

Structural and functional neuroimaging

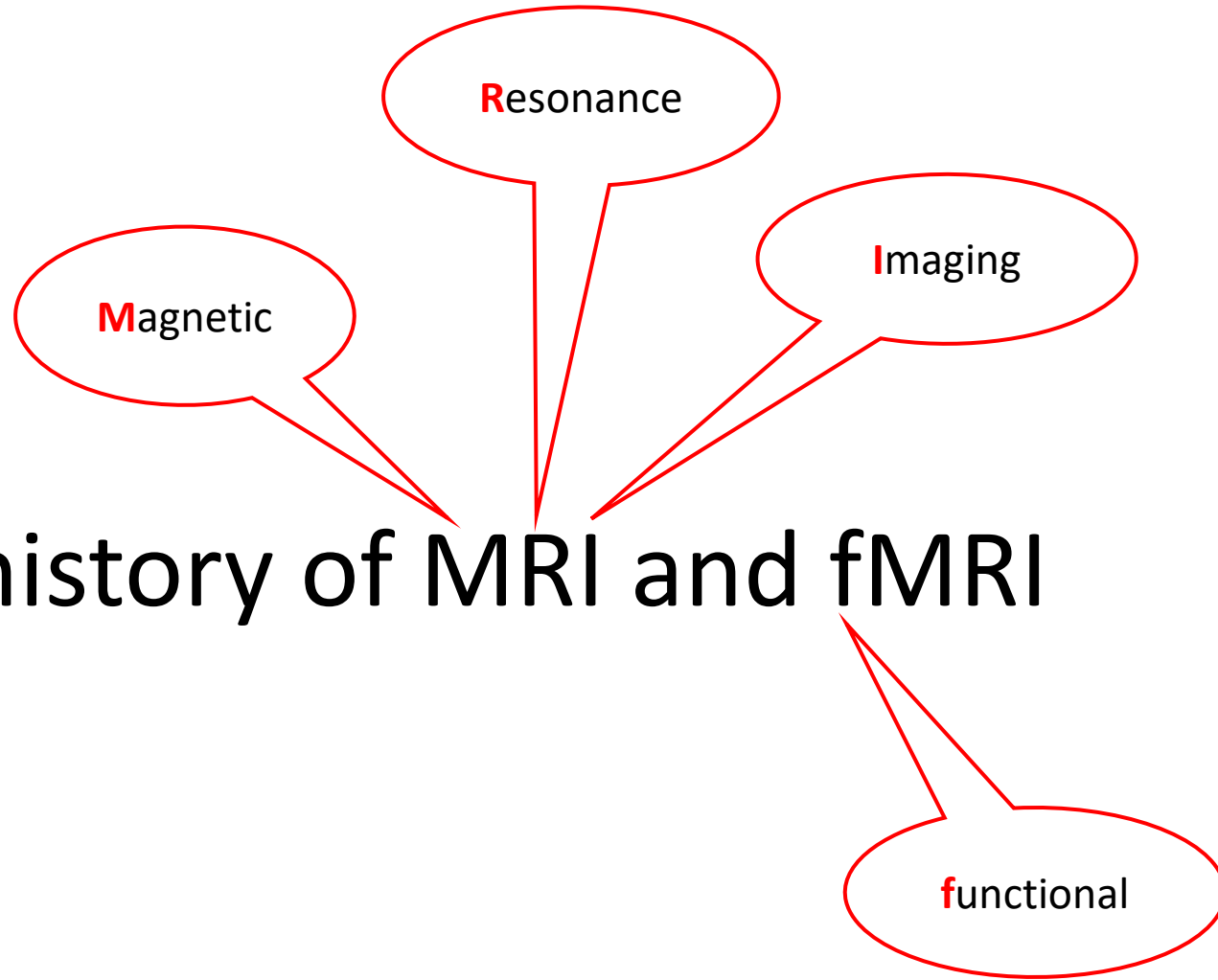
Dr. Lavinia Carmen Uscătescu

May 20th , 2024

Outline

1. Brief history of MRI and fMRI
2. MRI hardware
3. MRI – structural imaging
4. fMRI – functional imaging
 - (a) the BOLD signal
 - (b) noise and pre-processing steps
 - (c) experimental design
 - (d) analysis types
 - (e) levels of inference
5. Safety

Brief history of MRI and fMRI



1937



Isidor Isaac Rabi

The Nobel Prize in Physics 1944

Prize motivation: "for his resonance method for recording the magnetic properties of atomic nuclei"

Protons and neutrons in nuclei act like small, rotating magnets. Atoms and molecules therefore align in a magnetic field. In 1938, Isaac Isidor Rabi passed a beam of molecules through a magnetic field. When the beam was exposed to radio waves, the direction of rotation could be changed, but only in certain stages, in accordance with quantum mechanics. When the atoms returned to their original positions, they emitted electromagnetic radiation with uniquely characteristic frequencies.

APRIL 15, 1937

PHYSICAL REVIEW

VOLUME 51

Space Quantization in a Gyration Magnetic Field

I. I. RABI

Columbia University, New York, N. Y.

(Received March 1, 1937)

The nonadiabatic transitions which a system with angular momentum J makes in a magnetic field which is rotating about an axis inclined with respect to the field are calculated. It is shown that the effects depend on the sign of the magnetic moment of the system. We therefore have an absolute method for measuring the sign and magnitude of the moment of any system. Applications to the magnetic moment of the neutron, the rotational moment of molecules, and the nuclear moment of atoms with no extra-nuclear angular momentum are discussed.

<https://journals.aps.org/pr/abstract/10.1103/PhysRev.51.652>

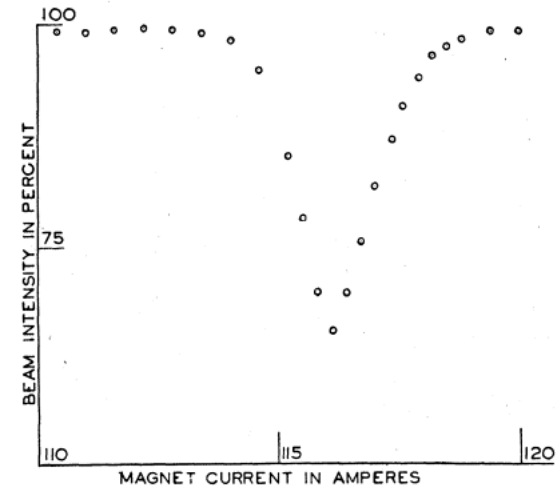


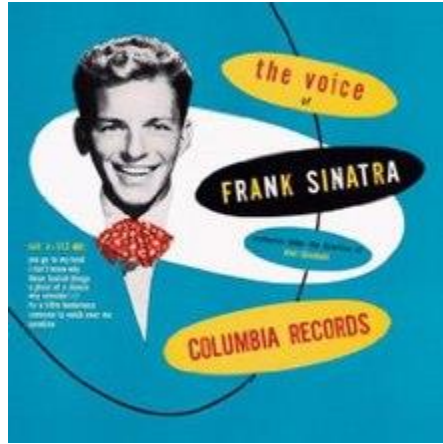
FIG. 1. Curve showing refocused beam intensity at various values of the homogeneous field. One ampere corresponds to about 18.4 gauss. The frequency of the oscillating field was held constant at 3.518×10^6 cycles per second.



Isidor Isaac Rabi
(1898 – 1988)



1946

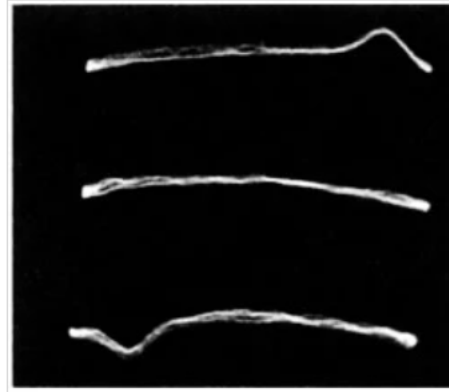


The Nuclear Induction Experiment

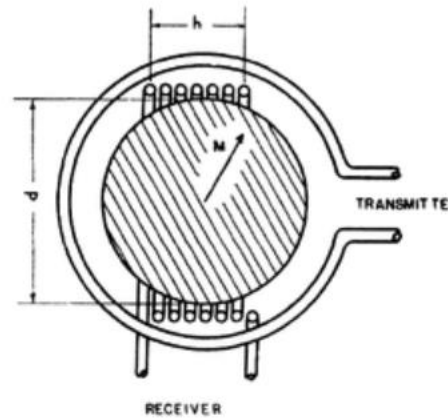
F. **BLOCH**, W. W. HANSEN, AND M. **PACKARD**
Stanford University, California
(Received July 19, 1946)

The phenomenon of **nuclear induction** has been studied experimentally. The apparatus used is described, both as to principle and detail. Experiments have been carried out in which the **signals from protons contained in a variety of substances were observed**. The results show the role played by the **relaxation time**, which was found to vary between about 10^{-6} second and many seconds.

<https://journals.aps.org/pr/abstract/10.1103/PhysRev.70.474>



First NMR signals from water. Image reprinted with permission from Bloch, F., Hansen, W. W. and Packard, M. *Phys. Rev.* **70**, 474-485 (1946); courtesy of the American Physical Society.

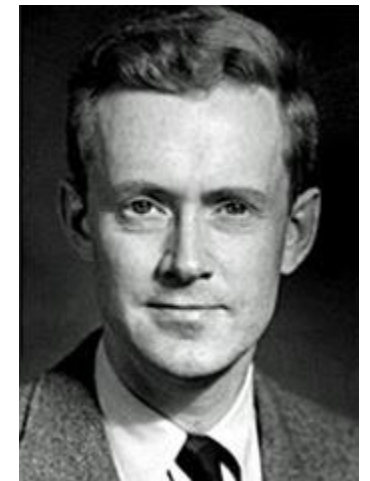


Bloch's apparatus. The **water** sample (hatched circle) is **surrounded by transmitter and receiver loops**. The main magnetic field (perpendicular to the plane) is not shown.

The Nobel Prize in **Physics 1952** was awarded jointly to **Felix Bloch** and **Edward Mills Purcell** "for their development of new methods for **nuclear magnetic precision measurements** and discoveries in connection therewith"

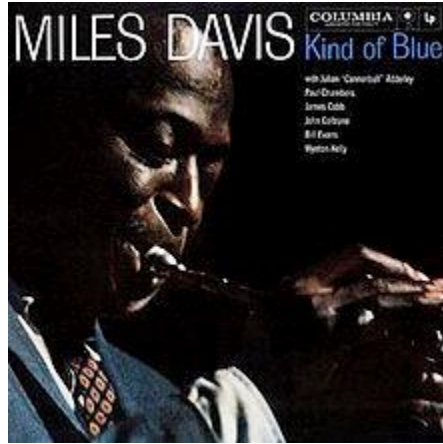


Felix Bloch
(1905 – 1983)



Edward Purcell
(1912 – 1997)

1959



> Science. 1959 Dec 11;130(3389):1652-3. doi: 10.1126/science.130.3389.1652.

Blood Flow Rates by Nuclear Magnetic Resonance Measurements

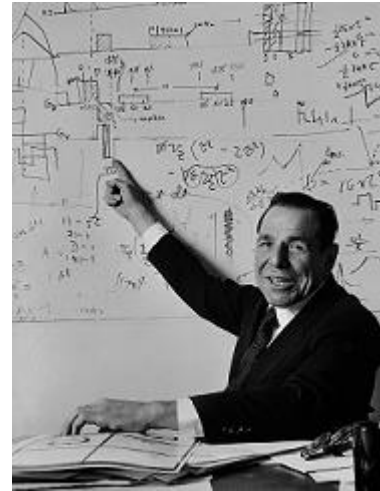
J R Singer

PMID: 17781388 DOI: 10.1126/science.130.3389.1652

Abstract

Blood flow rates may be determined by nuclear magnetic resonance relaxation time measurements. A set of experiments carried out on the flow of blood in mice tails has demonstrated the feasibility of the scheme. Two simple measurement methods are described, and the pertinent equations are given. In addition, some procedures for using nuclear magnetic resonance and electron paramagnetic resonance for tracing the flow of specific materials in the body are outlined.

<https://pubmed.ncbi.nlm.nih.gov/17781388/>



Jerome R. Singer
(1921 – 2019)

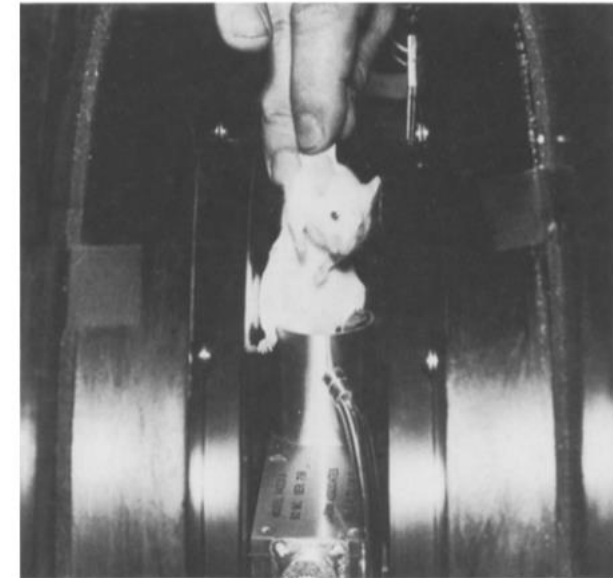
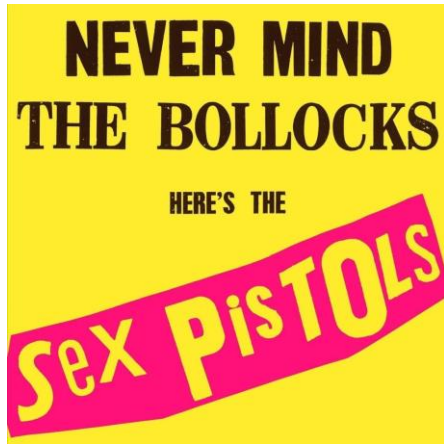


Fig. 4. The first NMR measurement of blood flow in vivo. The experiment was carried out in 1959. The mouse has been sedated by ether vapor, and the volume of blood flow was observed.



1977



> *Physiol Chem Phys.* 1977;9(1):97-100, 108.

NMR in cancer: XVI. FONAR image of the live human body

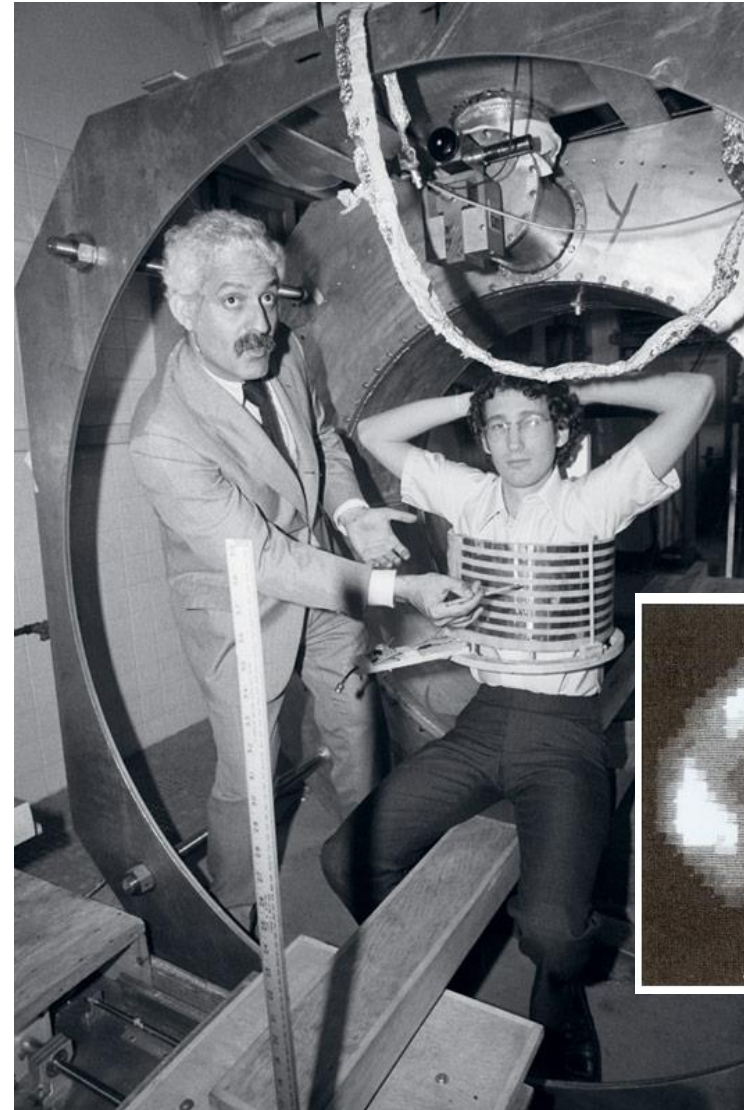
R Damadian, M Goldsmith, L Minkoff

PMID: 909957

Abstract

The FONAR technique that achieved the first chemical image of the **live human being** is described. Color and black-and-white video images of a **cross-section through the chest** at the level of the eighth thoracic vertebra were generated. The imaging showed the **heart** and mediastinum in the midline **between the left and right lungs** with the heart encroaching on the left lung space as it does at this level. Also seen was the descending aorta just left and anterior to the vertebral body.

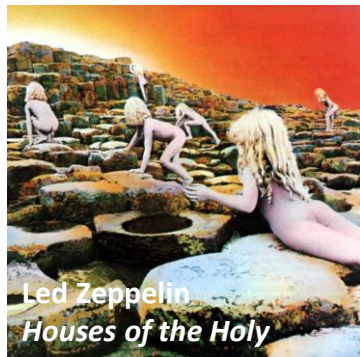
<https://pubmed.ncbi.nlm.nih.gov/909957/>



Raymond Damadian (1936 – 2022) – left – and Larry Minkoff, his postdoc (right).

Cross-section through the chest (bottom).

1973



Led Zeppelin
Houses of the Holy



Paul Lauterbur
(1929 – 2007)

Letter | Published: 16 March 1973

Image Formation by Induced Local Interactions: Examples Employing Nuclear Magnetic Resonance

P. C. LAUTERBUR

Nature 242, 190–191 (1973) | [Cite this article](#)

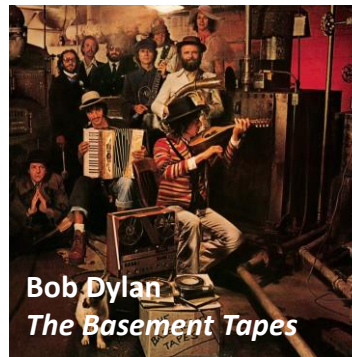
19k Accesses | 2450 Citations | 252 Altmetric | [Metrics](#)

AN image of an object may be defined as a graphical representation of the spatial distribution of one or more of its properties. Image formation usually requires that the object interact with a matter or radiation field characterized by a wavelength comparable to or smaller than the smallest features to be distinguished, so that the region of interaction may be restricted and a resolved image generated.

