# MRI Simulator

**Objective:**

This tool will be used to simulate roughly the steps of operating an MRI scanner. This includes planning of the exam, technical considerations, and the additional component of grading and seeing a final image.

I am not sure which would be easiest or most cost effective to host this simulation. Would it be easier to host:

- As a standalone activity?
- Wordpress plugin?

| Step 1: Planning | Step 2: Technical Considerations | Step 3: Grading |
| --- | --- | --- |
| **This includes:**<br>There should be 3 viewers with different sets of anatomical images within them. The boxes will be labeled anatomically as well and should communicate with each other.<br>**Defining two areas:**<br>● 1 area that needs to be covered. This is an area of the image that requires users to plan a coverage area through it.<br>● 1 area that defines areas that need to be accounted for. This means that users need to make sure that areas outside the first box are covered as well, but do not require users to plan through it.<br><br>We also need to define a correct angle. This will relate to the other 3 viewers. | **This includes:**<br>A list of parameters that can be changed by the user. The changes will:<br>● Change the area of coverage in the viewers.<br>● Produce calculations that will result in a grade. | A list of parameters and a resulting score that correlates with it that will add up to a final score. This score should be able to be exported.<br>Along with a grade, a stock photo will be displayed demonstrating a final image. Image filtering should manipulate the image based on the calculation results.<br><br>*Ex.*<br>● *Parameter SNR will apply a noise filter on the image making it look grainy.*<br>● *Parameter CNR will apply a blur filter on the image to make it look blurry.*<br>● *Parameter resolution will apply a sharp filter to make things look more detailed.*<br>● *Parameter FOV will apply a zoom filter to make thinks zoom in or out.* |

**Terminology**

*Activity: This is an entire lesson for a user, it contains individual simulations*

*Simulation: An independently graded activity situation a user will be challenged with*

*Learn Mode: This is a progression where users are guided to the correct answer.*

*Test Mode: This is a progression where users are tested on their performance.*

*Template: This is a format where the viewer and parameters will be laid out.*

*Viewer: This is a image box that contains multiple images. A user will work at covering the correct area on these images.*

*Parameters: A display of values that a user must manipulate.*

*High Level Parameters: The user will change parameters which will alter the high-level parameters. The user can not directly change the high-level parameters.*

*RF Coils: This is a selection by the user that will determine the results of their performance.*

*Field Strength: This is a selection defined by the admin on activity set up which will alter the result of the high-level parameters.*

*Question Exercise: This is an exercise used in place of a simulation. It will ask a question, teach a concept, or present information.*

*Parameter Exercise: This is an exercise that will test the user's ability to manipulate parameters and perform an MRI.*

*Anatomy Laterality: This is meant to describe the sides of our patient. (Right (R), Left (L), Anterior (A), Posterior (P), Foot (F), Head (H))*

*Image Orientation: This describes how we slice our patient. (Sag = separate patient into right and left side) (Cor = Separate patient into anterior and posterior side) (Ax = separates patient into a head and foot side(*

*Question Exercise: This is a simulation type that will ask the user a question, get an answer, and possibly show a solution as to why the answer is right or wrong. We can also determine if we want this exercise seen in the simulation list area.*

*Simulation list area: This is the area where a user can see all the simulations they still need to complete.*

*Image Contrast: Based on values the user selects, the image will look different. These are always the same based on specific values.*

*Pulse sequence: This is a way we can perform a simulation. It has specific parameters, limits, and values associated with it.*

*R-R: When using the cardiac exercise, we based all our scan time values off this period of time. It represents the cardiac cycle.*

*Grade Card: This is a pop up of what the user scored after each simulation.*

*Activity Results: This is a page seen after an activity which gives an overall score.*

*Body Part: This section is used for tagging activities and eventually requiring specific body parts to be completed for a user.*

*Lesson Area: This is a section on the frontend where education to the user can be presented. This area can present lessons or other content.*

*Vendor to Vendor: Parameters can have different layouts (vendor = template). When a vendor to vendor activity is selected, to parameter selections can be view (for each template selected) stacked on top of each other.*

*Box 1: This is a box representing an area that needs to be covered by the user.*

*Box 1 angle: This is the angle of the box that needs to match within a couple degrees of the correct answer.*

