

Dear reader,

Welcome to the Spinoza Centre MRI facilities! Running or assisting with running MRI experiments at the Spinoza Centre requires certification for MR safety and optionally as MR operator. To become certified you have to complete the following steps:

MR safety:

- Study this reader carefully.
- Read chapter 2 from Huettel, Song and McCarthy, Functional Magnetic Resonance Imaging.
- Read the wiki entries relevant to your project.
- Complete the screening form and have it checked by the SC staff to make sure you can safely enter the MRI (control) room.
- Follow an instruction (approximately one hour) on MR procedures and safety by the SC staff.
- Pass the safety exam consisting of a theoretical (written) and practical part (screening a subject).

MR operator:

- Obtain your MR safety certificate.
- Practice operating the scanner under the supervision of the qualified (certified) user assigned to train you. Note that the number of required training sessions differs between people and is based, amongst others, on the previous skill level and experience with MRI scanners.
- Show you have mastered operation of the scanner by running a (pretend) session of your experiment overseen by someone from the SC staff.
- Pass a formal examination, consisting of: a) being able to answer questions with regards to safety and safety procedures (written exam) b) being able to answer questions with regards to the use of the scanner.

Don't sign up for the examination until you think you are ready, i.e. when you feel comfortable with the safety procedures and/or working around the scanner. It is very important that you have a good overview of the workflow with regard to safety and instruction and handling of subjects.

Even after finishing the course, do not hesitate to contact SC staff or approach any of the other qualified MR users for further questions or recommendations. Have fun scanning!

## Contents

1. Certification levels
2. Relevant people
3. Safety zones
4. MRI associated risks and effects
  - a. Static magnetic field
  - b. Gradient system
  - c. RF system
  - d. Magnet quench
5. Emergencies, or what to do in case of
6. Preparing for an experiment
  - a. Subject screening
  - b. Scanner room preparation
7. During the experiment

## 1. Levels of certification – responsibilities and rights

### MR operator

After successfully completing the operator exam, you are ready to independently run an MRI experiment. You get access to the control room (via your badge) and access to the scanner room (via the code to the key locker). As MR operator:

- You have completed the safety certification.
- You have mastered operation of the MRI scanner, including table operation, planning and running scans, and basic troubleshooting.
- You are in charge during the entire experiment. If multiple researchers with MR operator certification are present, one should be appointed MR operator for that scanning session.
- You are responsible for the safety of your subjects as well as your colleagues, interns and all others that are present during the experiment. This means
  - o you perform a second screening by verbally checking all paper screening forms with subjects and colleagues etc.;
  - o you determine who is allowed to enter the scanner room, and perform the visual screening of all persons entering the room;
  - o you keep the number of people in the control room limited to what is needed to perform your experiment;
  - o you determine if a situation warrants quenching the magnet;
  - o in case of emergency you start the physical evacuation of a subject.
- You are responsible for the proper conduct of those that assist with your experiment.
- You are responsible for staying on time and leaving the scanner environment tidy for the next scanning session.

### Safety certified

After successfully completing the safety training (presentation, tour of the building and evacuation practice) and examination (both written and practical), you are ready to assist during an MRI experiment. You get access to the control room via your badge. Being safety certified;

- You are aware of the risks associated with the MRI scanner and know where and when they are present
- You are allowed to
  - o be in the MR control room by yourself;
  - o do the primary MRI screening of subjects and others that are present during an experiment using the screening form, and subsequently take them into the MR control room.
- Unless you have explicit permission from the MR operator, you are
  - o not allowed to enter the scanner room without permission of the MR operator;

- not allowed to operate the scanner (table and user interface);
  - not allowed to press the quench button.
- In case of an evacuation, you are the one notifying emergency services (AMC and ERO personnel).

### **No certification**

It is possible to assist with experiments without taking part in the full certification procedure. This can be an interesting option if your role is limited to interaction with the subject before and after the actual scanning, and/or in case of short-lasting internships. You are still required to attend the safety tour of the building, and are advised to attend the safety presentation. Several restrictions apply:

- You do not get access to the MR control room via your badge.
- You are not allowed to be in the MR control room by yourself.
- You do not take part in the MRI experiment. This means that
  - you are not involved in the screening of subjects, colleagues etc.;
  - you are not allowed to operate any part of the MRI scanner;
  - you are not allowed to enter the MRI scanner room;
  - you are not involved in the evacuation process.
- The number of people present without and with safety certification should be balanced i.e. roughly equal; this is left to the discretion of the MR operator.