<https://www.nature.com/articles/242190a0>



1975



Bob Dylan
The Basement Tapes



Peter Mansfield
(1933 – 2017)

"Diffraction" and microscopy in solids and liquids by NMR

P. Mansfield and P. K. Grannell

Phys. Rev. B 12, 3618 – Published 1 November 1975

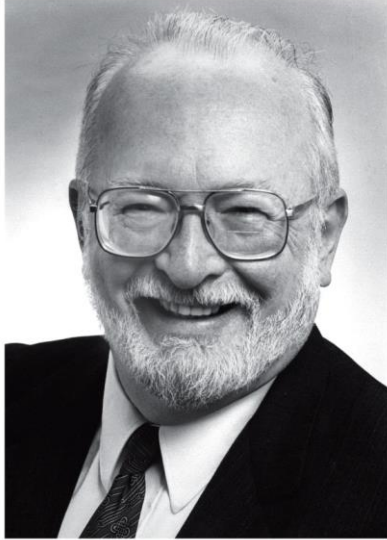
ABSTRACT

A new approach to the study of structure in solids and liquids by pulsed NMR is described. Either multiple-pulse line-narrowing sequences or single pulses, together with an applied linear magnetic field gradient are used. The theoretical analysis highlights the analogy with plane-wave scattering in optics and is illustrated experimentally with examples of diffraction by ordered and disordered systems and image formation or microscopy. The factors affecting the resolution of the technique are discussed, and the problems of reconstructing micrographs from their projections considered.

<https://journals.aps.org/prb/abstract/10.1103/PhysRevB.12.3618>



THE NOBEL DISPUTE

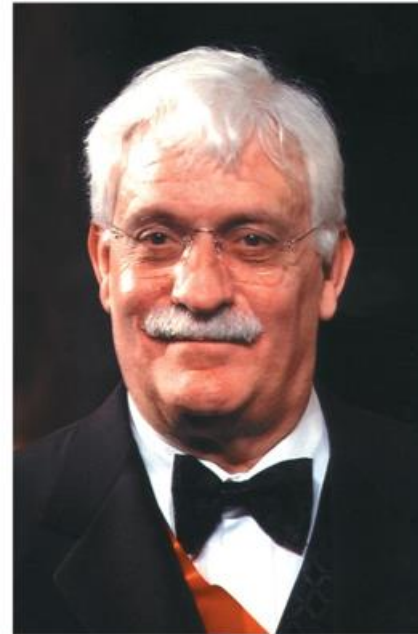


FUNCTIONAL MAGNETIC RESONANCE IMAGING 3e, Box 1.2 Figure 2
© 2014 Sinauer Associates, Inc.



Paul Lauterbur (left) and Peter Mansfield (right) shared the 2003 Nobel Prize in Physiology or Medicine for contributions to the development of MRI.

<https://www.ncbi.nlm.nih.gov/pmc/articles/PMC214010/>



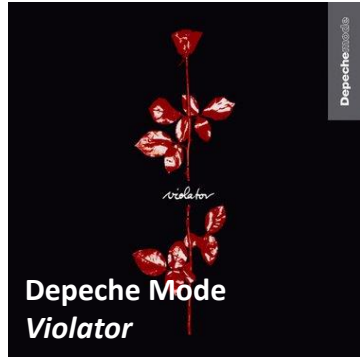
Raymond Damadian was not awarded the Nobel Prize.

<https://www.nytimes.com/2004/03/23/science/denied-nobel-for-mri-he-wins-another-prize.html>



FUNCTIONAL MAGNETIC RESONANCE IMAGING 3e, Box 1.2 Figure 1 (Part 2)
© 2014 Sinauer Associates, Inc.

1990



Seiji Ogawa
(1934 -)

[Proc Natl Acad Sci U S A.](#) 1990 Dec; 87(24): 9868–9872.
doi: [10.1073/pnas.87.24.9868](https://doi.org/10.1073/pnas.87.24.9868)

Brain magnetic resonance imaging with contrast dependent on blood oxygenation.

[S Ogawa](#), [T M Lee](#), [A R Kay](#), and [D W Tank](#)

▶ [Author information](#) ▶ [Copyright and License information](#) ▶ [PMC Disclaimer](#)

Abstract

Paramagnetic deoxyhemoglobin in venous blood is a naturally occurring contrast agent for magnetic resonance imaging (MRI). By accentuating the effects of this agent through the use of gradient-echo techniques in high fields, we demonstrate in vivo images of brain microvasculature with image contrast reflecting the blood oxygen level. This **blood oxygenation level-dependent (BOLD)** contrast follows blood oxygen changes induced by anesthetics, by insulin-induced hypoglycemia, and by inhaled gas mixtures that alter metabolic demand or blood flow. The results suggest that BOLD contrast can be used to provide **in vivo real-time maps of blood oxygenation in the brain** under normal physiological conditions. BOLD contrast adds an additional feature to magnetic resonance imaging and complements other techniques that are attempting to provide positron emission tomography-like measurements related to regional neural activity.

<https://www.ncbi.nlm.nih.gov/pmc/articles/PMC55275/>

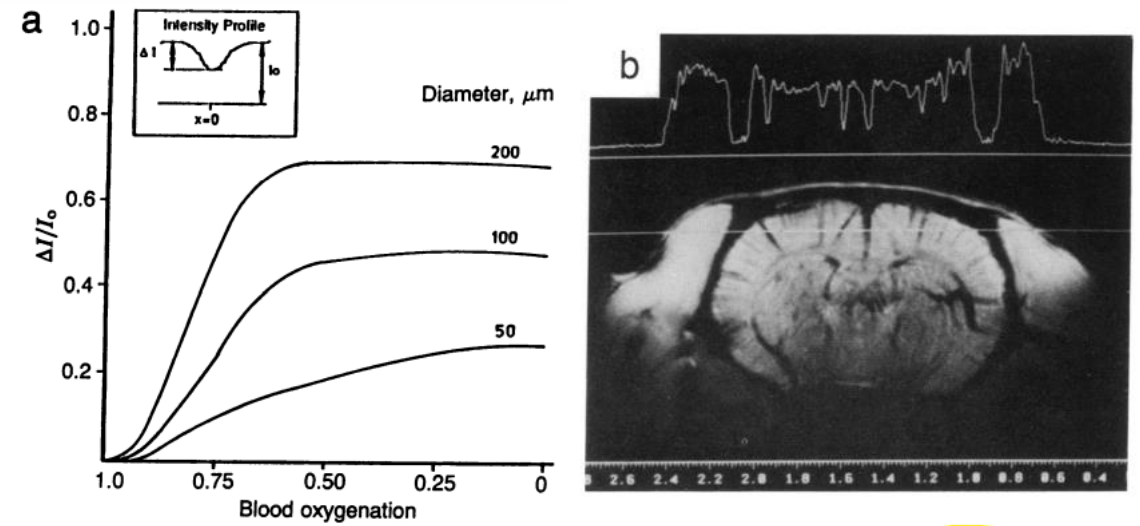


FIG. 4. (a) Relationship between BOLD contrast and blood oxygenation. The image simulation was performed for a blood vessel with its longitudinal axis perpendicular to the magnetic field and also perpendicular to the read-gradient axis in the slice plane. (b) Signal intensity profile along the line shown in the accompanying image of an anoxic brain (ventilation with 100% N₂).

[Review](#) > [Neuroimage](#). 2012 Aug 15;62(2):608-9. doi: [10.1016/j.neuroimage.2012.01.091](https://doi.org/10.1016/j.neuroimage.2012.01.091).
Epub 2012 Jan 28.

Finding the BOLD effect in brain images

[Seiji Ogawa](#) ¹

Abstract

A brief description of events that led to the finding of BOLD effect in brain images is presented. This is a recollection of what were in this author's mind in pre-1992 period.

<https://pubmed.ncbi.nlm.nih.gov/22309802/>



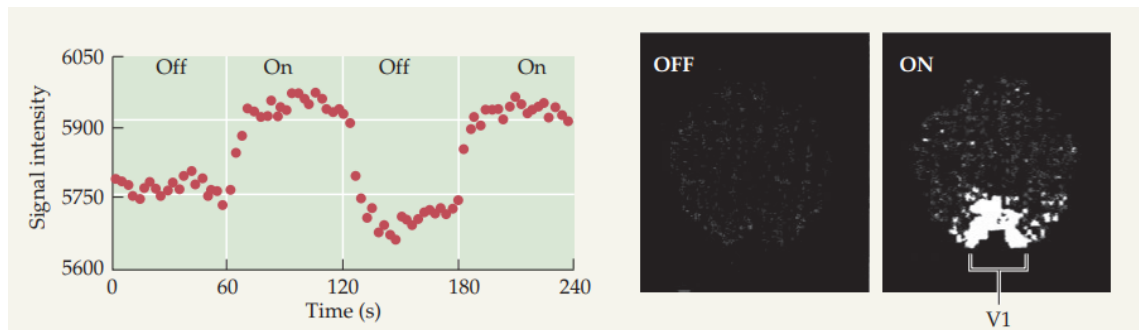
1992



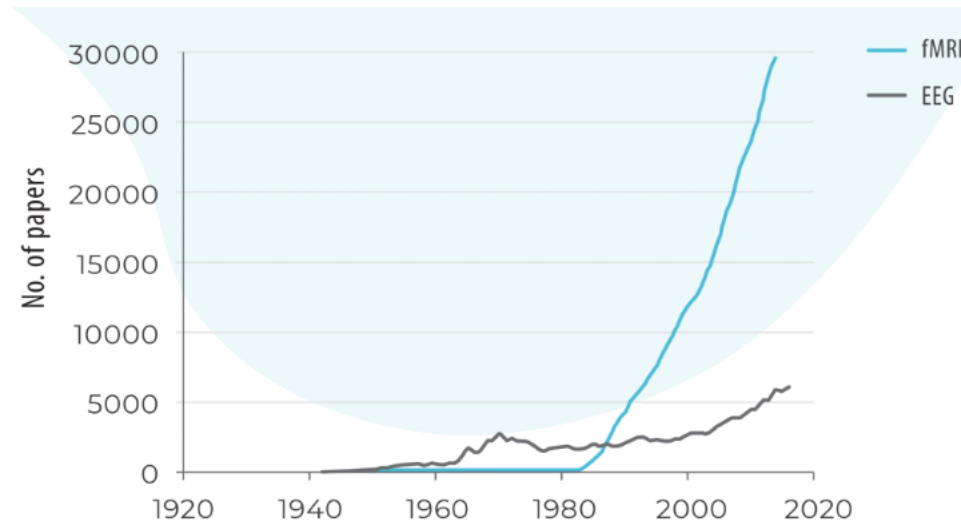
> Proc Natl Acad Sci U S A. 1992 Jun 15;89(12):5675-9. doi: 10.1073/pnas.89.12.5675.

Dynamic magnetic resonance imaging of human brain activity during primary sensory stimulation

K K Kwong¹, J W Belliveau, D A Chesler, I E Goldberg, R M Weisskoff, B P Poncelet, D N Kennedy, B E Hoppel, M S Cohen, R Turner, et al.

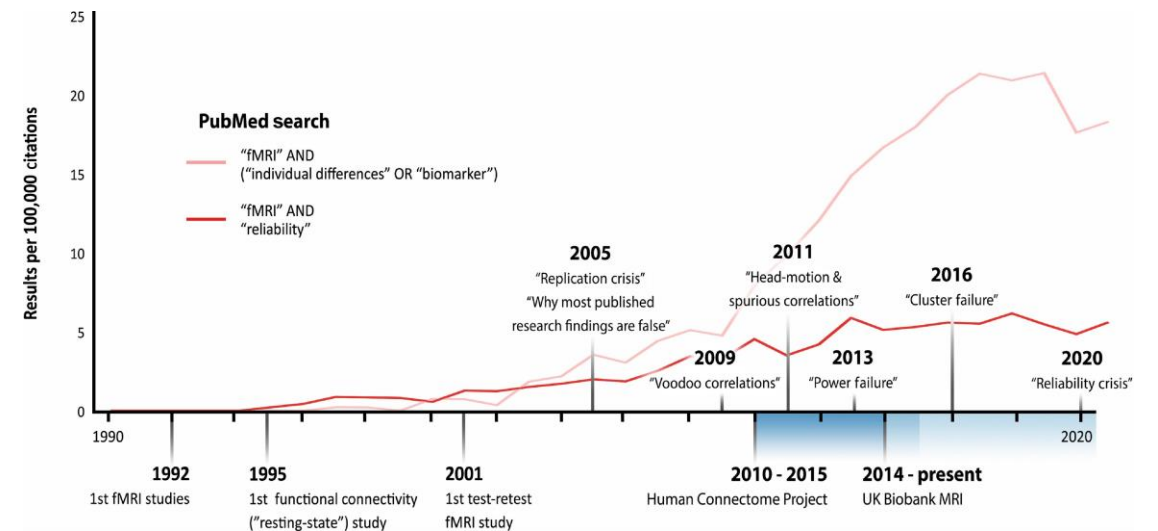


<https://pubmed.ncbi.nlm.nih.gov/1608978/>



Source: K. Smith, Nature 484, (2012) and J. R. Newton, The sapiens lab (2017).

<https://brainimpact.eu/why-fmri/>

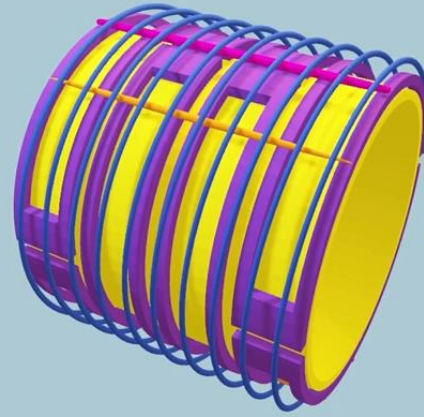
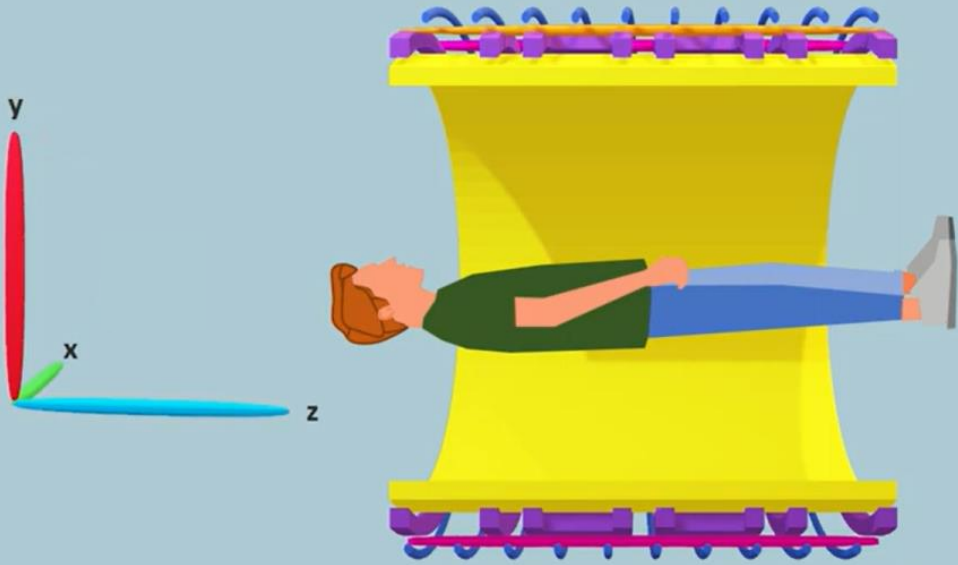


Elliott et al., (2021), Trends in Cog. Sci.

<https://www.sciencedirect.com/science/article/pii/S1364661321001297>

Trends in Cognitive Sciences

MRI hardware

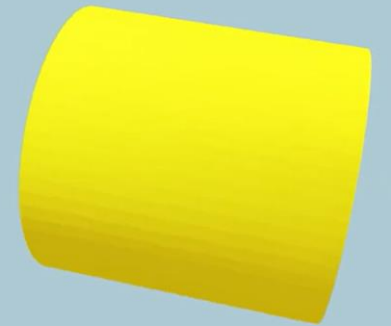
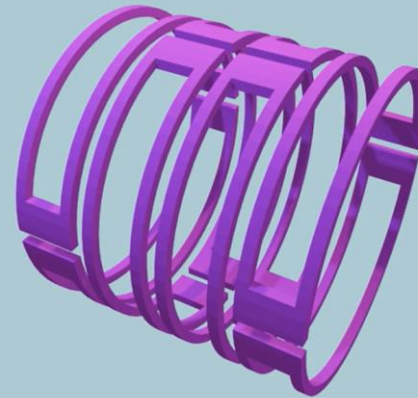
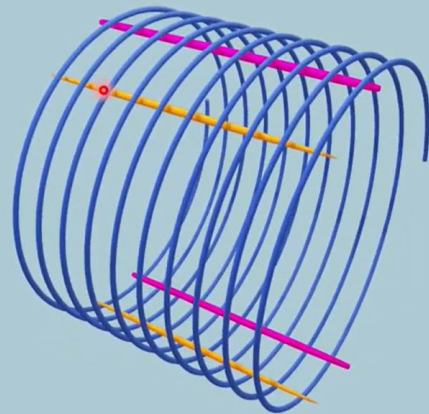
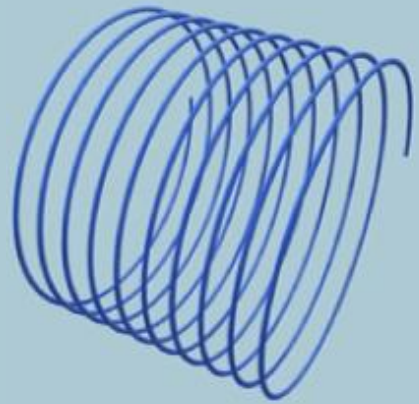


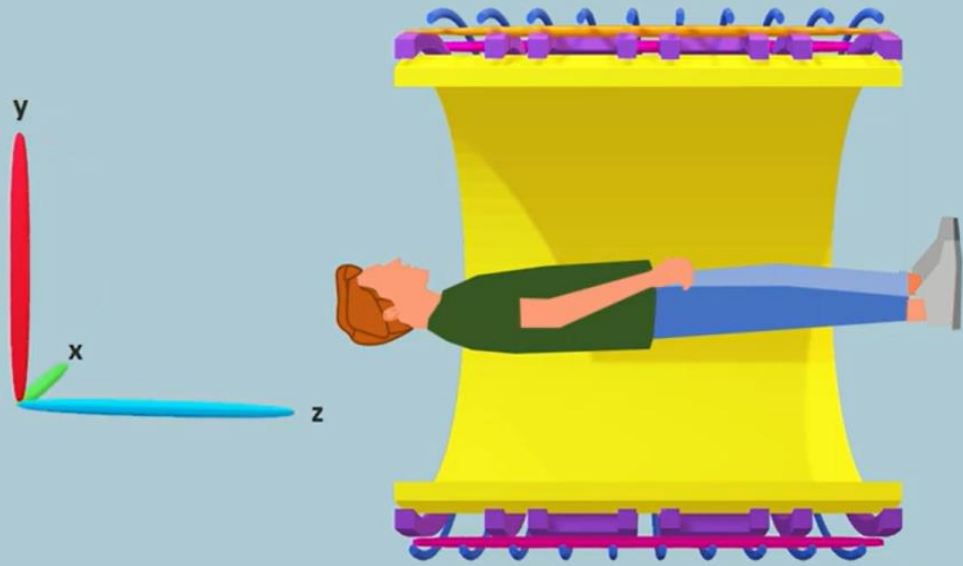
MAIN COIL

SHIMS

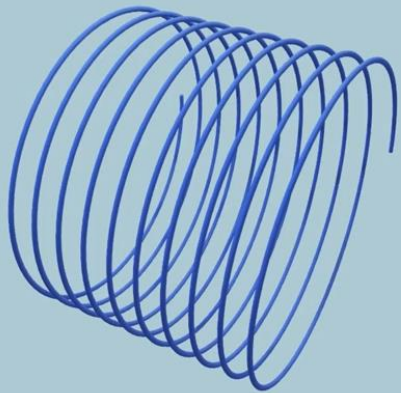
GRADIENT COILS

RADIOFREQUENCY COIL





MAIN COIL



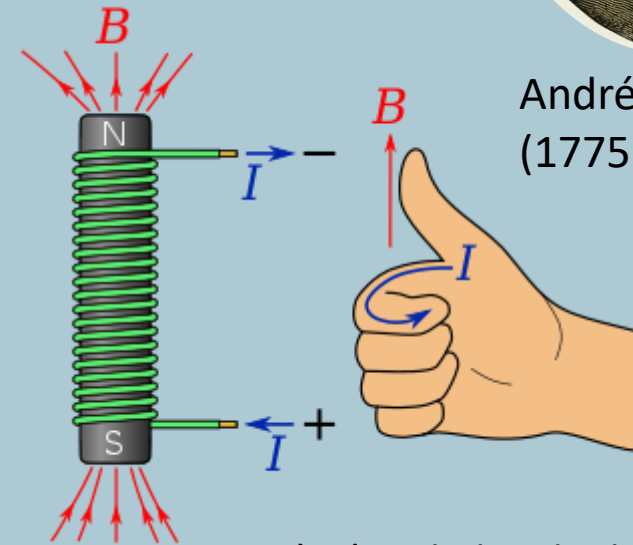
Magnetic field strength is dependent on:

- number of coils of wire;
- amount of current that runs through the wire.