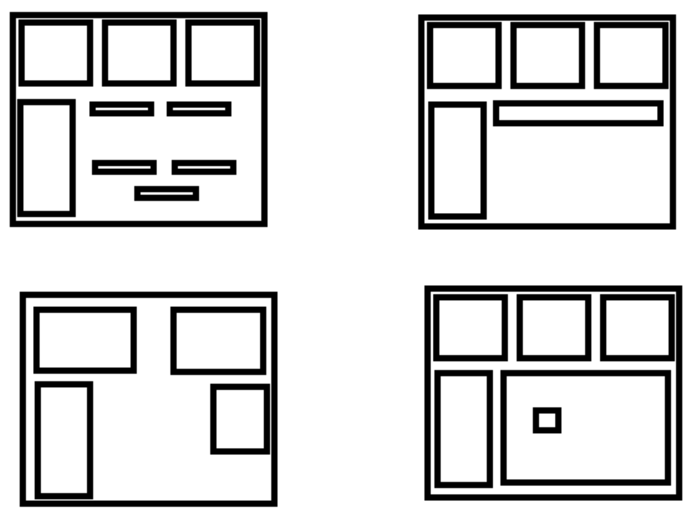
*Box 2: This is a box representing an area that the user does not need to include with parameter FOV, but still account for.*

*Image Filtering: This is a stage of the process where high-level parameters control the appearance of the final image.*

# Global Setting

Each activity will include a collection of separate simulations. Example:

- Activity 1 (With Global Setting)
  - Simulation 1 > show image
  - Simulation 2 > show image
  - Simulation 3 > show image
  - Question 1
  - …
  - Grade with score average

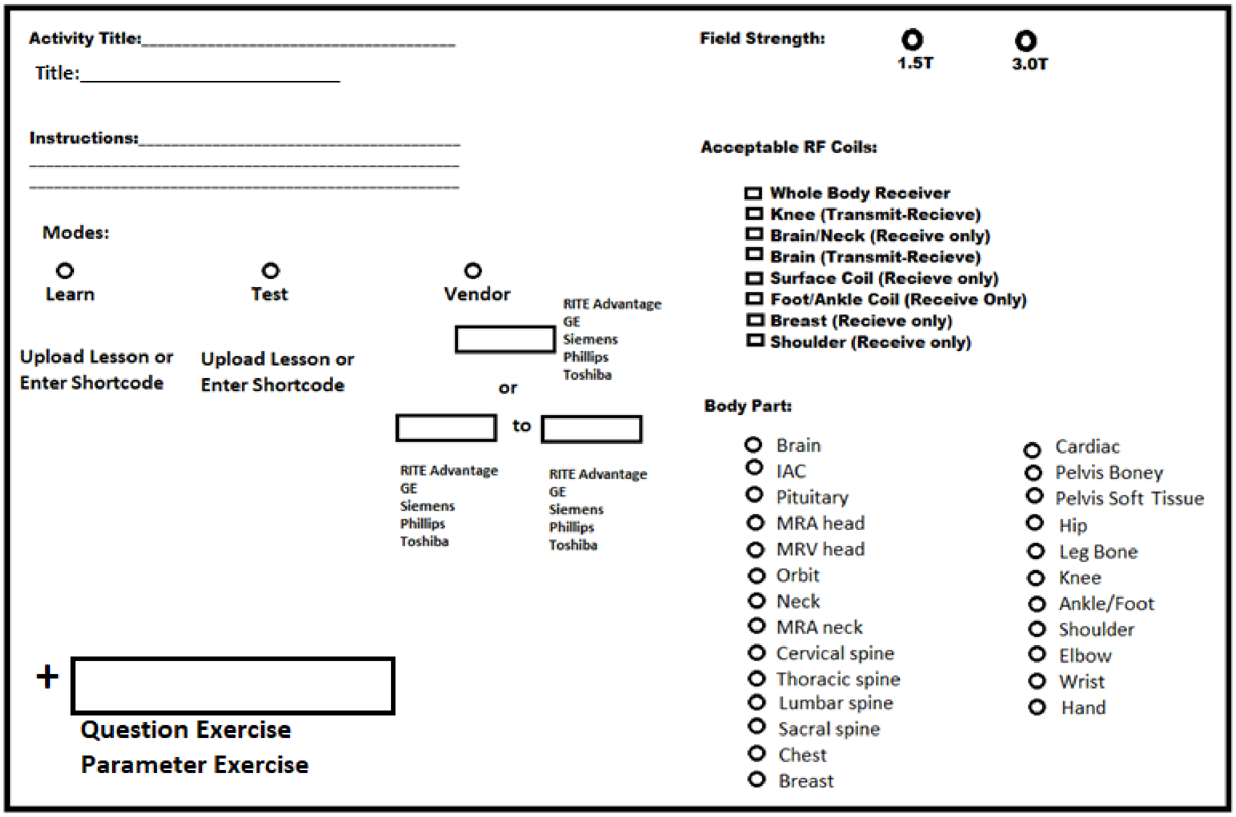
<table>
<tr><th>2 Modes of Operation</th><th>Templates (Optional)</th></tr>
<tr><td>
<ul>
<li>Learning mode: This will show descriptions and graphs demonstrating objectives. This will guide users through the planning of the exam and provide lessons.</li>
<li>Testing mode: This will be an open simulation that will present results for grading.</li>
</ul>
In both modes, the option to provide a simulation or question slide within an activity should be an option.<br><br>
<u>Parameters</u><br><br>
TR<br>
TE<br>
TI<br>
ETL<br>
etc.<br><br>
(Expanded on later)<br><br>
<u>Questions</u><br><br>
Title<br>
Image/video/shortcode<br><br>
Question/Statement<br>
Answer<br>
Answer<br>
Answer<br>
Answer<br>
Solution
</td><td>
This provides different layouts that I can choose to build with. In other words, the layout of the parameters will be different based on one of 4 templates I choose. All the parameters will have the same purpose, but will be displayed differently.
<ul>
<li>RITE Advantage</li>
<li>Siemens</li>
<li>GE</li>
<li>Toshiba</li>
<li>Phillips</li>
</ul>