## 2. Relevant people

- MR safety officer (Diederick Stoffers):
  - o Responsible for the safe operations of the MR facility
  - o Final say in safety-related matters, e.g. inclusion or exclusion of subjects, custom (peripheral) equipment
- Spinoza staff (Mayca Thijssen, Wietske van der Zwaag, Diederick Stoffers)
  - o Handle booking logistics
  - o Go-to people for questions about or malfunctions of MRI scanners or peripheral equipment
  - o Get in touch with Philips in case of unsolvable problems
- ERO "Emergency Response Officers" / BHV "bedrijfshulpverlening"
  - o Trained personnel who can help out with first aid, evacuation and emergency services.
  - o Should be called in case of an emergency
  - o While there are people working at the Spinoza Centre scanners there should always be an ERO in the building. Most members of Spinoza staff and all scanning assistants are EROs.
- Principal investigator / budget holder
  - o Ultimately responsible for conductance of researchers and ethics approval
  - o A list of PIs can be found on the Spinoza website



## 3. Safety zones

- Waiting area (Xs-01-110) or preparation room (Xs-01-112 / Xs-01-120):
  - o This is where you screen subjects, colleagues and visitors.
  - o People are only allowed to continue to the MRI control room with a completed and approved screening form. Visitor screening forms have to be approved by someone with an MR safety certificate, subject screening forms have to be approved by the MR operator.
- MRI control rooms:
  - o Make sure to restrict direct access to the MRI rooms for subjects and others who are not associated with your study.
  - o Special note for the **7T control room**: people with active implants (pacemakers, neurostimulators) may not enter the 7T control room! Also, bank cards and cell phones are not guaranteed to survive within the 5 Gauss zone so keeping them on the desk is at your own risk.
- Scanner rooms:
  - o This sign says: "Sterk magneetveld; dag en nacht in werking", or: "Strong magnetic field, day and night". As the sign says, an extremely strong magnetic field is present at all times. The magnetic field gets stronger towards the magnet, and towards the middle of the bore.

- The MR operator screens all persons for contraindications and (removable) metal objects before allowing access. Screening includes co-researchers and guests!
- Do not open the door to the scanner room until you are convinced all persons entering the room have removed all metal from their bodies.
- Keep the door closed, also when setting up your equipment and placing your subject in the scanner. This makes it more difficult for people to enter the scanner room unnoticed. [This also prevents subjects from walking into the control room and directly progressing into the scanner room.]
- Keep the number of people that go into the scanner room to the minimum required for the experiment.
- Always **lock the MR door** and store the key when leaving the control room.
- Mock scanner:
  - To access the mock scanner lab you cross the MRI control room zone.
  - When using the mock scanner, make sure to accompany your subjects at all times.
  - Point out the location of the toilet and instruct them not to wander into the control room area!

## 4. MRI associated risks and effects

The MRI scanner consists of several essential parts for its functioning: a **strong, static magnetic field** to generate a coherent signal from the proton spins, a **radiofrequency source** to manipulate the proton signal such that it can be measured, and **magnetic field gradients** to allow for spatial localization of the signal within the body. Each of these components has associated safety risks. It is important to know the risks and effects associated with each of the components, and have an idea of their underlying causes. A short overview along with their practical consequences is provided here, most of these topics are covered in more detail in Chapter 2 of Huettel et al.

### *Static magnetic Field*

First of all, it is very important to realize that **the static magnetic field is always on**, not only when a scan is running! Therefore you should follow the MRI safety procedures at any time. The static magnetic field pulls all ferromagnetic materials in its vicinity (the so called 'fringe field') towards the scanner and therefore **no ferromagnetic materials are allowed in the scanner room**.

Examples include: coins, pens, buckles, scissors, hair clips, staples, and screws (e.g. in chairs). Please note that not all materials are ferromagnetic.