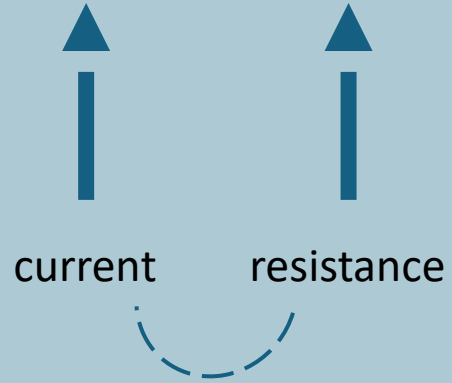
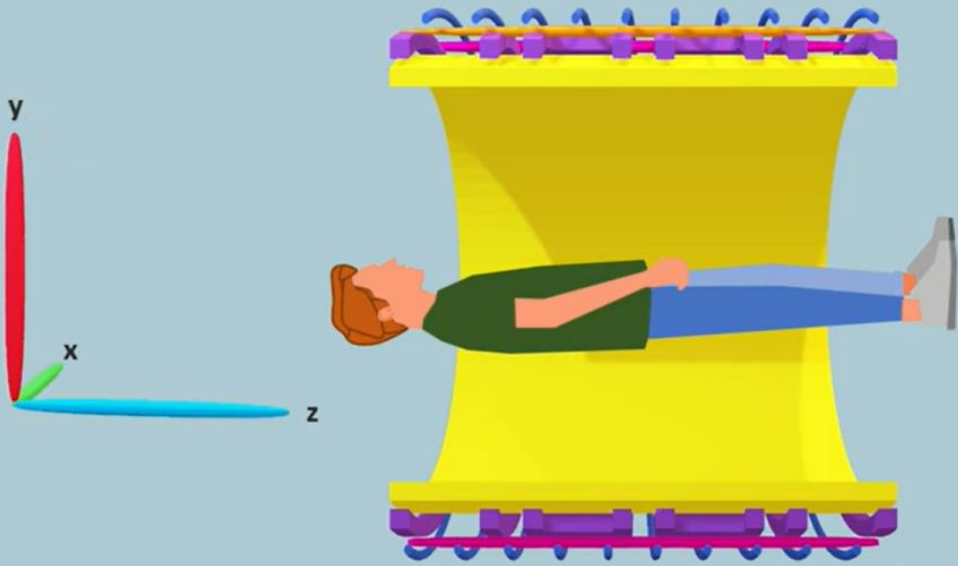
“The magnetic field created by an electric current is proportional to the size of that electric current with a constant of proportionality equal to the permeability of free space.”



André-Marie Ampère
(1775 – 1836)



Ampère's right hand rule

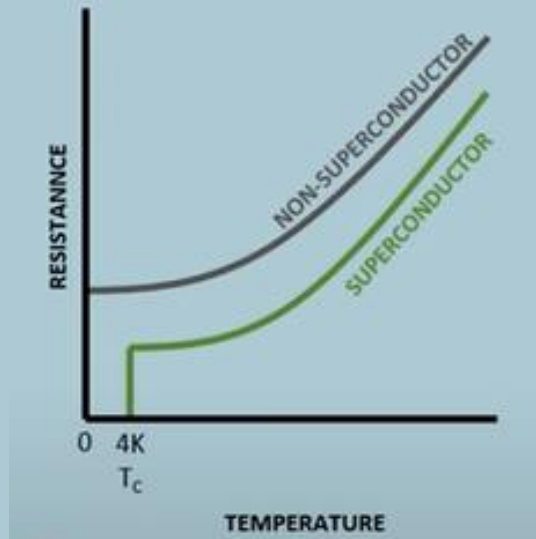
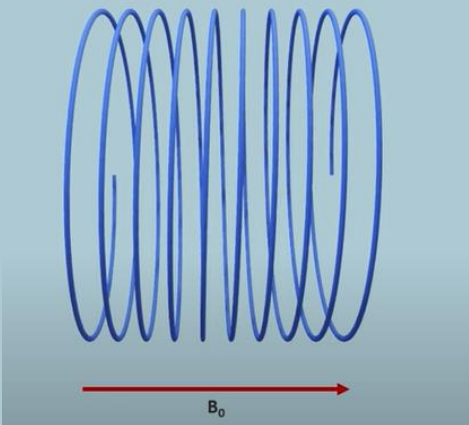


We overcome this by using a **superconductor** that will allow us to run a **strong enough current** through the wire and hence obtain a **strong enough magnetic field**

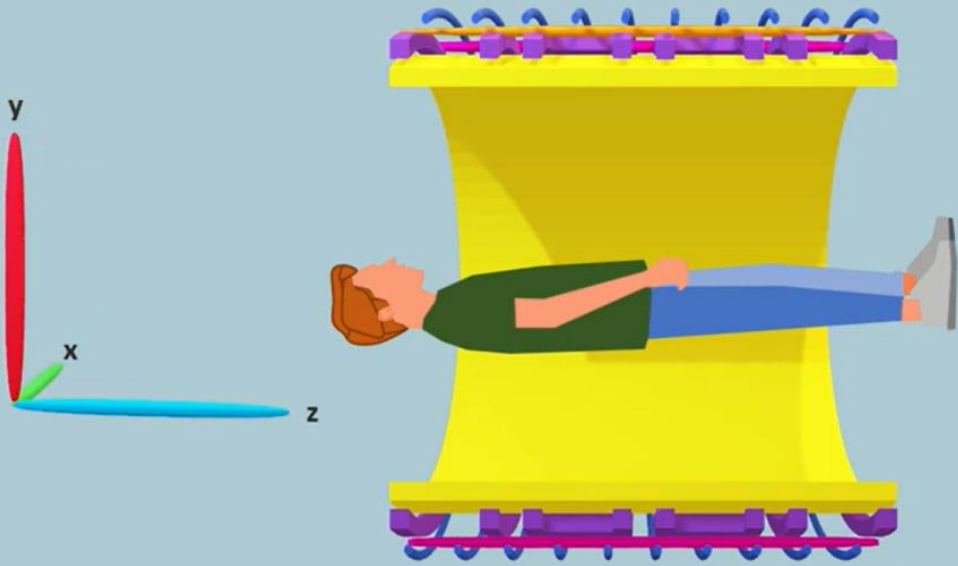
SUPERCONDUCTIVITY

Liquid Helium

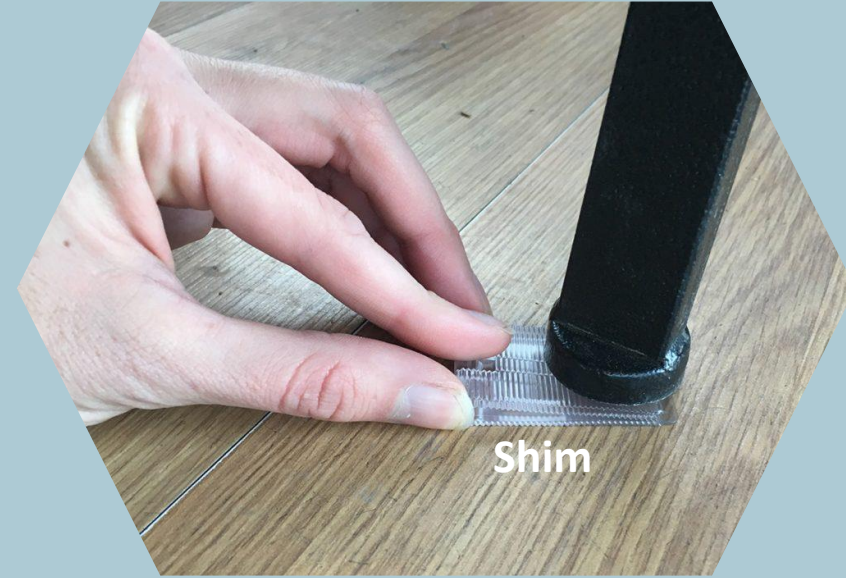
Niobium Titanium Alloy



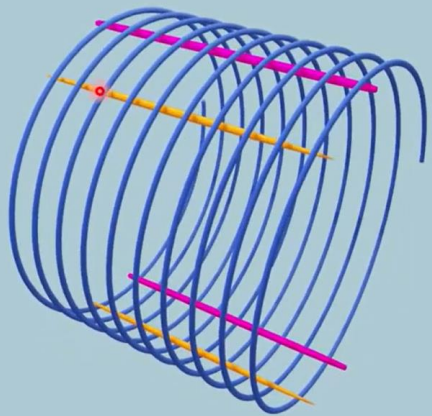
This superconducting wire is usually made of *Niobium Titanium Alloy* bathed in *liquid Helium* at -269°C (4.15 K)



SHIMS



Shims help maintain a homogenous main magnetic field

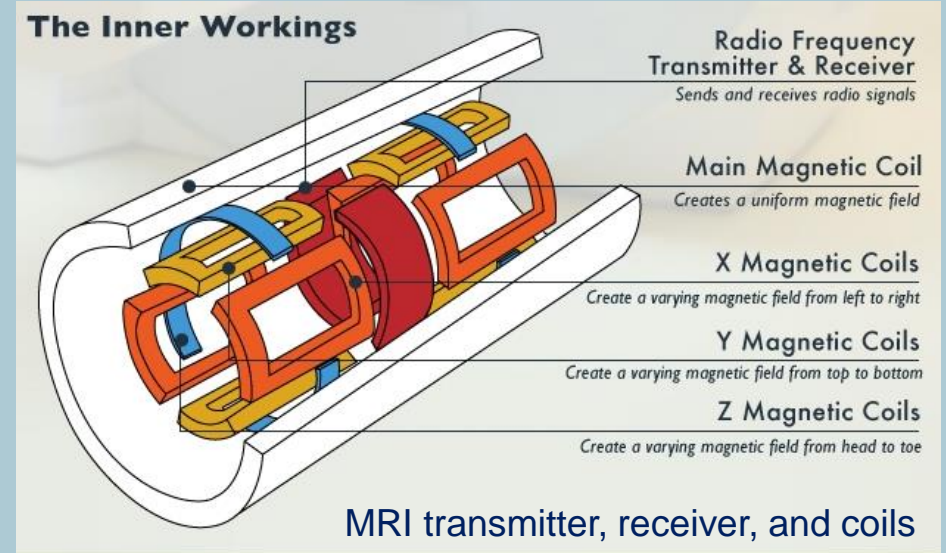
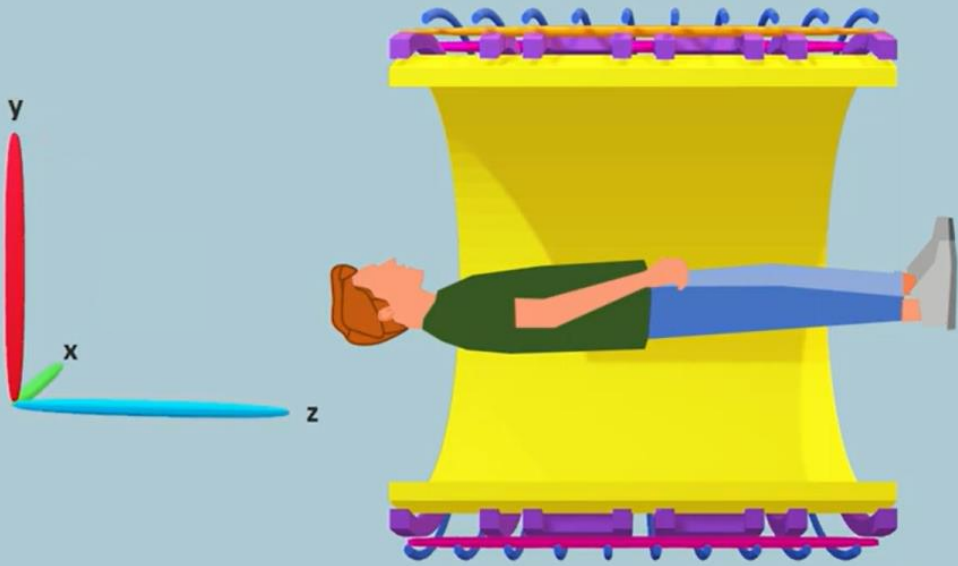


passive shim

sheet of ferromagnetic metal placed along the magnetic bore; manipulates the magnetic field

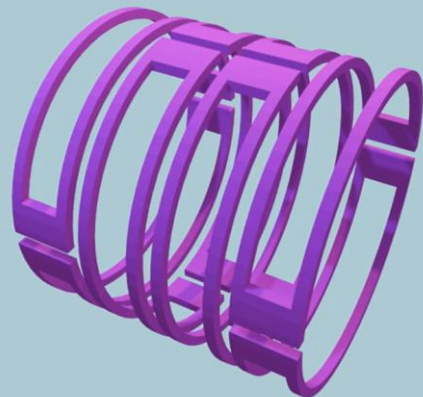
active shim

have their own electricity supply, which we can change in order to manipulate the magnetic field



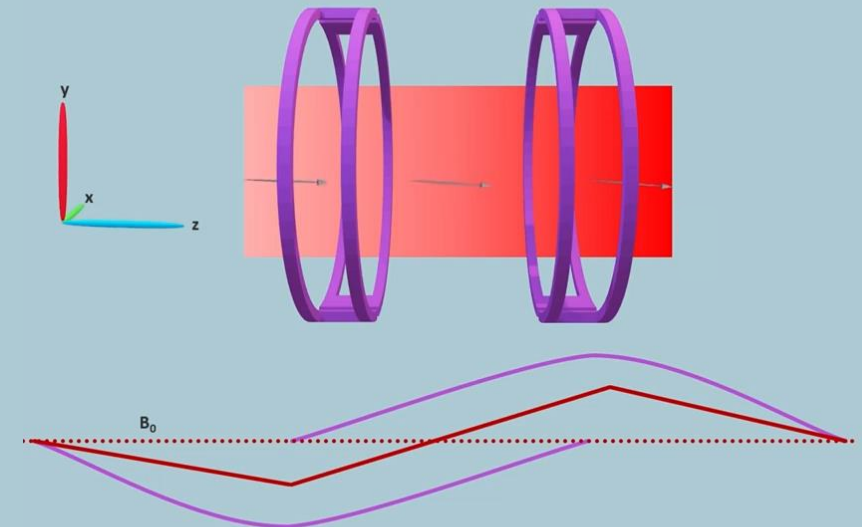
<https://ro.mouser.com/applications/medical-imaging-overview/>

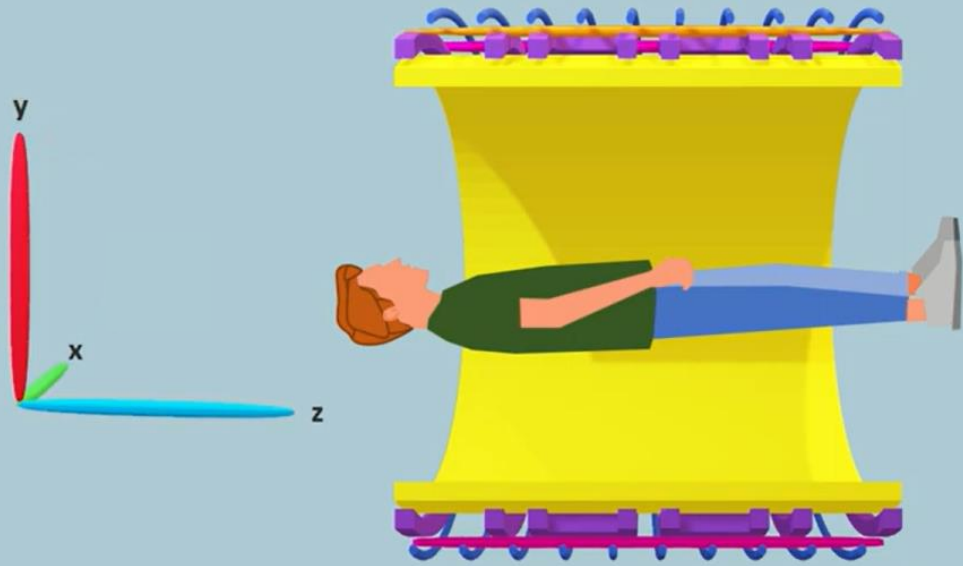
GRADIENT COILS



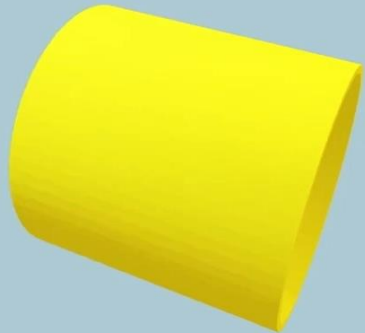
Gradient coils can create their **own magnetic field** => manipulate the main magnetic field (i.e., the *precession* of Hydrogen protons) => **spatial encoding**

GRADIENT COILS





RADIOFREQUENCY COIL

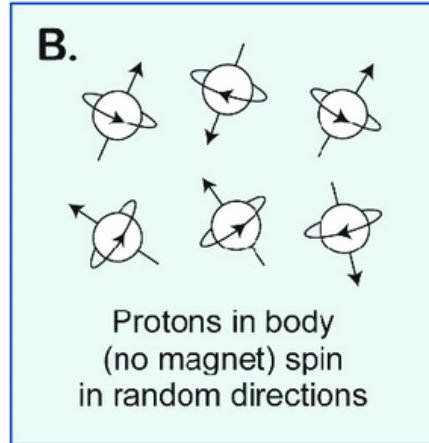
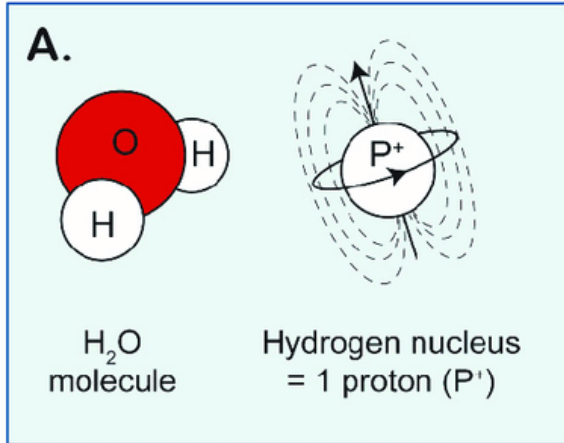


<https://www.youtube.com/watch?v=b6fwywMZEZA>

The radiofrequency coil generates an **alternating magnetic field** (i.e., *radio frequency pulse*) that is perpendicular to the main magnetic field