</td></tr>
</table>

## Backend Global Setting for Activity

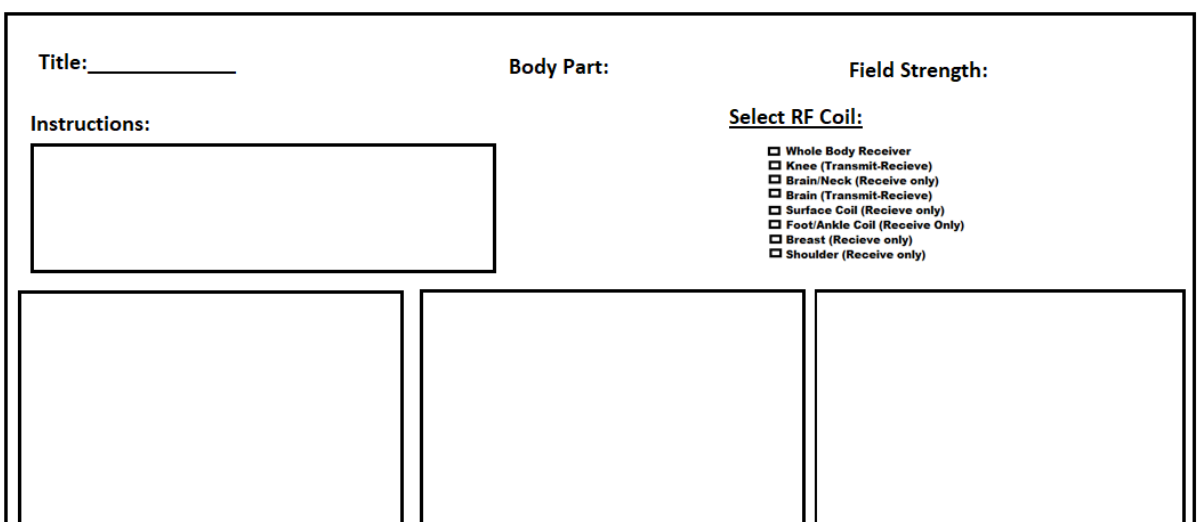
- Activity Name:
- Instructions: (To explain the purpose of the activity)
  - Text area where instructions can be provided to user
- Mode: (To define how the simulations will be handled and what the goal for the user is)
  - **Learn**: Run stimulation in a learning setting defined below.
  - **Test**: Test Users
- Template: (Optional parameter display)
  - **Siemens**: Display parameters with a specific template
  - **GE**: Display parameters with a specific template
  - **Phillips**: Display parameters with a specific template
  - **Toshiba**: Display parameters with a specific template
  - **RITE** Advantage: Display parameters with a specific template
- RF Coil: (Used to test user on correct setup and for high-level parameter calculation)
  - Body
  - Knee
  - Brain and Neck
  - Brain T-R
  - Surface Coil
  - Foot
  - Breast
  - Shoulder
- Field Strength: (Used for high-level calculation)
  - 1.5T
  - 3T
- Body Part: (Used for advanced activity tracking)
  - Brain
  - IAC
  - Pituitary
  - MRA head
  - MRV head
  - Orbit
  - Neck
  - MRA neck
  - Cervical spine
  - Thoracic spine
  - Lumbar spine
  - Sacral spine
  - Chest
  - Breast
  - Cardiac
  - Pelvis Boney
  - Pelvis Soft Tissue
  - Hip
  - Leg Bone
  - Knee
  - Ankle/Foot
  - Shoulder
  - Elbow