Material types

Ferromagnetic	Non-ferromagnetic, conductive	Other
Iron	Titanium	Plastics
Cobalt	Copper	Wood
Nickel	Aluminium	Glass
		

In the scanner room the lightest object can turn into a dangerous **projectile!** You can find many examples on Youtube, e.g. "[How dangerous are magnetic items near an MRI magnet](#)") and "[basic MRI safety scissors](#)"). Also ferromagnetic objects *in the body* (e.g. metal splinters) can lead to serious injury because of their tendency to **align themselves with the magnetic field**, which can cause serious internal injuries. Lastly, the static magnetic field will induce a current in all conducting materials being moved into that field, which in turn causes a **force opposing motion** of the object into the magnetic field. This can be clearly felt when positioning e.g. an EEG amplifier at the scanner, but can also affect large (non-ferrous) metal implants and consequently be felt by subjects.

Another effect of the static magnetic field is that it **disturbs electronic components** unless these are explicitly designed to work in the magnetic field. This means that people with active implants such as pace makers and neurostimulators are never allowed to go into the scanner room. Note that **at the 7 Tesla** the hazardous area for active implants extends outside of the scanner room into the control room, indicated with a **solid red line**. This underscores the importance of thoroughly screening everyone before allowing access to the MRI control room!

A system for categorizing the risk for objects has been developed. There are three categories: *MR safe*, *MR conditional* and *MR unsafe*:

MR safe	MR conditional	MR unsafe
 <p>These objects have no safety hazards in the MR environment. Participants with MR safe devices have no scanning restrictions.</p>	 <p>These objects may enter the MR environment only under very specific conditions (described on the label). Participants with MR conditional devices should not be scanned unless the conditions for safe use are met.</p>	 <p>These objects are not allowed into the MR environment. Participants with MR unsafe devices should not be scanned.</p>

*Gradients: Noise, PNS*

During an MRI scan, the magnetic field is switched in time very rapidly. The time-varying magnetic field has two main effects. First, it creates a mechanical force on the scanner itself which, for most scans, produces a **loud noise**. For this reason double hearing protection should be provided to the subjects using headphones and earplugs. In addition, the time-varying magnetic field can cause currents to flow and stimulate nerves and muscles inside the subject's body, which in turn can lead to a tingling or twitching sensation. While the effect is harmless, it may cause serious discomfort to your subject. If you run a scan with increased risk of PNS the scanner will inform you, and you should in turn inform your subject of its potential occurrence.

*RF: SAR, burns*

During an MRI scan, radiofrequency (RF) waves are used to manipulate the signal from the proton spins. This causes energy to be deposited inside the subject's body. While the scanner strictly regulates the maximum amount of power that can be delivered to the body, it is important to correctly position your subject and equipment to prevent burns resulting from local heating of the tissue. You should prevent contact between the subjects' skin with the scanner bore itself, conducting wires and also other parts of the skin (e.g. arms and torso); see patient positioning for full instructions. Certain metal implants can also cause a local increase of energy deposition, which has the potential to cause internal tissue damage. If you want to scan a subject with an implant it is therefore of great importance that the implant has been tested and determined safe at the relevant scanning conditions (e.g. field strength). Check the annotated screening form or [mrisafety.com](http://mrisafety.com) for more information, or ask Spinoza staff to help assess the safety.

*Magnet quench*

The scanner magnet is superconducting, which means current is able to flow through the wires without resistance. Super conductance is attained by cooling the wires with liquid helium. A quench by – spontaneous or deliberate – local heating of the wires, which leads to loss of the superconducting properties and hence further heating due to increasing resistance, causing a

cascade across the whole magnet. The heat that is produced in this process causes the helium in the magnet to evaporate through the quench pipe mounted on top of the magnet. There is a very small chance that the helium enters the scanner room. This will initially cause a white fog and leads to asphyxiation hazard due to the displacement of oxygen and frost bite. Do not enter the room if this happens!

## 5. EMERGENCIES, OR WHAT DO IN CASE OF

In general you should alert the ERO/BHV officer and if necessary SC staff. Phone and pager numbers can be found next to the scanner console. Procedures for contacting emergency services in case of fire or medical emergencies are located at the scanner console.