MRI – structural imaging

Hydrogen atoms => abundant in the human body

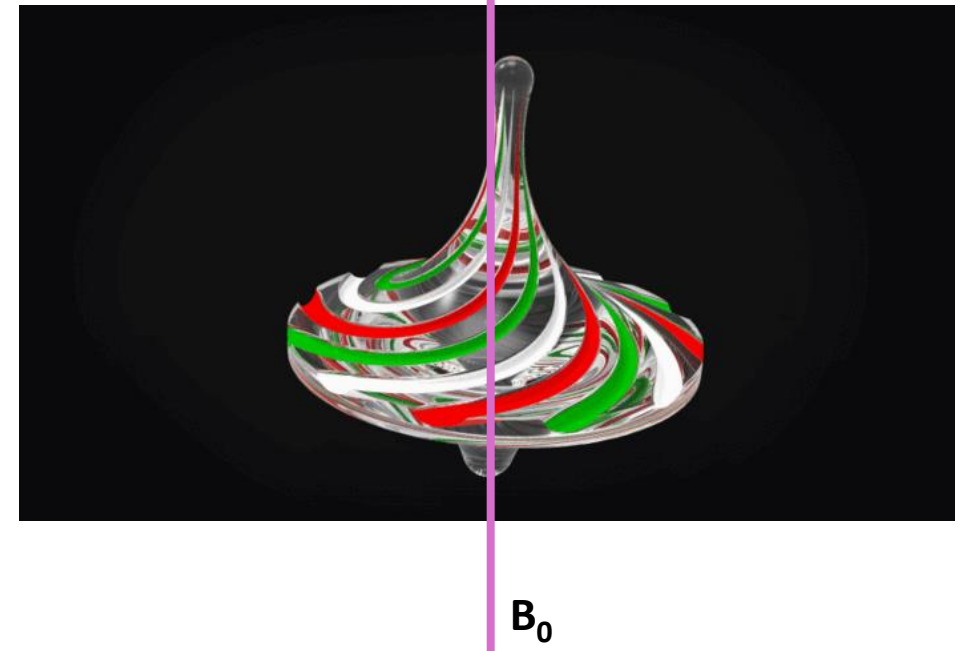
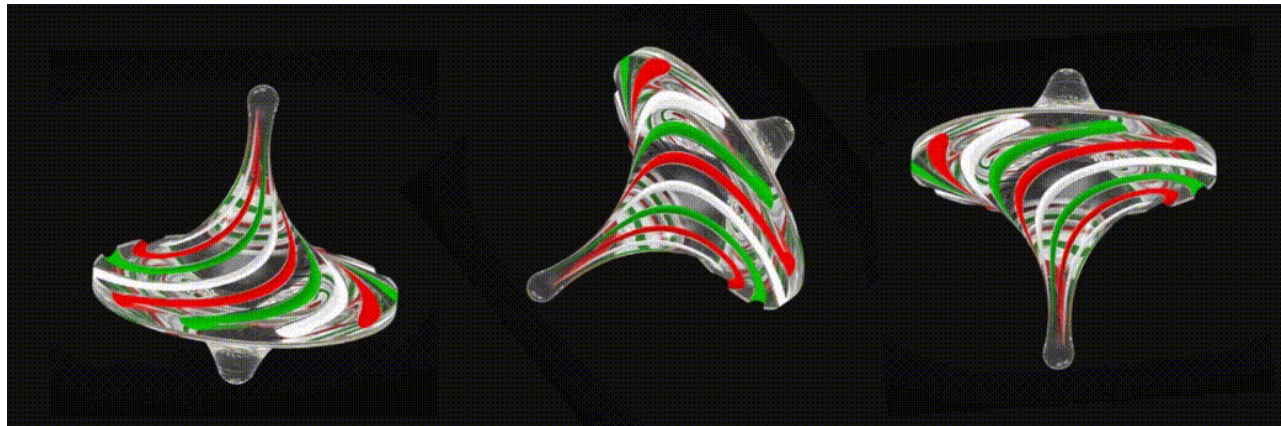


The **protons** in the **nucleus** of the **Hydrogen atoms** are characterized by *spin* and *precession*

spin
rotation around own axis

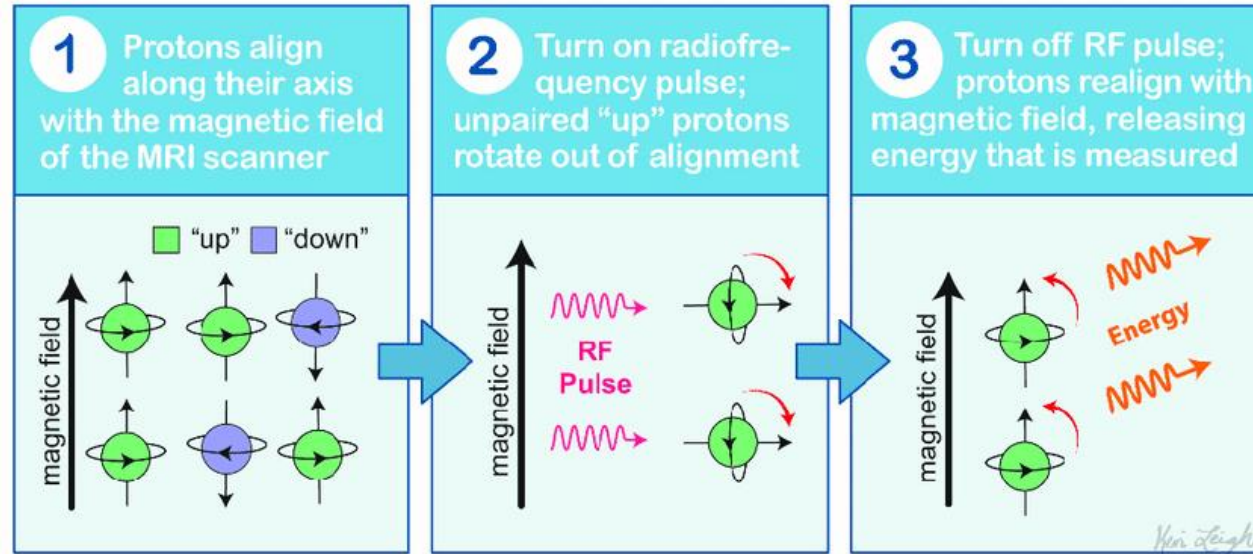
precession
tilt around the B₀ axis

Fordham et al., (2021)
<https://pubmed.ncbi.nlm.nih.gov/34199151/>



When placed in the MRI scanner, proton axes align to the B_0 axis

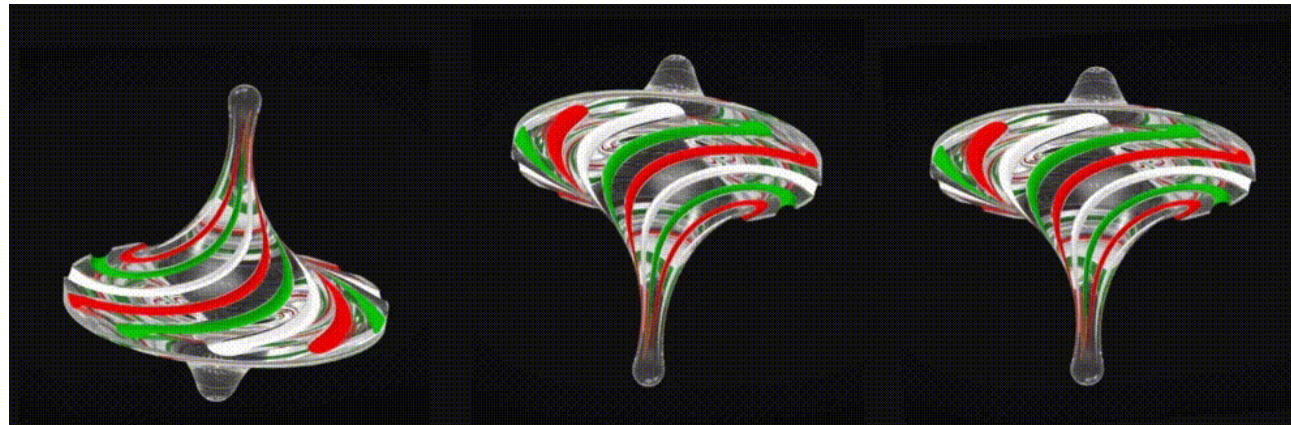
C.



Fordham et al., (2021)

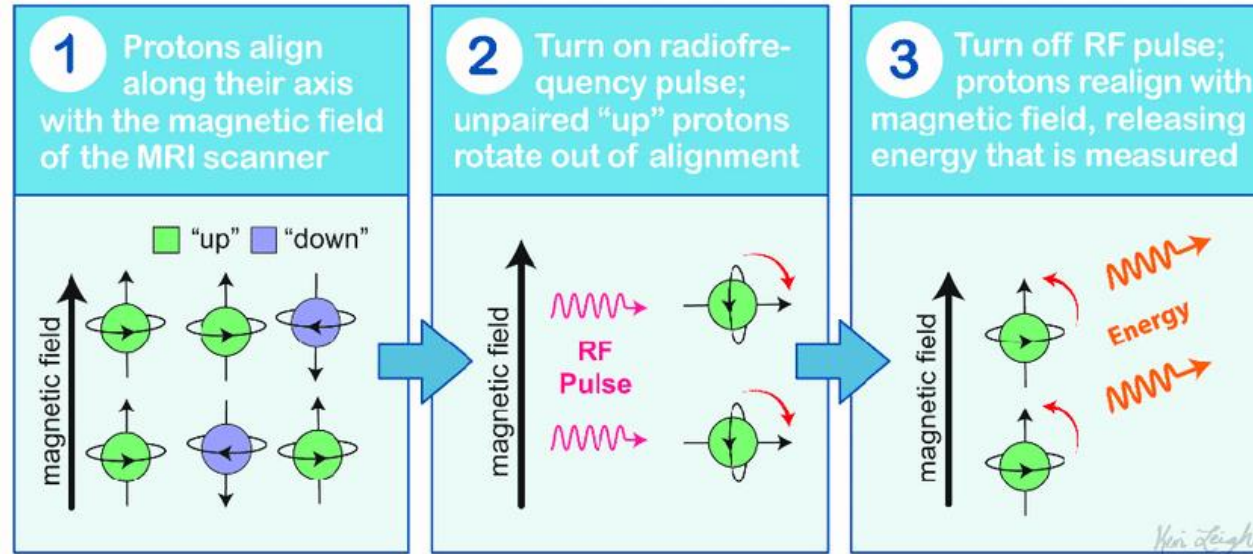
<https://pubmed.ncbi.nlm.nih.gov/34199151/>

B_0



Then a **radio frequency (RF) pulse** causes the protons to precess **in phase**

C.



Fordham et al., (2021)

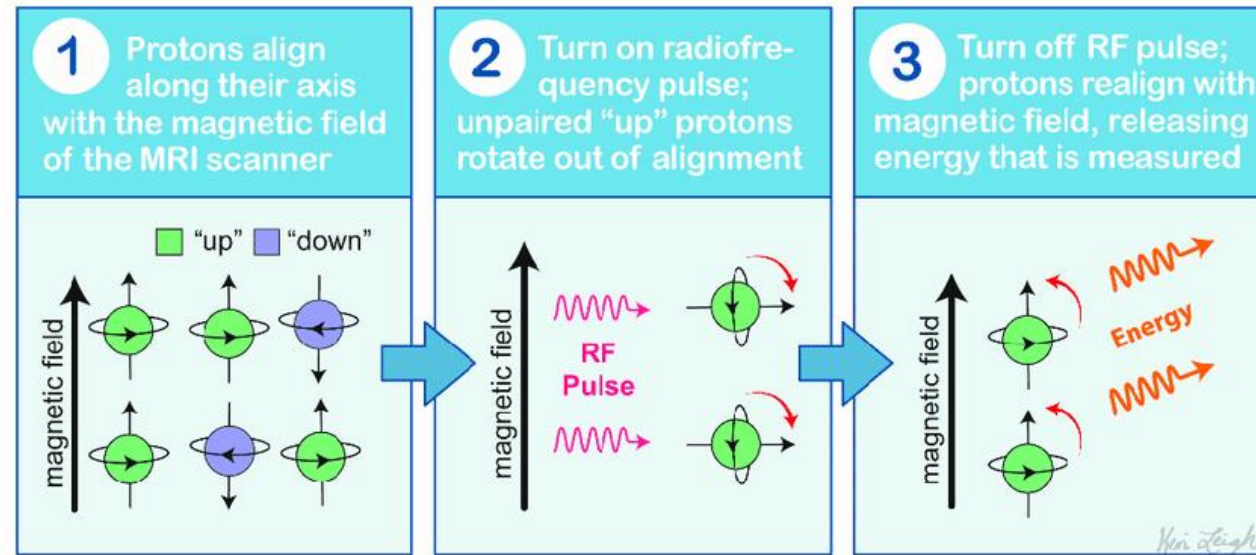
<https://pubmed.ncbi.nlm.nih.gov/34199151/>



B_0

Then a **radio frequency (RF) pulse** causes the protons to precess **in phase**

C.



Fordham et al., (2021)

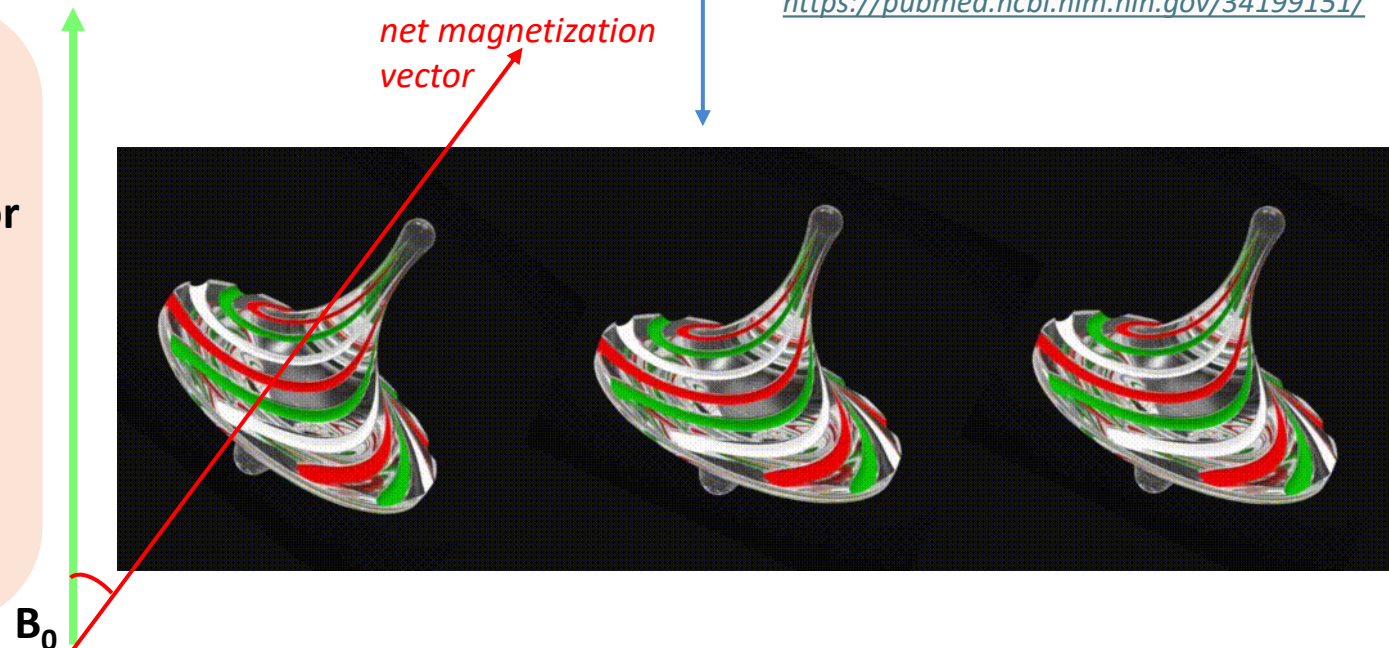
<https://pubmed.ncbi.nlm.nih.gov/34199151/>

net magnetization vector

the **summation** of all the magnetic moments of the individual H nuclei

flip angle

the angle at which the **net magnetization vector** is **rotated** away from the z-axis by an RF pulse, relative to the main magnetic field (B_0)



The RF pulse must match the natural **frequency** of the H protons
(the **Larmor frequency**)

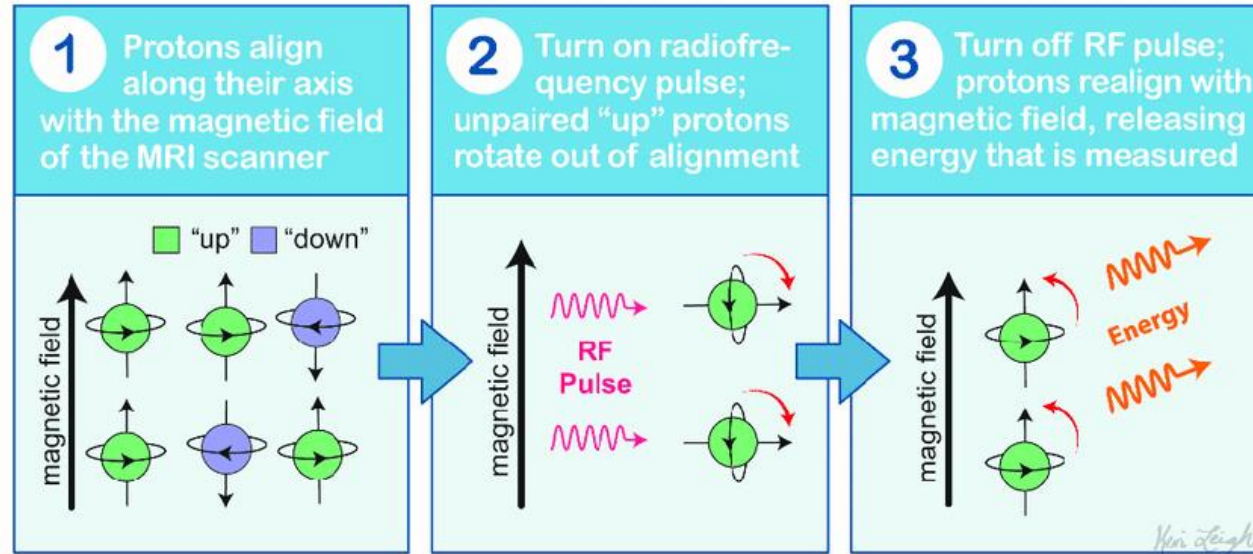
Larmor frequency
(in MHz)

$$\omega = \gamma B$$

gyromagnetic ratio
(in MHz/T)

strength of the static
magnetic field B_0 (in T)

C.