- Wrist
- Hand

## Backend Set-up




## Frontend View

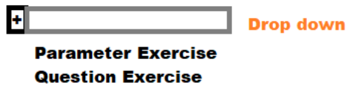


# Step 1

When setting up the simulation, a specify way to test a user will be displayed. There are two paths.

1. A list of parameters that can be manipulated and graded.
2. A popup slide that can be shown on the frontend or hidden that present messages or questions.

On the backend, the admin should be able to select what they want to add.




If Question Exercise is selection see part 2. No image planning is required for this type.

If Parameter Exercise is selected, continue to image planning.

## Simulation Builder: Image Planning

### Backend Builder

- Area to upload multiple images into one of 3 separate viewers
- <u>**Two boxes**</u>
  - **Box 1** = Area that needs to be covered with the following parameters *(See next section)*
    - *FOV*
    - *Slice thickness*
    - *Gap*
  - **Box 2** = Area that needs to be accounted for with the following parameters.
    - *FOV*
    - *RectFOV*
    - *Anti-Aliasing*
- <u>**Box 1 angle**</u>
  - I would like to set a correct angle on the image with a degree of acceptance. This will give a range of correct answers.
  - The angle will correlate with a plane selected
  - ***Axial*** (parallel to R-L and A-P, but perpendicular to H-F)
  - ***Coronal*** (parallel to R-L and H-F, but perpendicular to A-P)
  - ***Sagittal*** (parallel to H-F and A-P, but perpendicular to R-L)
  - *Other* = don't grade

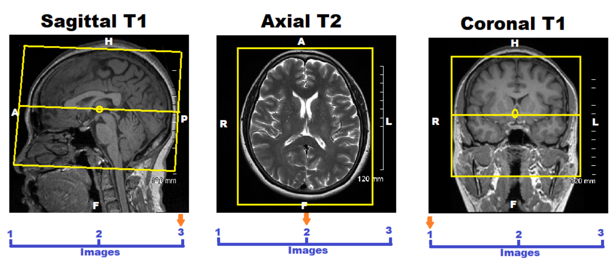
**Rough view for Backend Builder**

Each of these viewers can have 3 to 4 images of the same body part. I should be able to load these images.

### Frontend User view

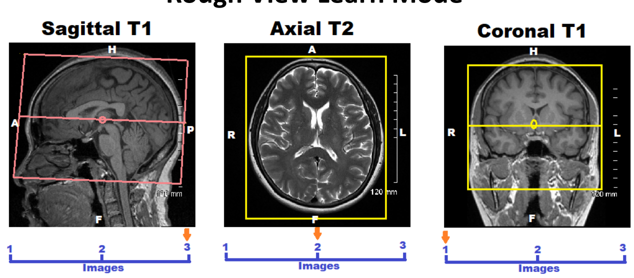
The frontend user will be given a box to manipulate. They can move the box anywhere on the image and angle any way they please.