- **A fire (in the MR room, in the technical room, in the building)**
  - o Abort your experiment and if safe, evacuate your subject. Follow the fire emergency procedure located at the scanner console.
  - o Only attempt to extinguish the fire if it is small and contained. Make sure you know the location of the MR safe fire extinguishers.
  - o If the fire is in the MR room, make sure everyone entering the scanner room is screened for ferromagnetic objects (oxygen tanks, extinguishers, tools etc., but also pacemakers and other implants).
  - o If the fire is in the technical room, access routes away from the scanner should preferentially be used.
  - o In case of a building evacuation, wait for the ERO to escort you outside.
- **A subject squeezing the alarm button**
  - o Responds after contacting via intercom: ask whether to stop experiment or not.
  - o No response after contacting via intercom: start scanner evacuation procedure (see below).
- **A subject becoming unwell in the scanner room (e.g. (suspected) panic attack, heart attack, epileptic seizure)**
  - o Start the scanner evacuation procedure (see below).
  - o If necessary follow the medical emergency procedure located at the scanner.
  - o Note: do not bring the AED into the scanner room, it is NOT MR safe.
- **An object getting stuck to the magnet (keys/pens/screwdriver or chairs/larger items)**
  - o Abort scanning, alert SC staff, if applicable evacuate subject from MR scanner room.
  - o Do not quench the magnet! If necessary Philips will remove the field gradually, preventing loss of helium and potential damage to the magnet.

- **A person getting trapped by a ferromagnetic object**
  - o Only in case of serious bodily harm: quench the magnet, start emergency procedure. A quench is effected by pressing one of the quench buttons. Make sure you know where to locate them.
  - o Try to determine whether or not evacuation from the scanner might (further) hurt the person.
- **A (spontaneous) quench**
  - o With subject in scanner: check for signs of helium in the room (low oxygen percentage, white clouds, ice crystals) to determine whether it is safe enough to enter yourself and evacuate the subject.
  - o Without a subject in the scanner: leave the scanner room.
  - o In the very rare occurrence that the helium does not flow out through the quench pipe but enters the room, DO NOT enter the scanner room and leave the door closed. Open all other windows and doors and go to the waiting area.
- **Doubts regarding subject compatibility**
  - o Ask the SC staff, specifically the MR safety officer.
  - o In case you cannot reach staff members or the safety officer: your subject must be excluded.
- **Incidental findings**
  - o See the procedure located at the scanner and on the Spinoza wiki.

**Scanner evacuation procedure:**

- Remove the table with the subject from the scanner (unless he or she is trapped).
- If the subject cannot be removed from the scanner room, the MR Operator has to make sure no one (including ambulance, hospital personnel etc.) can enter the scanner room without having been screened.
- If necessary call **88** with the fixed phone on the desk to reach emergency services. You are in building Xs. Stay with your subject in the MR control room.
- Alert the ERO/BHV officer of the day. Also, have someone wait at the front door to welcome emergency personnel. Make sure to take a badge to the entrance. **NEVER** leave your subject alone.

## 6. Preparing for an experiment

### Subject screening

**Start at home:** if possible instruct the participant to wear or bring a plain (long sleeve) T-shirt and (cotton) sweat pants to the experiment, leave all jewelry including piercings at home, and not to use any mascara. This improves the workflow and minimizes the chance that you have to send your subject home, e.g. because of a piercing that won't come out.

**MR screening:** the screening process takes place in the waiting or preparation areas. A **completed and approved screening form is required for all persons** to continue to the MR control room. This includes colleagues, people accompanying the subject and guests. Preferably, companions stay in the waiting area. The completed form should be verbally reviewed with the subject by the designated MR operator. An annotated version of the screening form is available on the Spinoza wiki. If you have any doubts with respect to MRI compatibility of your subject contact the MR safety officer. If you are not sure and no SC staff is around, abandon the scan (or find another participant).

If you routinely work at the MRI scanners you only have to fill in a new screening form if the answer to one or more of the questions on the screening form changes. In this case make sure to notify the SC staff to arrange a new approved screening form.