Fordham et al., (2021)

<https://pubmed.ncbi.nlm.nih.gov/34199151/>

resonance

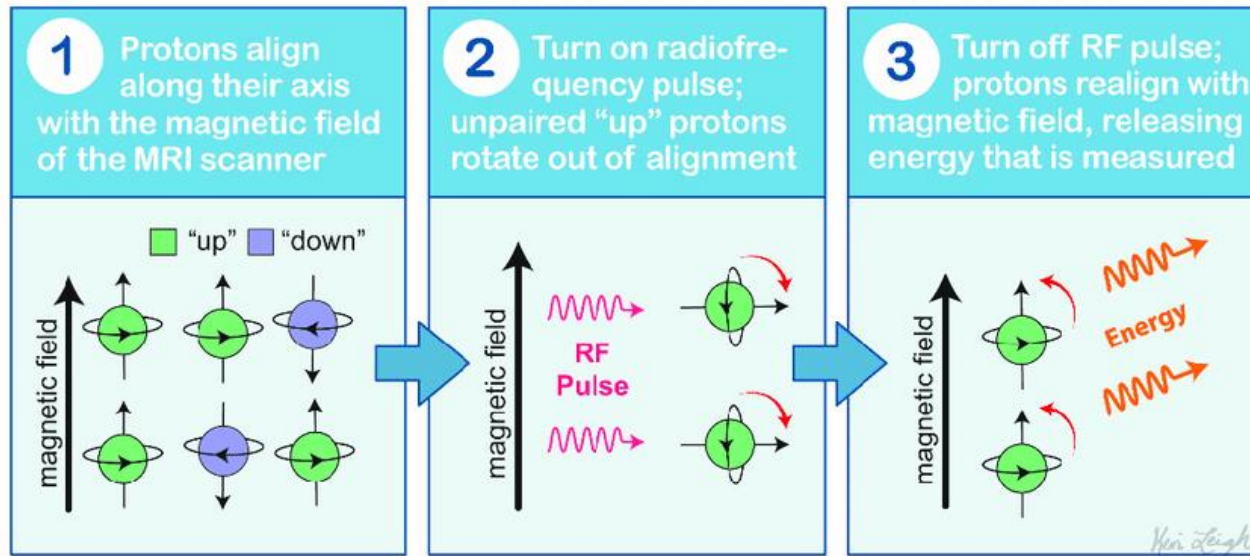
selective response of an object/system that **vibrates** in phase with an externally applied **oscillatory force**



For Hydrogen, γ is 42.58 MHz/T

In a field (B_0) of 1.5T, the resonance frequency of ^1H would be $(42.58 \text{ MHz/T}) \times (1.5\text{T}) = 63.87 \text{ MHz}$

C.



Fordham et al., (2021)
<https://pubmed.ncbi.nlm.nih.gov/34199151/>

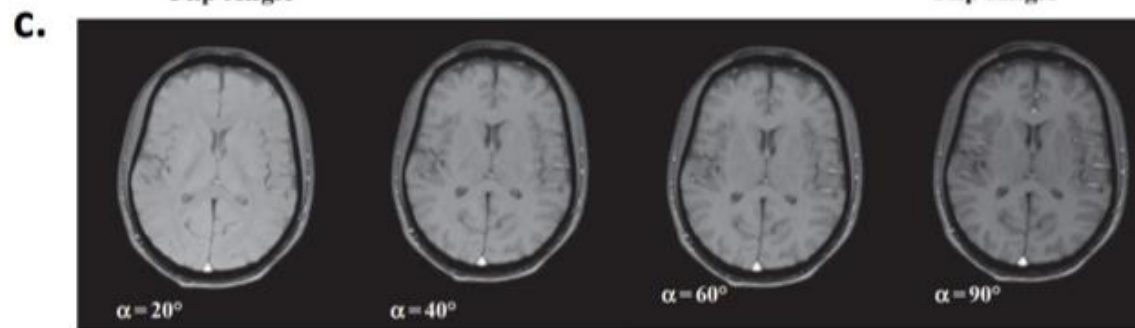
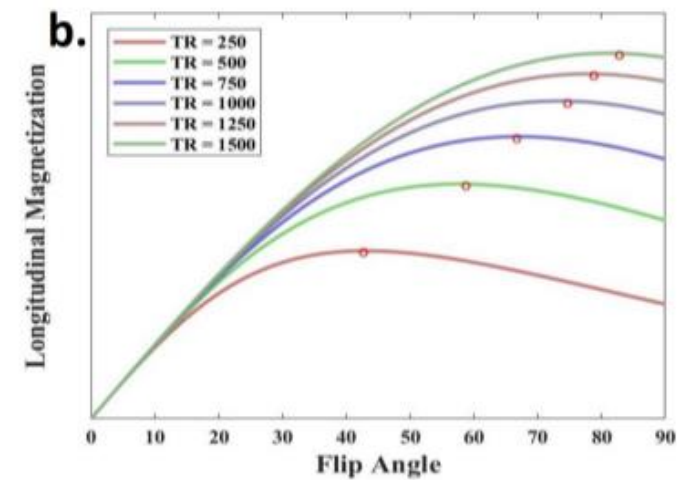
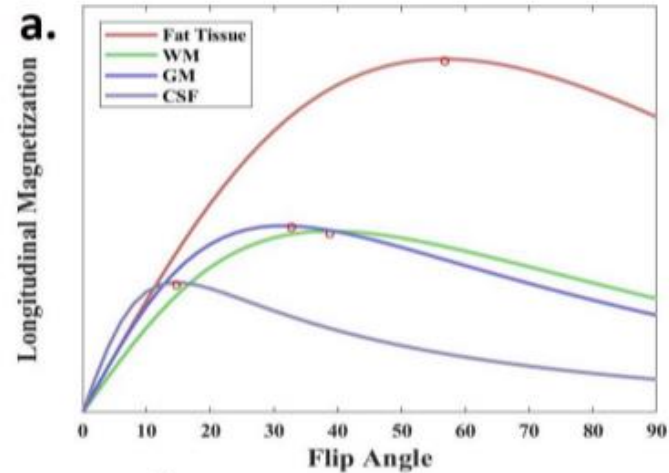
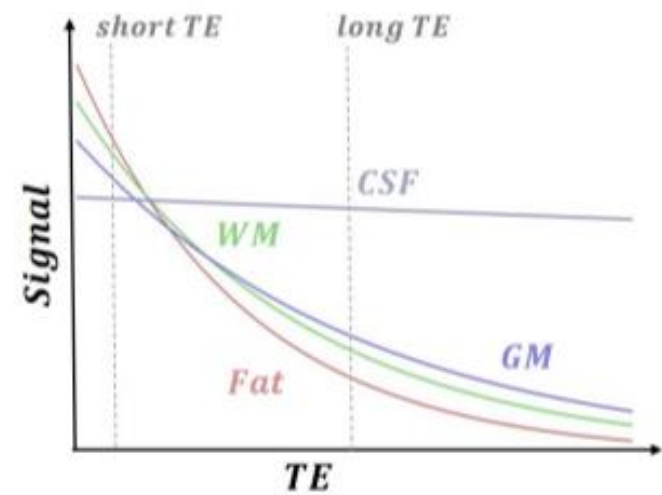
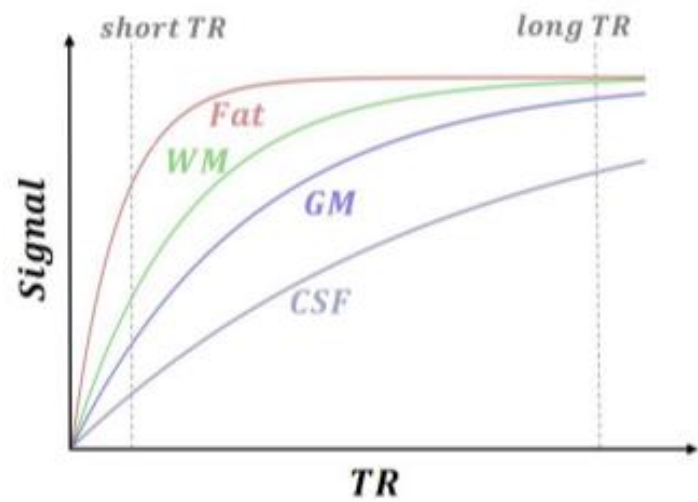


When the **RF pulse** is turned **off**, protons realign to the B_0 axis (**relaxation**).

We then measure the **energy** they release as they relax.

Repetition Time (TR)
time **between** two successive **RF pulses**

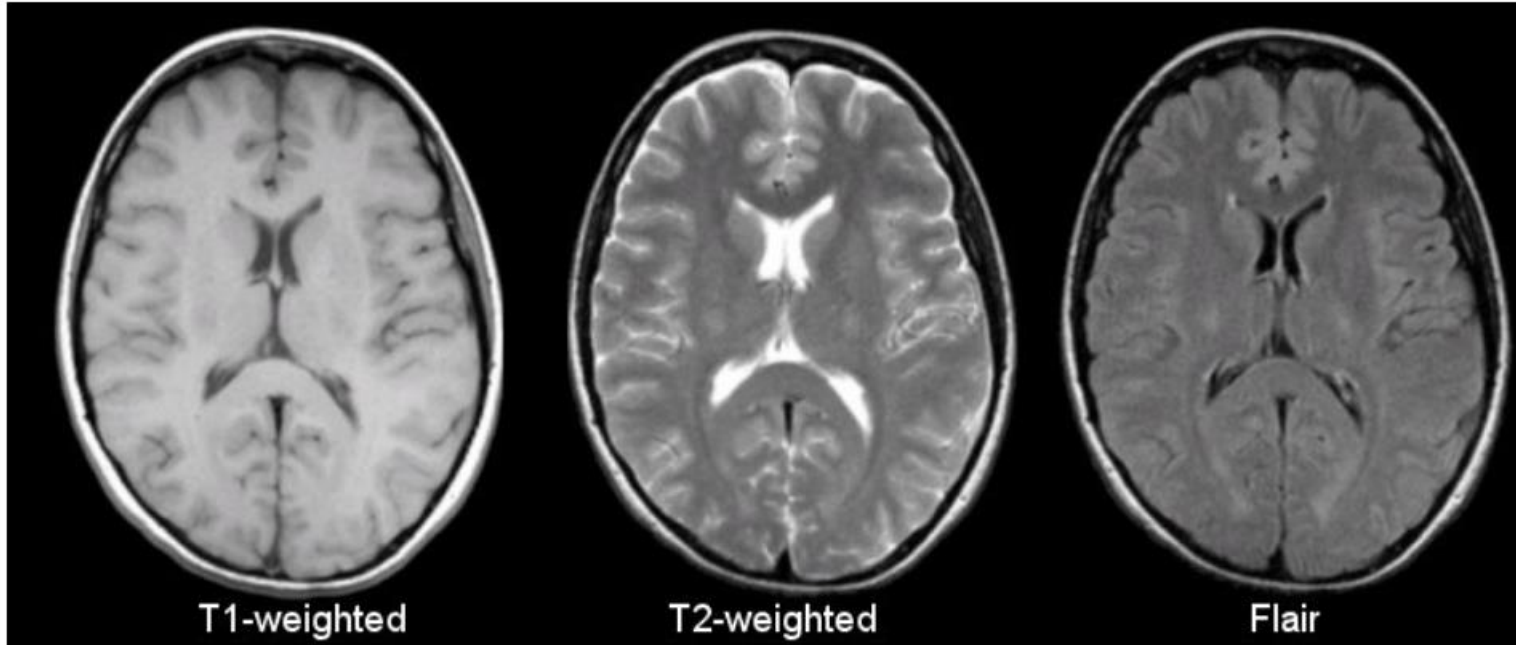
Echo Time (TE)
time **between** an **RF pulse** and **signal read-out**



Liu, (2020)

<https://www.researchgate.net/publication/347240832>

Comparison of T1 vs. T2 vs. Flair (Brain)



By varying **TR** and **TE** => different kinds of structural images

T1W => most used in **research** is the

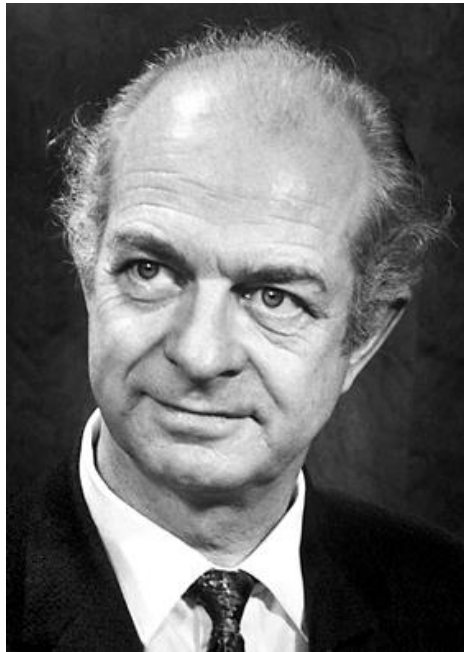
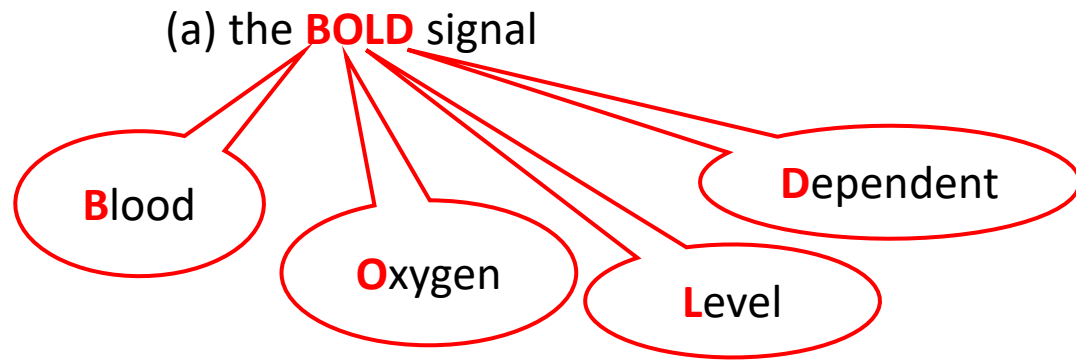
T2W & Flair => preferred for **clinical** diagnoses

Tissue	T1-Weighted	T2-Weighted	Flair
CSF	Dark	Bright	Dark
White Matter	Light	Dark Gray	Dark Gray
Cortex	Gray	Light Gray	Light Gray
Fat (within bone marrow)	Bright	Light	Light
Inflammation (infection, demyelination)	Dark	Bright	Bright

	TR (msec)	TE (msec)
T1-Weighted (short TR and TE)	500	14
T2-Weighted (long TR and TE)	4000	90
Flair (very long TR and TE)	9000	114

<https://case.edu/med/neurology/NR/MRI%20Basics.htm>

fMRI – functional imaging



Linus Pauling
(1901 – 1994)

The **Nobel Prize in Chemistry 1954** was awarded to Linus Carl Pauling "for his research into the nature of the **chemical bond** and its application to the elucidation of the structure of complex substances"

The **Nobel Peace Prize 1962** was awarded to Linus Carl Pauling "for his fight **against the nuclear arms race** between East and West"

He discovered that **haemoglobin changes its magnetic properties** depending on its **Oxygen concentration**.

Deoxygenated haemoglobin is **paramagnetic** (i.e., *attracted* to a magnetic field).

Oxygenated haemoglobin, however, is **diamagnetic** (i.e., creates no magnetic moment).

These fluctuations induce **magnetic field inhomogeneities** which can be recorded (i.e., the $T2^*$ signal)

Oxygenated haemoglobin



diamagnetic

(i.e., creates *no magnetic* moment)

Deoxygenated haemoglobin



paramagnetic

(i.e., *attracted* to a magnetic field)

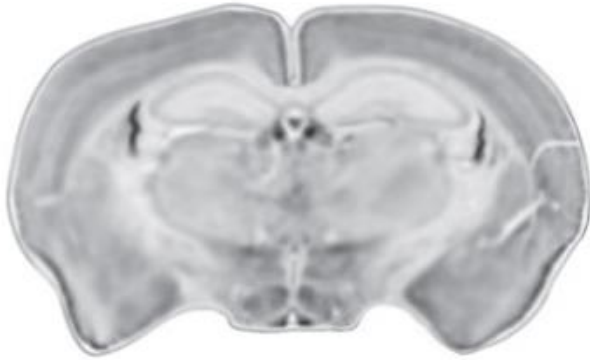
What do we measure with Functional MRI?



<https://www.youtube.com/watch?v=4UOeBM5BwdY>

Developed a way to record the **BOLD** signal from **living tissue** and established a **direct relationship** between the level of **oxygenated haemoglobin** and **functional image** properties.

(A)



(B)

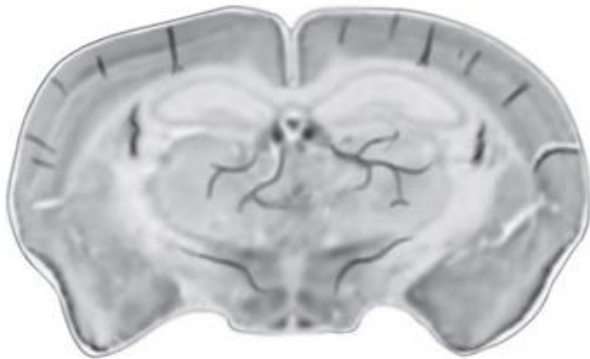
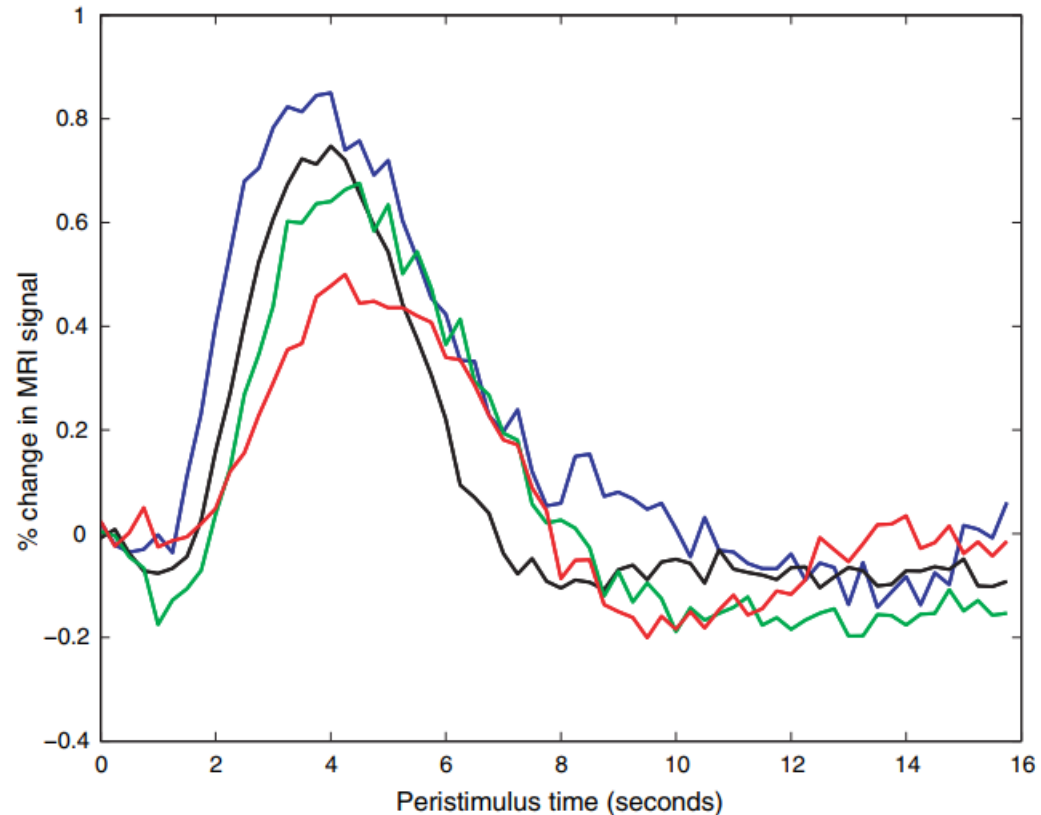


Figure 7.2 An illustration of BOLD contrast. Ogawa and colleagues manipulated the amount of oxygen in the blood of rats by adjusting the content of the air the rats breathed. (A) When the rats breathed pure oxygen, the cortical surface had a uniform texture on images sensitive to T_2^* contrast. (B) When the rats breathed normal air, however, there were areas of signal loss, shown as lines corresponding to blood vessels within the cortex. These lines indicated areas with increased amounts of deoxygenated hemoglobin, which forms the basis for BOLD contrast. (After Ogawa et al., 1990.)