Each viewer allows for images to be paged through They should be able to click through these images to make sure they are positioned correctly.

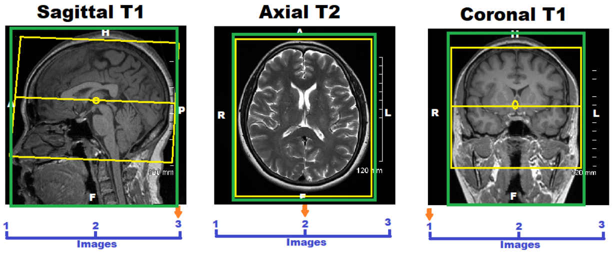



**Learn mode**= If the user angles different than how it was built, the box will turn red. This will not let user continue until they have the correct angle

**Rough View Learn Mode**




**Test mode** = No sign of correct or not will be given, it will be graded as correct or incorrect. This view won't turn the box red if the position or angle is off.

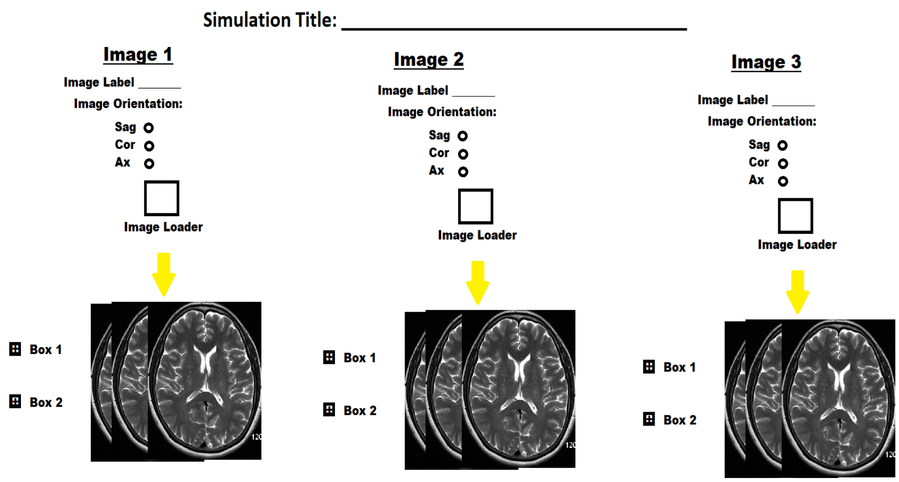



The yellow box represents “Box 1”. This tests the user on the angle and area of coverage. This is the only box the user sees.

The green box represents “Box 2”. This defines the rest of the anatomy that needs accounted for in the image.

# Image Labeling and Function

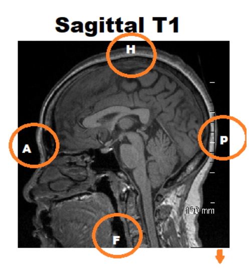
**Backend Design Idea**



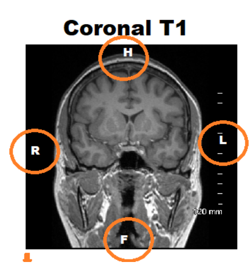

“Simulation Title” will be displayed in the “simulation view” .The “image label” is the gallery descriptor *(In the image below, it is “Sagittal T1”).*

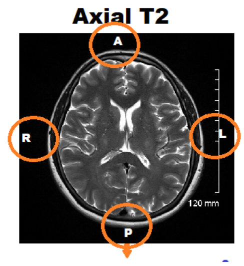
The “anatomy laterality” is defined by the image orientation.

