitably trained and aware of the risks. So make sure that you seek out appropriate safety training at your facility.