Seiji Ogawa
(1934 -)

Closely related to the BOLD signal is the **Haemodynamic Response Function (HRF)**



An example of the hemodynamic responses evoked in area V1 by a contrast-reversing checkerboard displayed for 500 ms. The four different lines are data from four different individuals, showing how variable these responses can be across people. The MRI signal was measured every 250 ms, which accounts for the noisiness of the plots. (Data courtesy of Stephen Engel, University of Minnesota)

Poldrack et al. (2011), p. 13

hemodynamic response

the **increase** in **blood flow** that follows a brief period of **neuronal activity**

The *haemodynamic response* is **slow** (approx. 5 s to peak following stimulation), whereas brain processes occur in the span of milliseconds => fMRI **temporal resolution** is **small** => influences the way we plan our experimental design

(b) **noise** and pre-processing steps

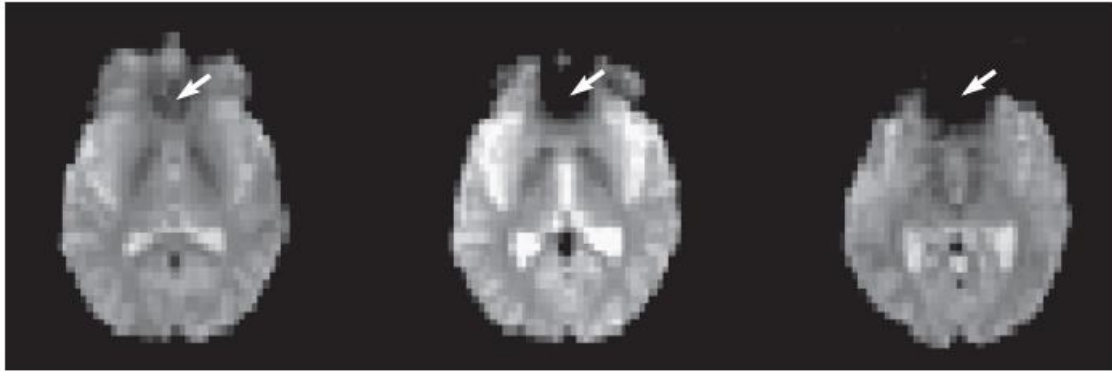
Just like when taking a picture, if we move the camera, or the subject moves, the picture will come out *blurry*. Similarly, the fMRI signal can be affected by various sources of *noise*, e.g., **head motion**, but also **physiological signals**.

The magnetic field B_0 can also contain *fluctuations* (i.e., **inhomogeneities**) around the *air–tissue interfaces* (e.g., orbitofrontal cortex) , leading to *signal drop-out* or *geometric distortions*.

In addition, **spikes** can occur due to *electrical instability in the scanner*.

Pre-processing (i.e., signal clean-up and quality assurance/QA), are CRUCIAL!

(A) 1.5 T



(B) 4.0 T

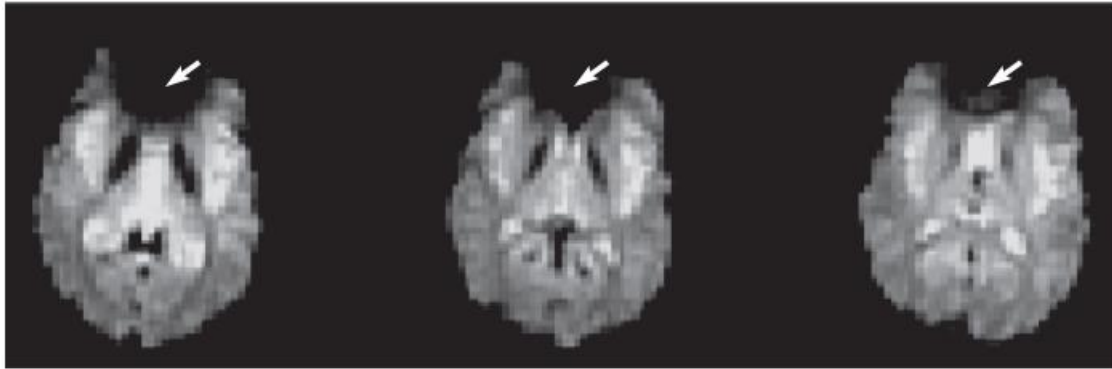
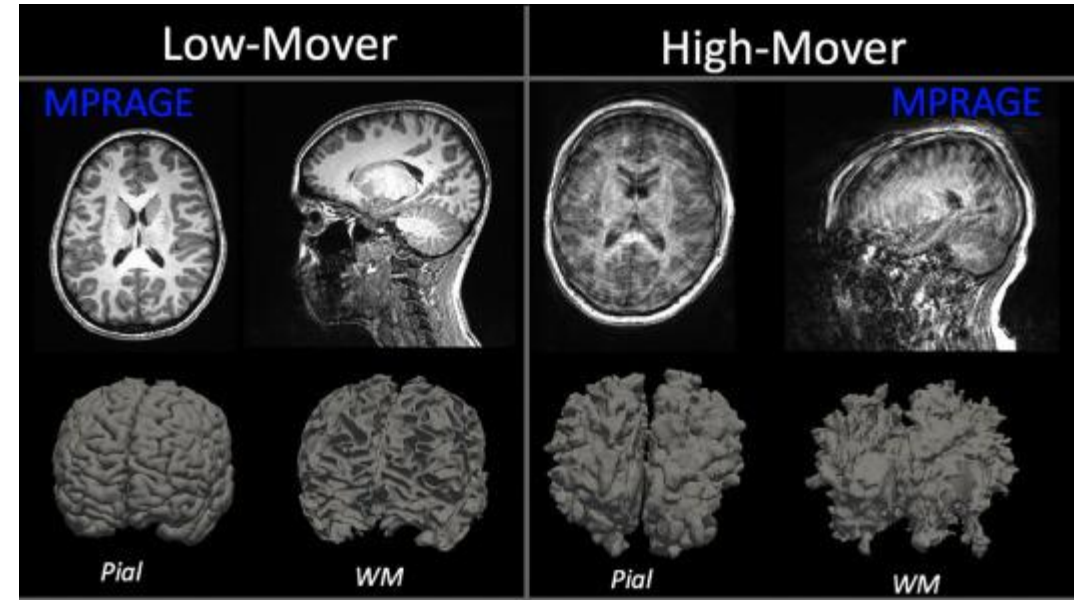


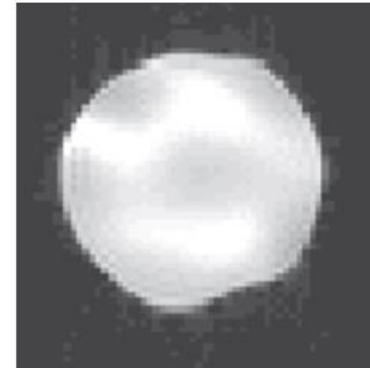
Figure 8.7 Susceptibility artifacts increase at higher field strengths. Although susceptibility artifacts at air-tissue boundaries are present on gradient-echo images at all field strengths, they increase in spatial extent at higher field strengths. Shown are images from three subjects, each scanned at both 1.5 T (A) and 4.0 T (B). Visible in all images are areas of signal loss in the ventral frontal lobe, which is indicated by the arrows. Note that the areas of signal loss are more extensive in the 4.0-T images.

Huettel et al. (2014), p. 283

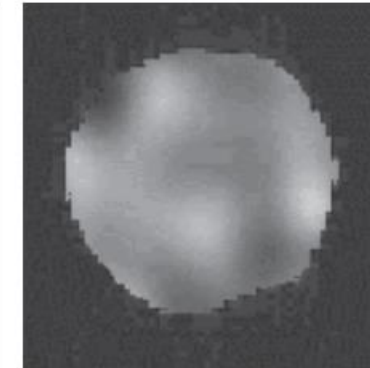


<https://www.sciencedirect.com/science/article/pii/S1053811920310703>

(A)



(B)



(C)

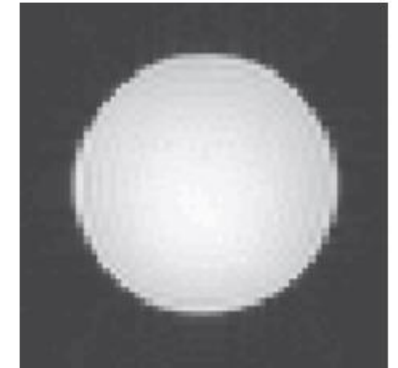


Figure 8.22 Correction of geometric distortions in functional images. (A) In this image of a spherical phantom, there is obvious geometric distortion. (B) To correct for the distortion, a map of magnetic field intensity is acquired. (C) The intensity map can be used to generate a corrected image.

Huettel et al. (2014), p. 306

SNR (Signal to Noise Ratio)

the strength of our **signal** of interest compared to background **noise**

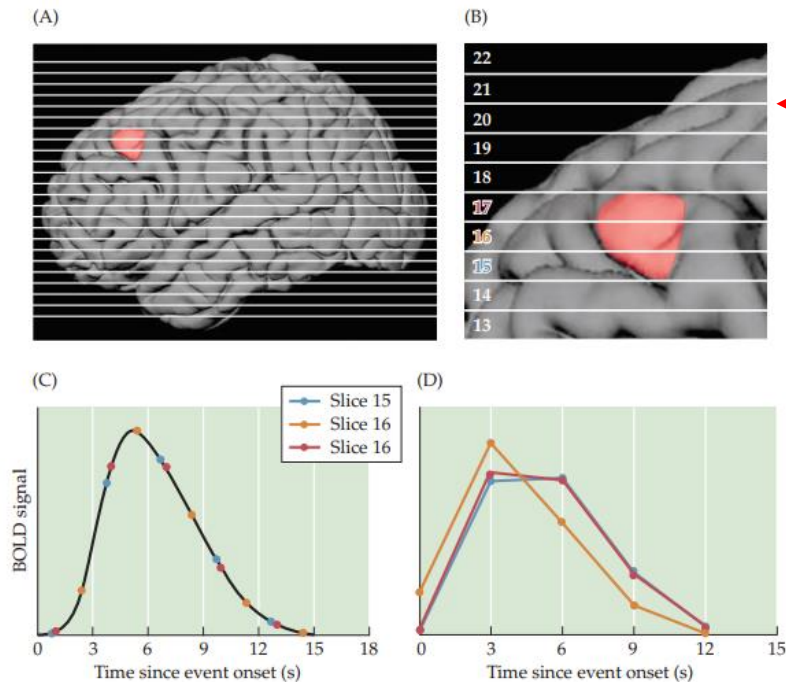
The higher the better!

Pre-processing essentially aims to *increase* the SNR.

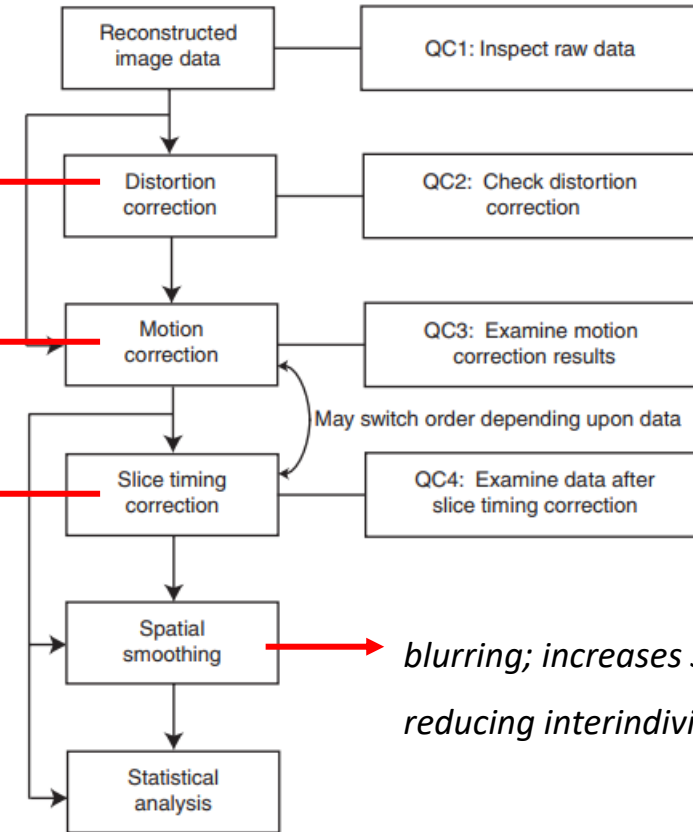
e.g., by acquiring *field maps* to quantify B_0 inhomogeneities

e.g., independent component analysis (ICA)

Figure 8.16 Effects of slice acquisition time on the hemodynamic response. Imagine that a single brain region, shown in red (A), is uniformly active following presentation of a stimulus. This region spans three slices, 15 to 17, within the imaging volume, which is acquired with a standard interleaved sequence (i.e., one that first acquires the odd-numbered slices and then acquires the even-numbered slices) (B). Because the slices within this region are acquired at different times within the 3-s TR, the hemodynamic response within the slices will have different time courses. The signal recorded from the different slices is plotted against the time each slice was acquired (C). Yet, without correcting for the time of acquisition of each slice, the time courses would seem to differ across slices (D). The hemodynamic response in slice 16 (acquired late in the TR) appears to peak earlier than those in the surrounding slices (acquired early in the TR), even though the underlying activation is identical.



Huettel et al. (2014), p. 298



blurring; increases SNR, e.g., by reducing interindividual variability

An overview of the standard fMRI preprocessing stream. The appropriate quality control steps are noted at each point. With the exception of motion correction, the rest of the preprocessing steps can be viewed as optional, and their use will depend upon the needs of the study and the available data.

Poldrack et al. (2011), p. 46

(functional–structural) **co-registration**

matches *functional* data to higher-resolution *structural* images => a better **anatomical localization** of activation within a subject

normalization

mathematically *warps* subjects' brains to a standard **stereotaxic framework** => better comparisons between individuals within a study & allows the reporting of data derived from **common coordinates** for **comparisons between studies**

Common pre-processing pipelines and reporting standards are crucial to overcome the **reproducibility crisis!**

***fMRIPrep*: A Robust Preprocessing Pipeline for fMRI Data**

fMRIPrep is a NiPreps (*NeuroImaging PREProcessing tools*) application (www.nipreps.org) for the preprocessing of task-based and resting-state functional MRI (fMRI).

(c) experimental design

- Task-based**
- (a) **event-related** = stimuli are presented in *short succession* (e.g., 10 s)
 - (b) **block design** = stimuli are presented in *groups* called “*blocks*”, and varied at larger intervals (e.g., 1 m)
 - (c) **naturalistic viewing** (e.g., movies)

Resting state

- records brain activity *at rest*
- *no cognitive* load for participants
- more *inclusive* than task based (can be used with participants who are unable to respond, e.g., coma)
- allows for *various* analyses

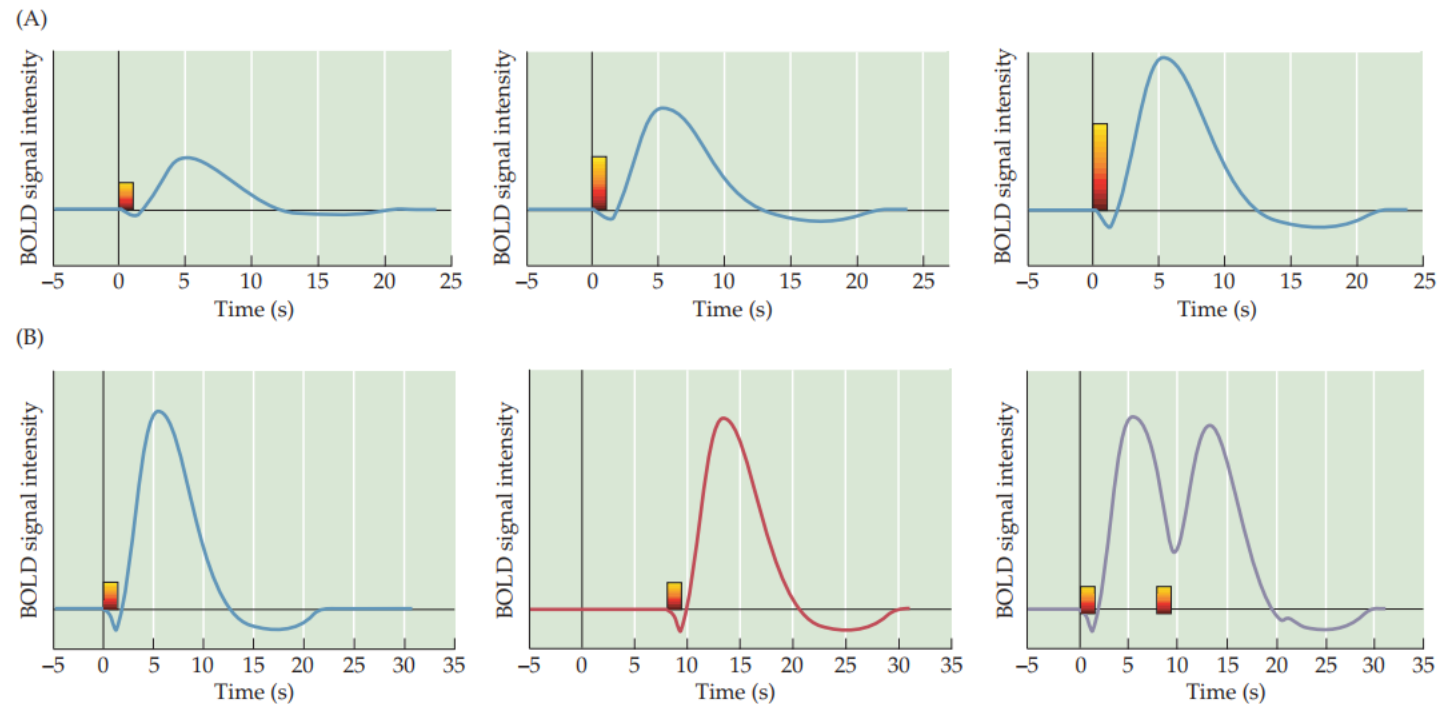
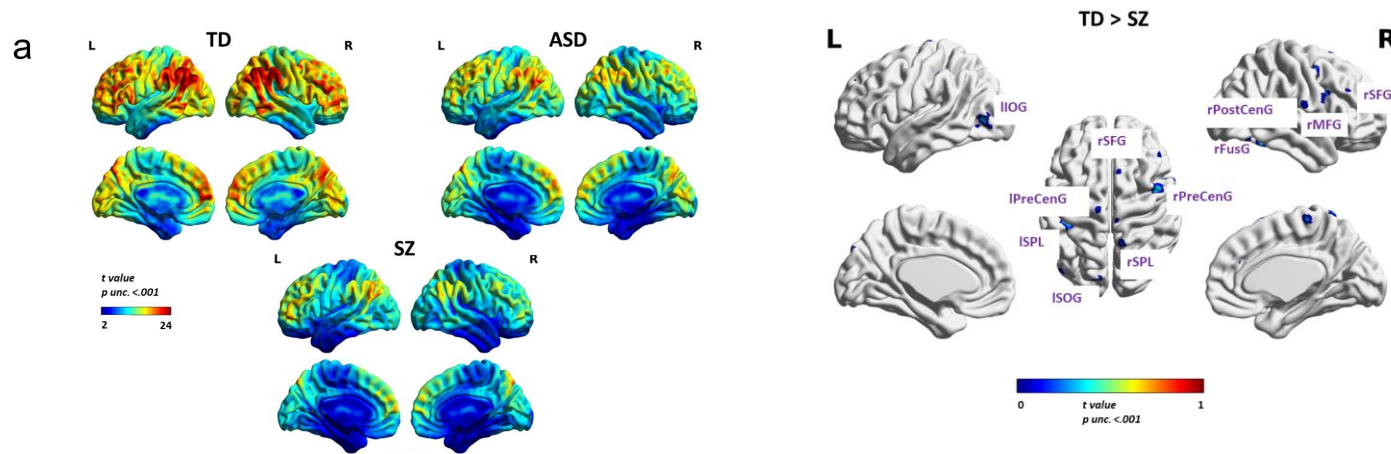


Figure 7.28 Scaling and superposition. (A) The principle of scaling states that the output of a linear system is proportional to the magnitude of the input. For fMRI, this principle implies that the amplitude of the hemodynamic response reflects the amount of underlying neuronal activity. (B) The principle of superposition states that the output of a linear system with more than one input is the sum of the responses to the individual inputs.