**If Sag =**




**If Cor =**

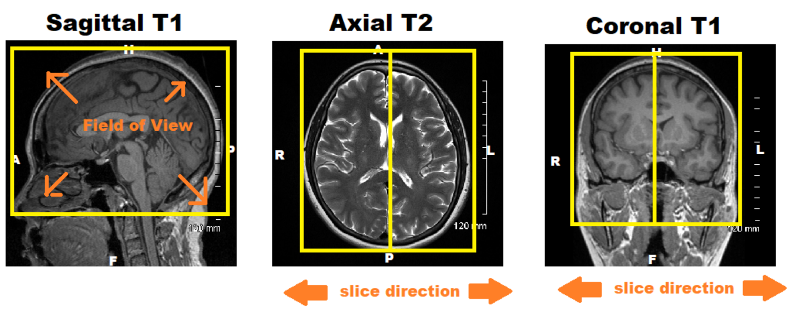


If Ax = 

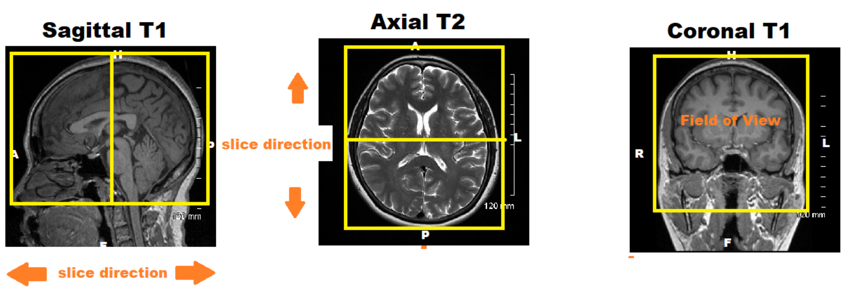

Then we should be able to set the boxes. “Box 1” sets the area that needs to be covered. We can refer to this as the **Field of View**.

The yellow line on the image on defines the slice direction.