**Informing participants:** summarize the content of your information letter. Inform the subject that

- the MRI scanner is a strong magnet, hence they have to remove all objects from their body to prevent things flying into the scanner.
- the MRI scanner makes a loud noise, hence they will have to put in ear plugs and will additionally wear headphones which are also used for communication, or (at 7T) additional padding for sound insulation.
- the MRI scanner makes detailed images so they have to lie very still for the images to be sharp.
- Due to the scanner noise, verbal communication with the MR operator is only possible in between scans, hence they are given an alarm to indicate they want to be taken out of the scanner.
- they have the right to abandon the experiment at any time without giving any reason.
- they consent to being informed of a medically relevant incidental finding (see subject info and informed consent form for details); they have to realize that not hearing anything after the experiment should not be taken as a sign of good health, and follow up complaints with their general practitioner as they would normally do

**Remove all loose and metal objects:** Subjects have to remove these, including but not limited to:

- Anything they might have in their pockets
- hair clips and elastic bands, watch, jewelry (including piercings), belt
- Sweater with zipper (because of artefacts)

- Underwired bra, shoes

In case subjects have objects on their body that they can't or won't take off (e.g. festival bracelets), you must ensure that they do not contain any metal parts. If you can't establish this, you have to exclude your subject from the experiment.

Inform participants with **tattoos or other permanent cosmetics** that there is a very small chance it will contain some metal, which might cause a temperature increase in the tissue. Instruct them to push the alarm bell as soon as they feel a tingling or burning sensation at the site of the tattoo.

If subjects arrive with wet clothes or clothes that leave a lot of skin uncovered (tops, shorts) provide them with a T-shirt and/or pants.

### Scanner room preparation

If at all possible, prepare the scanner room before the arrival of your participant, or while the participant is in the waiting room.

- Place paper on the table and in the coil.
- Put earplugs and hair net on the table.
- Replace the ear covers around the headphones.
- Position / switch on any of the following: button boxes, respiratory belt, PPU, eye tracker, stimulus display.
- Make sure you use the correct RF coil and it is plugged in properly
- Make sure you use the correct mirror (as there is one specifically intended for use with the eye tracker).
- Enter your subject into the administration before placing him/her in the scanner, as the scanner software will often not recognize the laser-defined position of the subject.
- Participants wearing glasses can use the MR compatible glasses. Reserve some time to test them.

## 7. During the experiment

### Subject placement

- The MR operator should only open the door to the scanner room after making sure the participant and possible colleagues are free of metal: make sure participants and colleagues actually put their hands in their pockets, let people with long hair go through their hairs with their hands to make sure there are no clips or elastics, and let people show you their wrists. Check again for the belt. Lead the way in and after entering close the door behind you.
- Provide the participant with earplugs (and proper instructions on how to insert them), a hair net, and the alarm ball. Let the subject press the alarm bell and check whether the alarm sounds in the control room. If applicable position button boxes, respiration belt, PPU etc. Give subjects the headphones and let them lie down in the head coil. If necessary use extra padding to fixate the head. Make sure the plugs of the head coil are properly connected.

- To minimize risk of peripheral nerve stimulation and heating of the skin the forming of conductive loops should be prevented by **avoiding contact between skin and wires, the scanner, and other parts of skin**. Place towels or pads between arms and wires and scanner bore. Instruct subjects not to cross their hands or legs. Keep conducting wires as straight as possible and preferably along the long axis of the scanner.
- Place the triangular pillow under the subject's knees for comfort.
- Position the subject with the help of the laser. Stay with him/her while they move into the scanner. If the subject seems uncomfortable, remove him/her immediately.
- Adjust the air flow in the scanner bore, either via the button at the scanner or through the software.
- If desired switch off the light in the bore and/or that of the ring.
- After leaving the scanner room, first check whether communication via the subject intercom works.

#### **During scanning**

- Please write down error messages in the log (in English) and report them to SC staff.
- Take note of the climate in the control and scanner room. Report to the SC staff if it is unusually cold, warm, humid etc. The scanner itself will bring up a warning if humidity in the scanner or technical room is above 80%.
- Immediately report to the SC staff all adverse and near adverse events (e.g. objects flying into the scanner, subjects becoming unwell) even if you manage to handle the situation yourself.
- Know where to find the incidental finding protocol and how to use it following your own ethics approval.