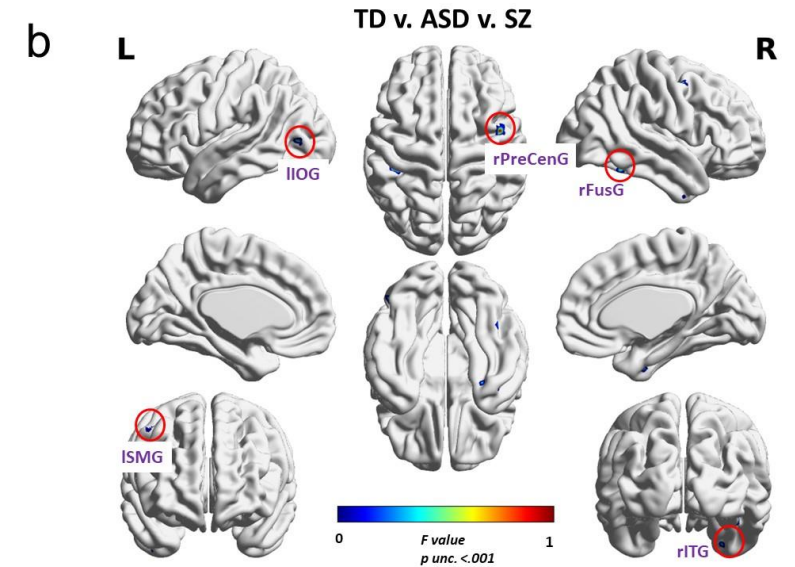
(d) analysis types

Contrasts => Statistical parametric maps



Within group; one-sample t test

Between two groups; two-sample t test



Across groups; ANOVA

Uscatescu et al., (2023)

<https://www.nature.com/articles/s41537-023-00344-1>

Functional (undirected) connectivity

synchronisation between **spatially remote brain areas**,
when exposed to simultaneous stimulation

Effective (directed) connectivity

estimates the **direction** in which brain areas
increase each-other's activity

(e) levels of inference

At the **voxel level**

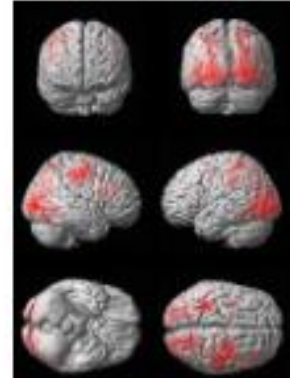
voxel

the most basic unit of measurement;
usually 3 X 3 X 3 mm;
the **volumetric** equivalent of a pixel

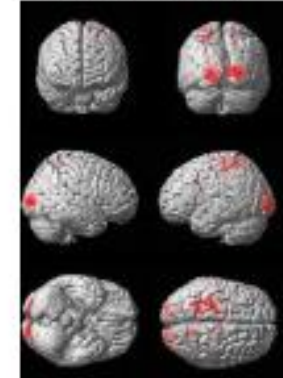
e.g., in Multi-Voxel Pattern Analysis (MVPA)
=> which patterns of voxels are preferentially
activated by different experimental condition?

- **MVPA (leave-one-out; SVM)**
- **XY vs X only vs Y only** • **X only vs Y only**

T(18) = 7.17, p < 0.05 (FWE)



T(18) = 3.61, p < 0.001 (unc.)



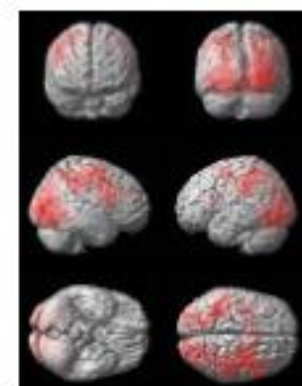
- **XY vs X only**

T(18) = 6.99, p < 0.05 (FWE)



- **XY vs Y only**

T(18) = 6.99, p < 0.05 (FWE)



Uscatescu et al., (2018)

DOI: [10.13140/RG.2.2.30653.72163](https://doi.org/10.13140/RG.2.2.30653.72163)

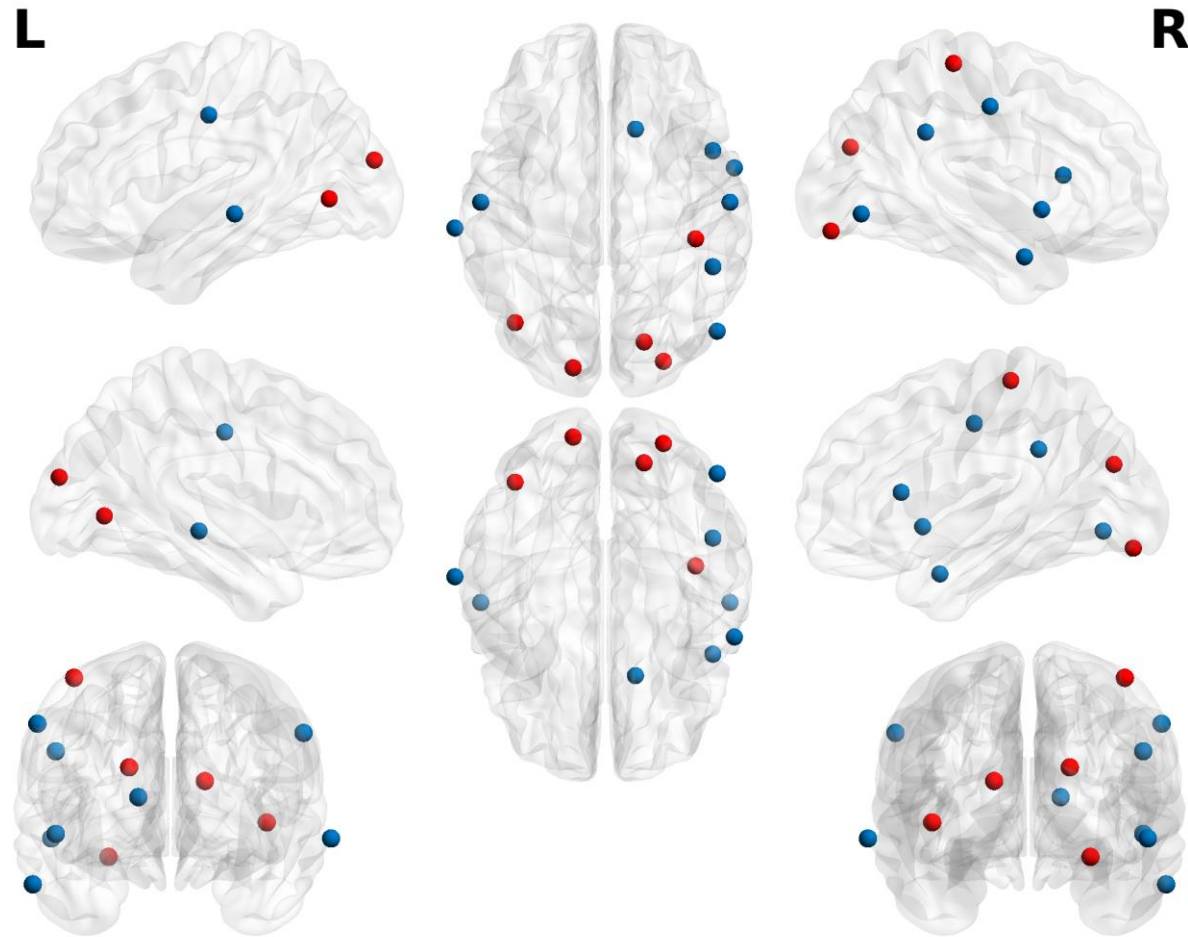
At the **region of interest (ROI)** level

Region of Interest (ROI)

pre-defined brain region;

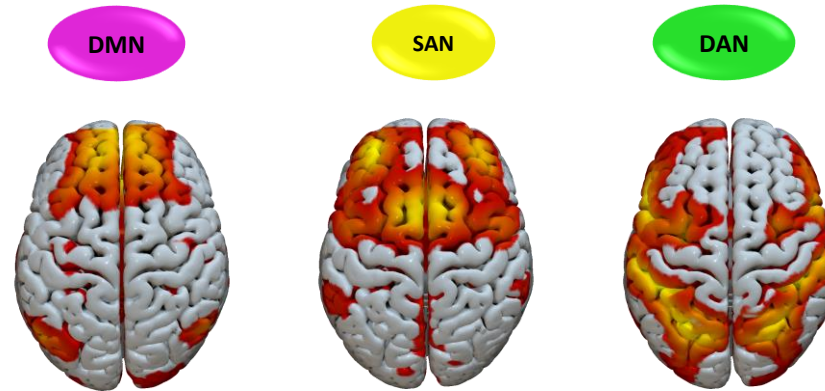
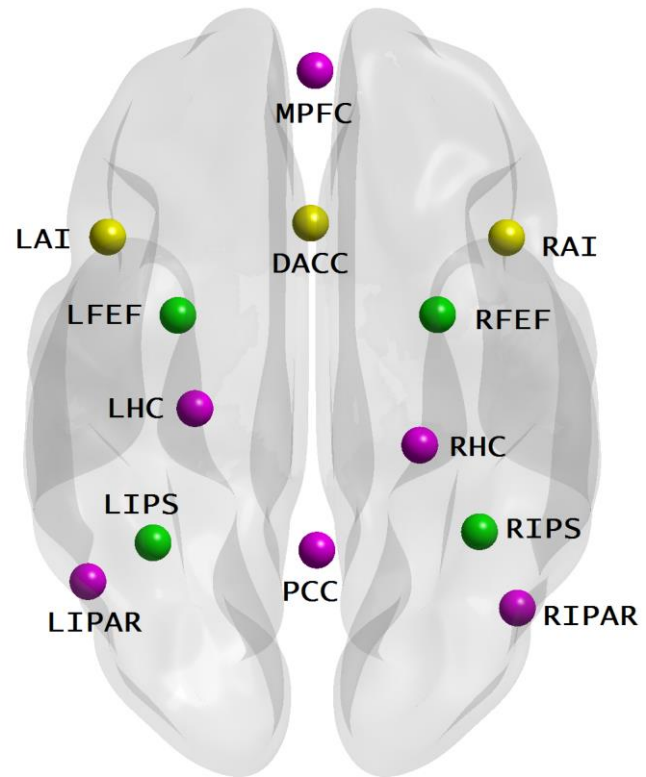
useful for multiple comparison control

(i.e., limits the risk of *false positives*)



At the **network level** => pre-defined brain networks; can be identified, e.g., through *Independent Component Analysis (ICA)*

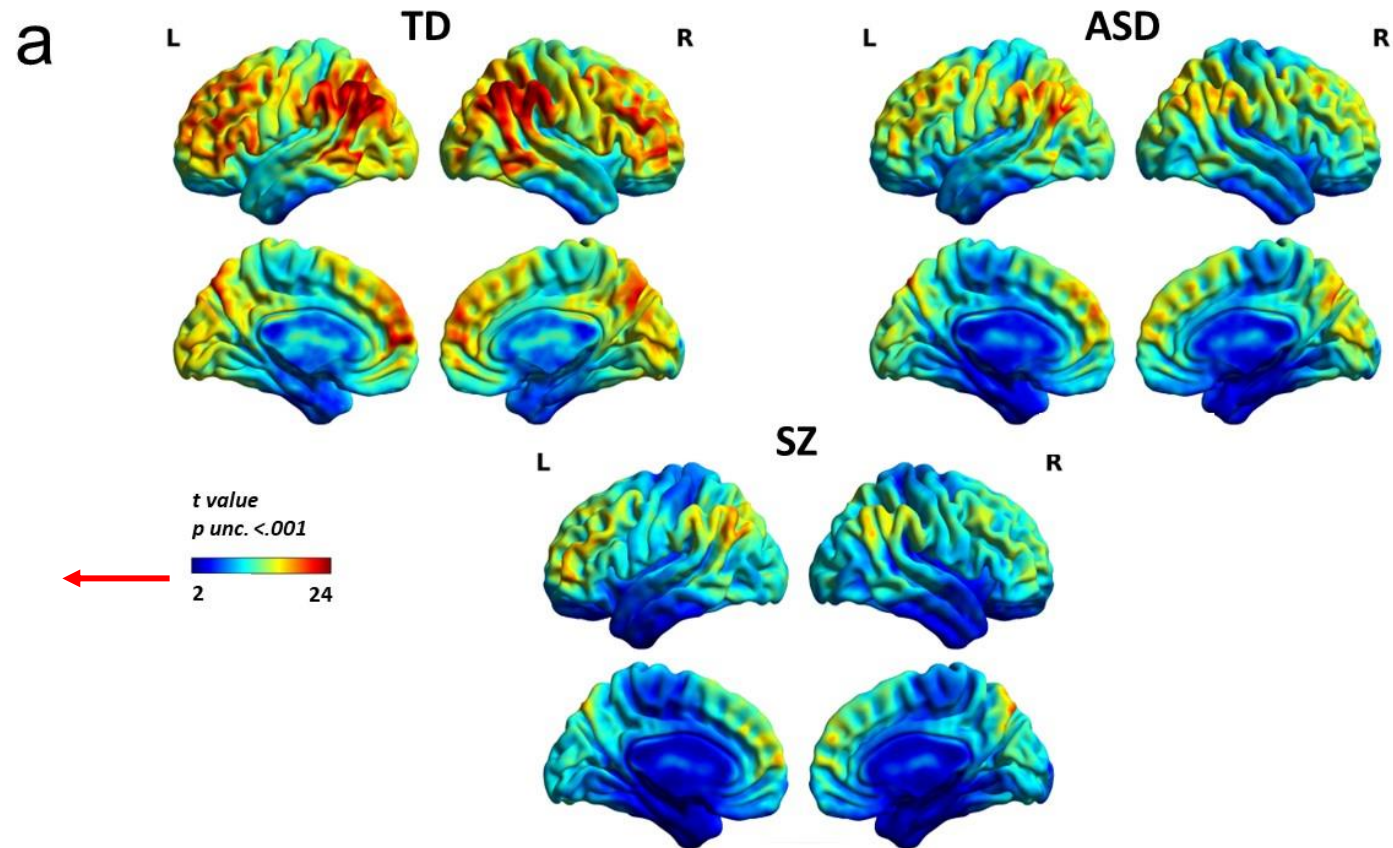
Widely used in rsfMRI



Uscatescu et al., (2021)

<https://link.springer.com/article/10.1007/s10548-021-00868-8>

At the **whole brain level** => very useful for exploratory analyses



*notice whether the reported results
are corrected or uncorrected for
multiple comparisons*

Uscatescu et al., (2023)

<https://www.nature.com/articles/s41537-023-00344-1>

Safety

The MRI, while **non-invasive**, has a **very powerful magnet** which can cause damage unless precautions are taken.

Both experimenters and participants **MUST comply** with safety screening.

When available, a **metal detector** should be used before allowing participants in the scanner room.

Likewise, maintenance personnel **MUST** be instructed accordingly.

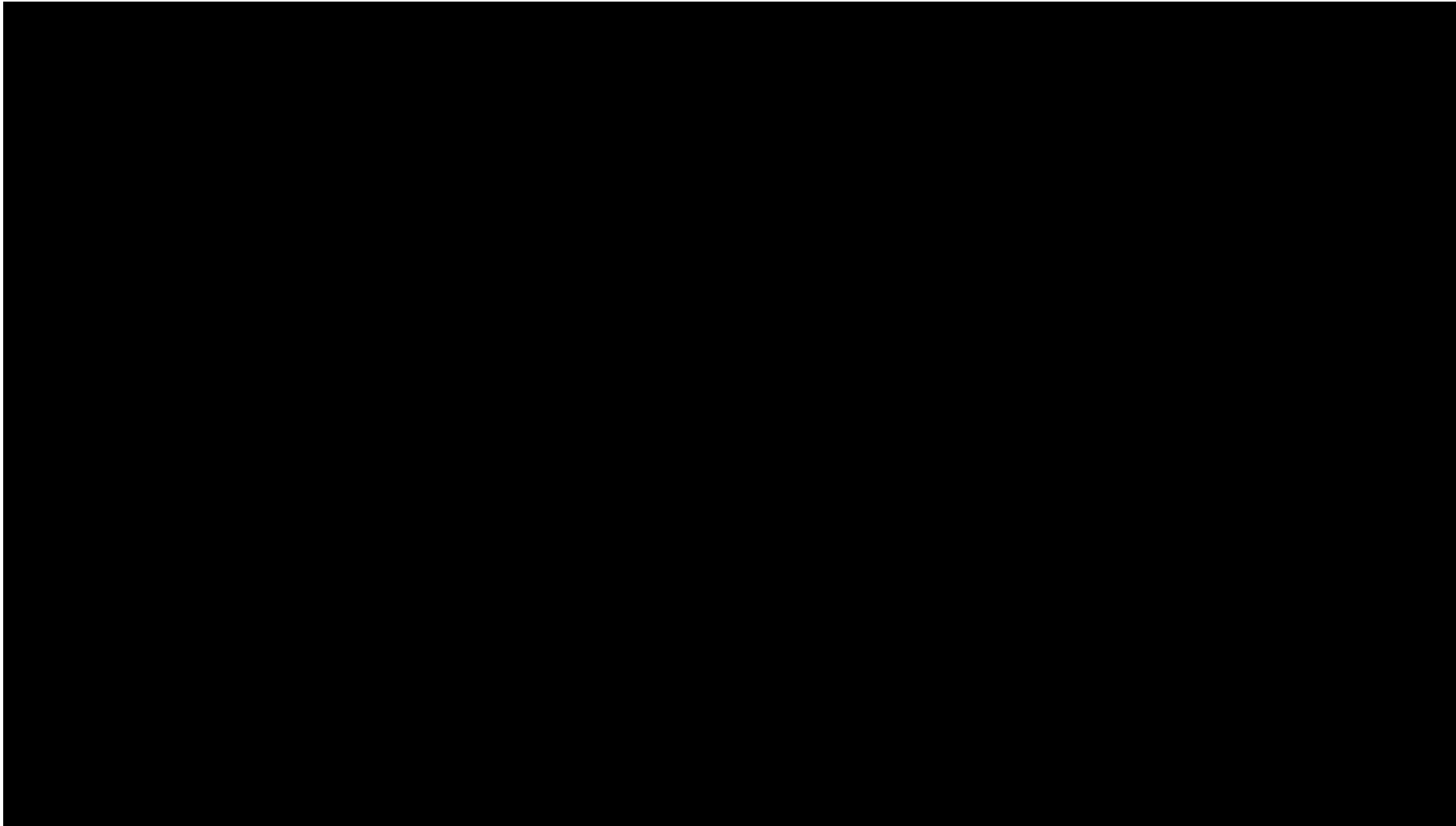
NO ferromagnetic utensils, objects, jewellery should **EVER** be allowed in the **scanner room**.

Serious damage can be caused, such as getting **burns** or **hit** by flying metallic objects.

The main magnet **IS ALWAYS ON** unless **quenched** (i.e., the liquid helium is released, thus deactivating the magnet).