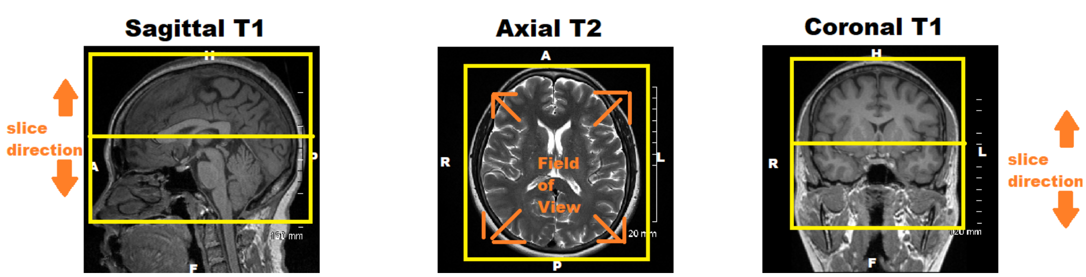
## Sag slice =



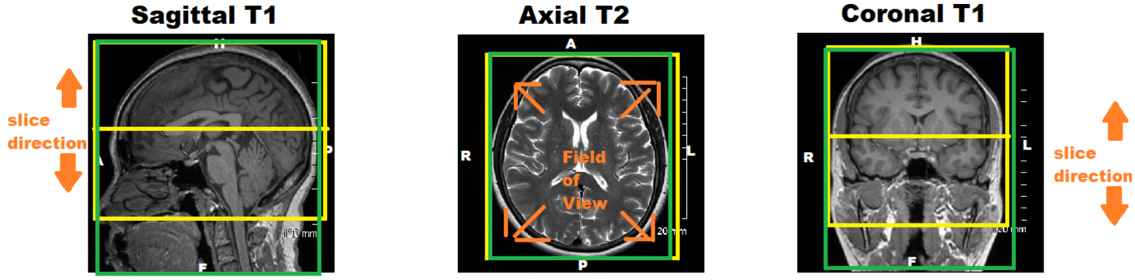

## Cor Slice =




## Axial Slice=

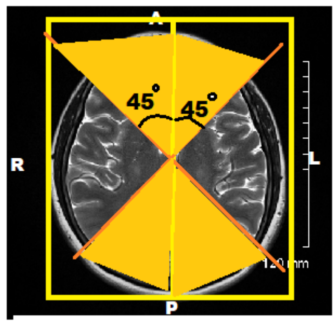


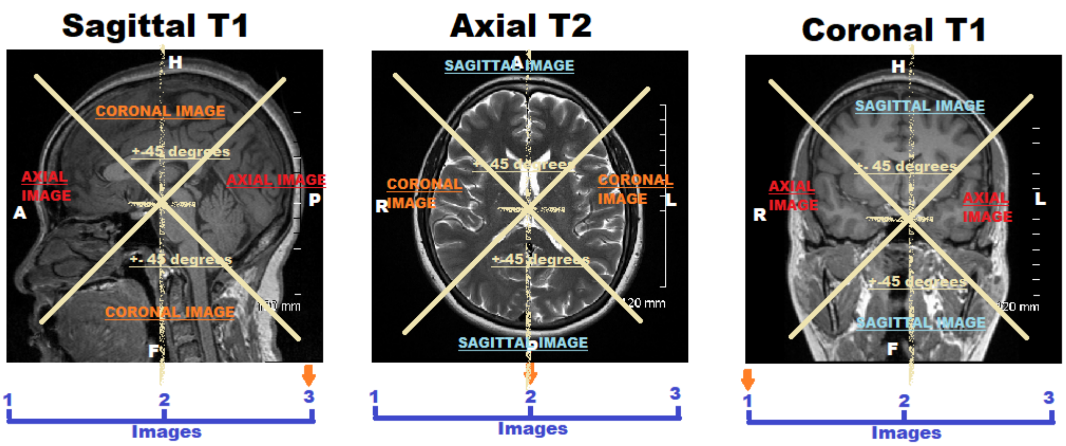

Then box 2 can be placed.




The slice direction will remain as defined (sagittal, coronal, axial) unless the angle is + - 45 degrees. Then it will default to the next slice direction.

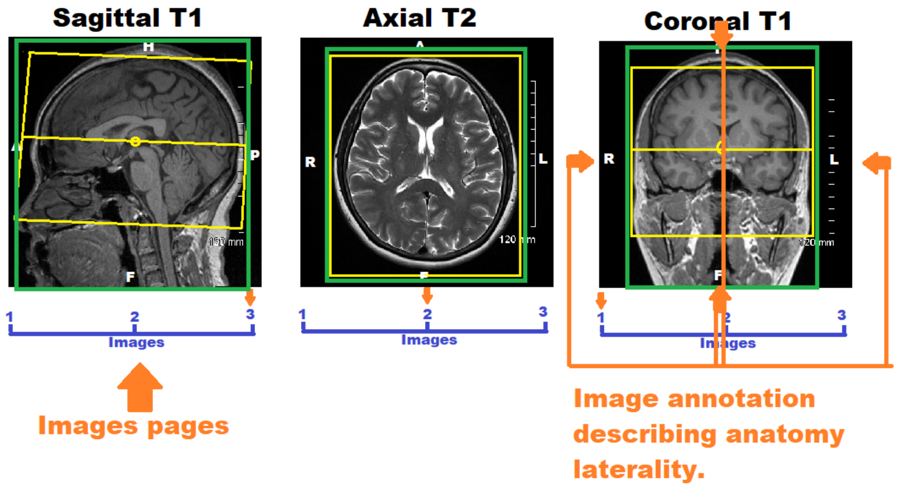
In the image below, it is planned as a sagittal. If we move beyond + - 45 degrees, it becomes a coronal. (see image planes above for slice directions.




The slice direction is defined by *slice thickness* and *gap*. (see next section). As we increase the slice thickness and gap, we increase the coverage in the slice direction and visa versa.

**Additional Labelling**




**Any move of the field of view will reflect across all viewers. Example: If the field of view is moved to the "R", it will move to the "R" on the axial and coronal. If it moves towards the "A" it will move on the axial and sagittal viewers. Etc..**

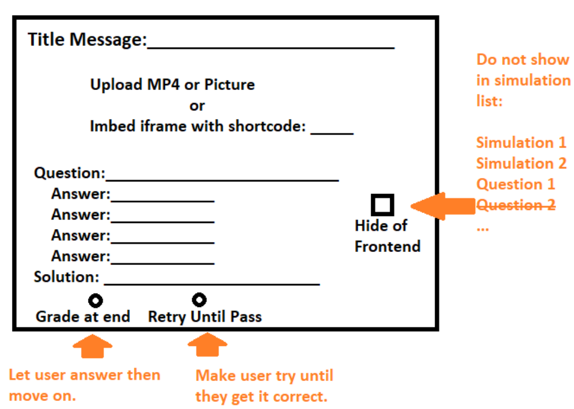
**(See Video)**

## Step 2: Technical Considerations

A list of parameters will be found on the template that has been chosen. There will be two types of simulations.