Participant **screening** is performed **before study enrolment**, and contains many safety questions such as:

- are you claustrophobic?
- do you have any metal implants, or dental fillings?
- do you work with metal?
- do you have any tattoos (how old)?
- do you have a pacemaker?
- do you have an IUD (i.e., intra-uterine device)?
- do you have any piercings that might be hard or impossible to remove?
- are you pregnant?
- if you have any implants/dental fillings, do you know what material they are made of, or is it possible to obtain clearance from the doctor who implanted them?



<https://www.youtube.com/watch?v=6BBx8BwLhqq>

The patient narrowly missed being hit as well as the chair was sucked up by the machine's magnetic field.



© CEN
Oops! A family in Shanghai made a mistake when they brought a wheelchair into a MRI scanning room



© CEN
Removal service: Security staff were called in to help try and move the wheelchair from the machine

An expert from Dalian Central Hospital wrote on social media site Weibo that if the machine was indeed broken then the cost of fixing it would be around 300,000 yuan (£34,582).

<https://www.dailymail.co.uk/news/peoplesdaily/article-3678822/Wheelchair-ended-STUCK-MRI-machine-eager-family-pushed-treatment-room-soon-cost-300-000.html>

Spontaneous Discharge of a Firearm in an MR Imaging Environment

Authors: Anton Oscar Beitia, Steven P. Meyers, Emanuel Kanal, and William Bartell | [AUTHOR INFO & AFFILIATIONS](#)

Volume 178, Issue 5 | <https://doi.org/10.2214/ajr.178.5.1781092>

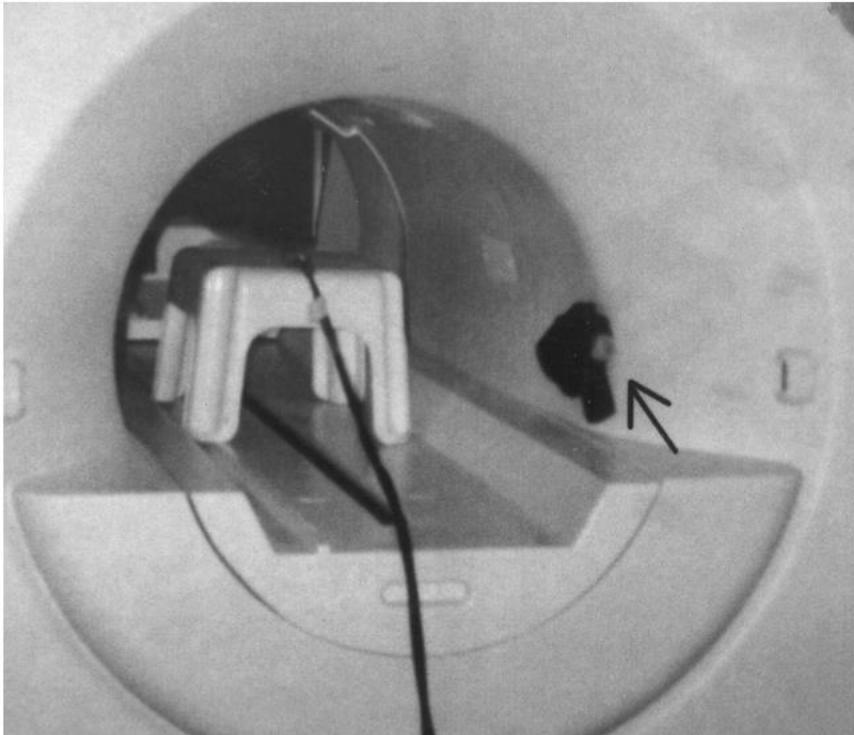


Fig. 1. —Photograph shows gun (*arrow*) stuck on right side of MR imaging magnet bore.

<https://www.ajronline.org/doi/10.2214/ajr.178.5.1781092>

An off-duty police officer went to an outpatient imaging center (not affiliated with our institution) in western New York State to have an MR imaging examination. The facility housed a 1.5-T MR unit (Signa; General Electric Medical Systems, Milwaukee, WI) with active shielding. The officer was carrying a model 1991 A-1 compact .45 caliber semiautomatic pistol (Colt's Manufacturing, Hartford, CT).

The officer notified the technologist that he was carrying the weapon before entering the MR dressing room. The technologist told the officer to take the gun with him. The technologist intended to meet the officer in the MR patient waiting area before the examination and secure the weapon in that room, where he felt it would be safe. However, the officer apparently misunderstood and took the gun into the MR suite. The technologist was entering the officer's personal data into the computer and did not see him entering the MR suite.

Once the officer was inside the MR suite, the gun was pulled from his hand as he attempted to place the gun on top of a cabinet 3 ft (0.9 m) away from the magnet bore. The gun was immediately pulled into the bore, where it struck the left side and spontaneously discharged a round into the wall of the room at the rear of the magnet. Fortunately, no one was injured. Although the gun struck the magnet bore, only minimal cosmetic damage occurred to the magnet itself. The MR unit had full functional capability immediately after the gun discharged. The weapon's thumb safety was reportedly engaged when the gun discharged.

An unsuccessful attempt to remove the gun from the magnet resulted in the gun being pulled to the right side of the magnet (Fig. 1). The decision was then made to power down the magnet to remove the gun.

MRI accident in India injures 2 employees

AuntMinnie.com staff writers

Nov 10, 2014

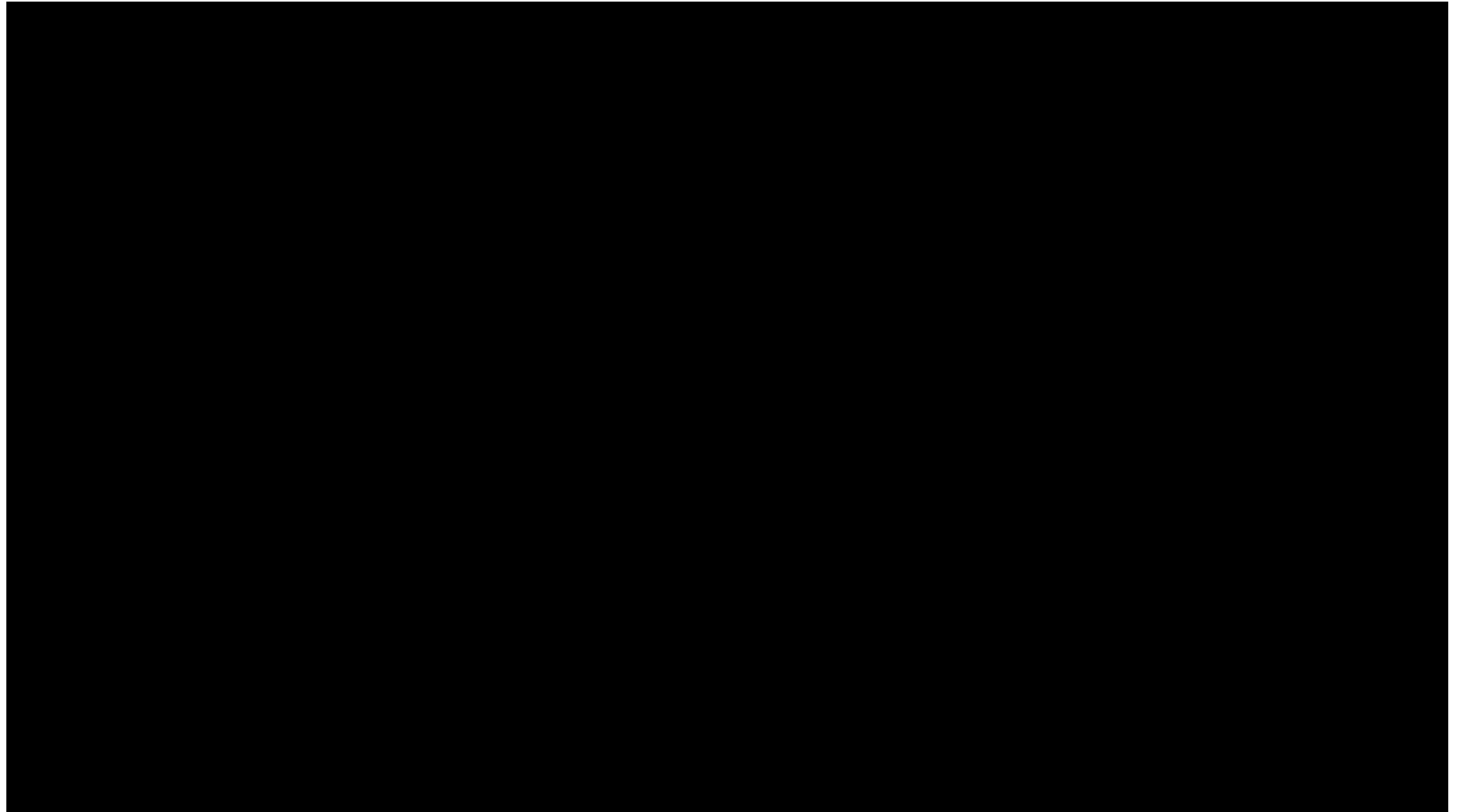


An inquiry into the November 8 mishap at a Tata Memorial research and treatment centre, where two employees remained stuck to an MRI machine for four hours after one of them walked into the room carrying an oxygen cylinder, has revealed that the machine's manufacturer, GE Healthcare, had disabled a switch that could have instantly deactivated the machine's magnetic field.

According to an [article](#) in the *Mumbai Mirror*, two employees were injured on November 8 when one -- a general duty assistant, or ward boy -- walked into the MRI room carrying an oxygen tank. Both men were pulled into the magnet and stuck there for almost four hours until an engineer arrived and deactivated the magnetic field.

The ward boy fractured an elbow, while the technician, who was wedged between the ward boy, the tank, and the scanner, had a punctured urinary bladder, severe internal bleeding, and other lower body injuries, according to the article.

<https://www.auntminnie.com/clinical-news/mri/article/15610888/mri-accident-in-india-injures-2-employees>



<https://www.youtube.com/watch?v=9SOUJP5dFEg>



A first degree tattoo burn caused by an MRI machine. (Image credit: Moriel NessAiver | simplyphysics.com)

Tattoos can hinder an MRI scan depending on the [ingredients used in the tattoo ink](#) and the size of the tattoo. Since there are currently no FDA-approved tattoo inks, determining which chemicals were used in a tattoo can be tricky. But experts say that some ink colors cause more of a reaction than others.

The dye used in red tattoo inks contains iron (for example, think of the color rust), which is magnetic and very susceptible to the [magnetic fields](#) used in MRI machines, said Moriel NessAiver, a physicist who teaches MRI safety in Baltimore.

Specific absorption rate (SAR)

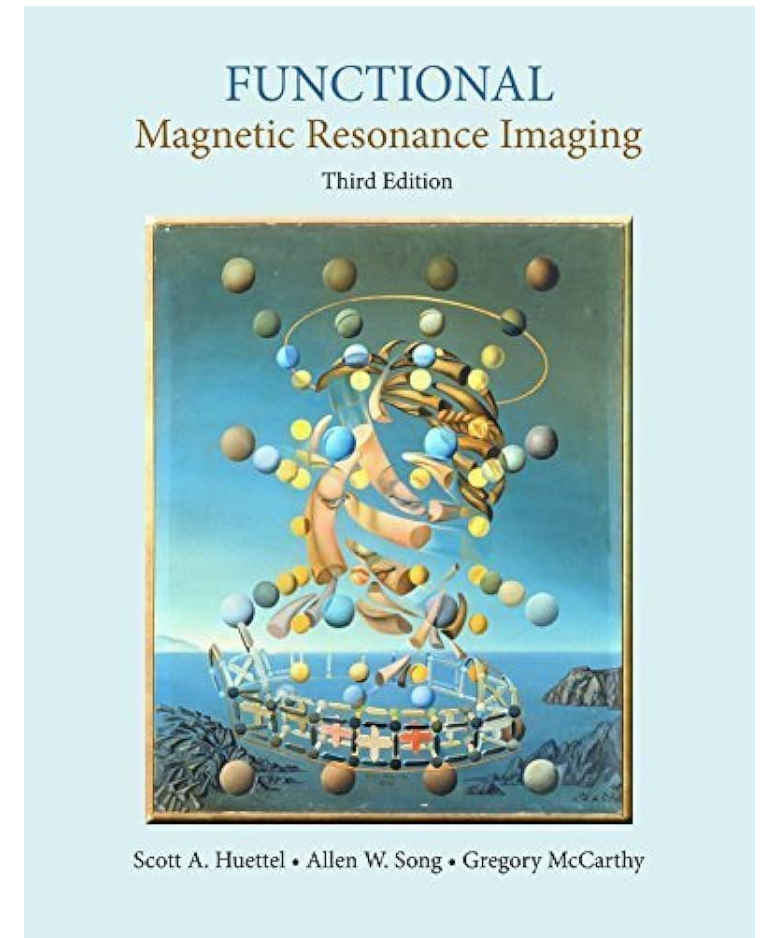
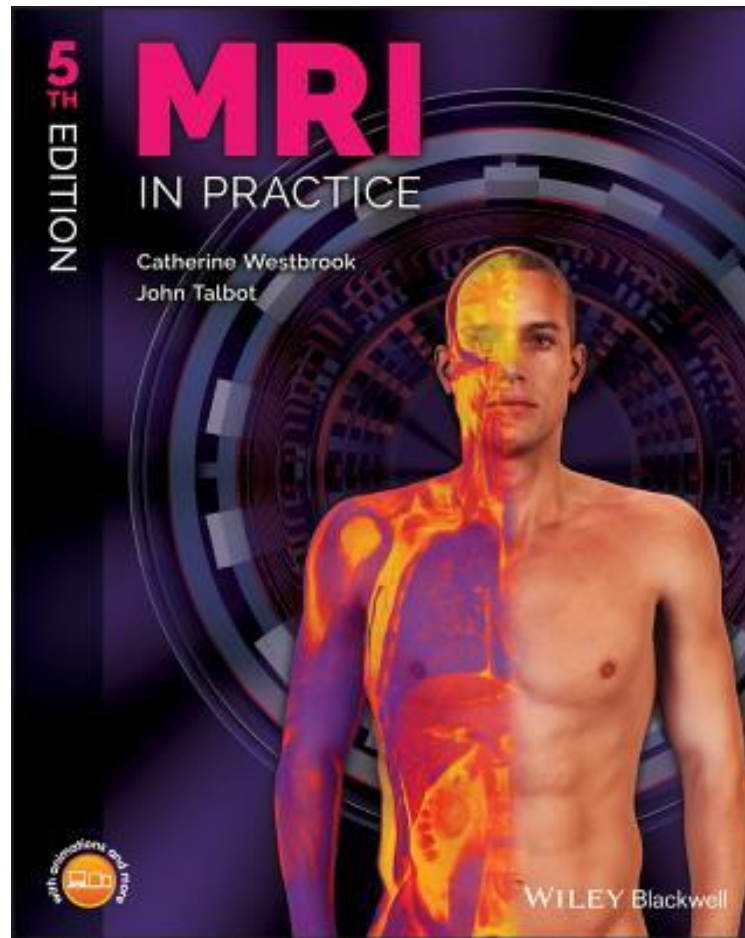
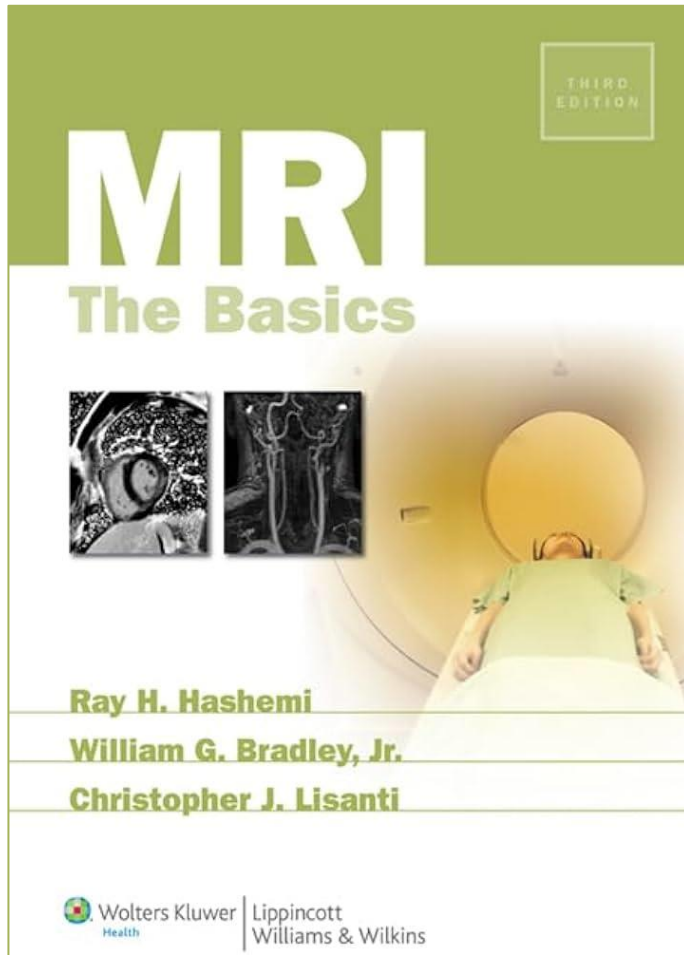
the rate that **electromagnetic energy** in the radiofrequency pulses is **absorbed by tissues** during MR image acquisition measured in watts per kilogram (W/kg)

"Since iron can conduct electricity, loops of current are induced when the magnetic fields are rapidly changing during the imaging process," NessAiver told Life's Little Mysteries. "Any time you have a current flowing, as in a wire or other metal, that metal can get hot hot enough to burn."

If the tattoo is in the shape of a loop, it can act like an antenna, and can also get increasingly hotter as the ink pigments pick up more energy from the magnets, according to NessAiver. The reaction can result in swelling of the [tattooed skin](#) and its surrounding area, as well as the flesh feeling hot and irritated.


The most serious reactions result in first and second-degree burns, according to a 2009 study conducted by Italian scientists and published in the International Journal of Environmental Research and Public Health.

Further resources



Further resources

luscatescu@vt.edu



OHBM Neurosalience

By OHBM

The **Organization for Human Brain Mapping (OHBM)** presents the **Neurosalience podcast**. In this series of interviews you'll discover the latest developments in techniques for measuring brain structure and function. You'll hear about how these tools can provide insight into the function of the brain from childhood to old age, and why these normal processes may be affected in neurological and psychiatric conditions. Dr. **Peter Bandettini** interviews brain scientists of all types and discusses the latest developments, controversies and challenges related to their work in the field of brain mapping.

See less

<https://podcasters.spotify.com/pod/show/ohbm>



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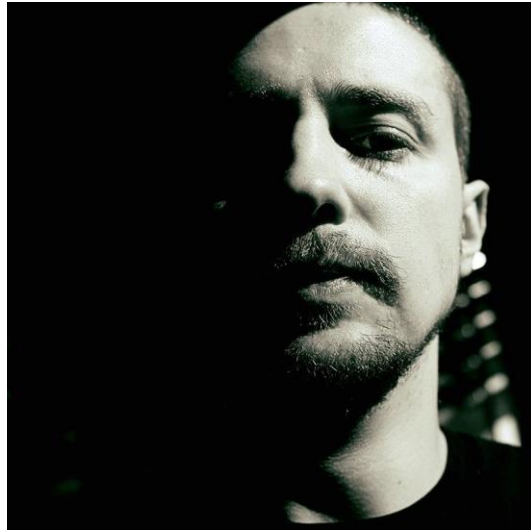
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Barbu Isloi



Dr. Raluca Szekely-Copindean

Thank you!



brain sticker

A ~~penny~~ for your thoughts?