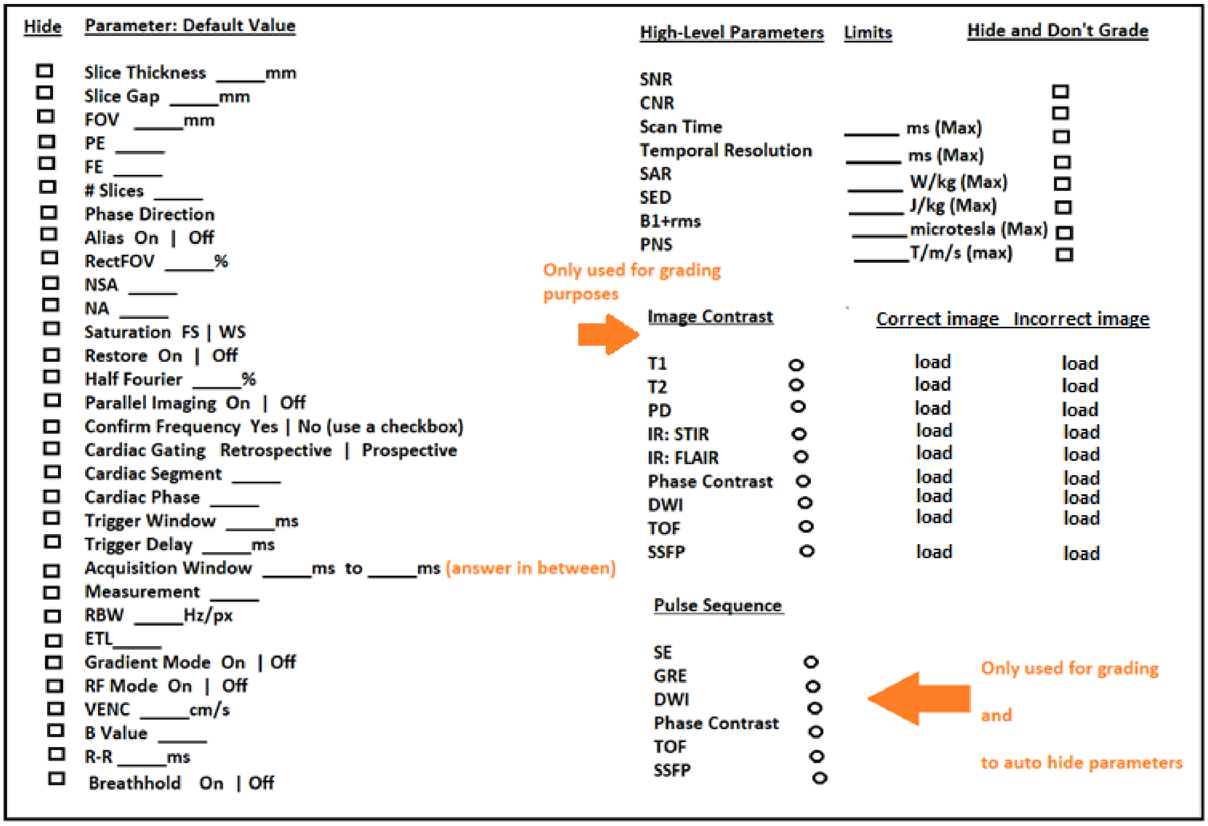
1. *Question exercise*
2. *Parameter exercise*

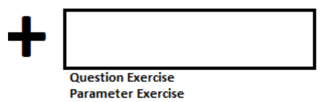
1. If question is selected, information would be required to display appropriately on the frontend.




*It would be nice to have the ability to also post shortcode for other plugins (such as H5P) that can be presented in an iframe.*

2. If Parameter Exercise is selected, a list of parameters should be displayed. The option to input default fields would be needed.




Here is a list of the parameter and functionality. If the "learn mode" is selected, an ⓘ can be found next to the parameter and when clicked, the "description" will be displayed.

| Parameters | | | | | | |
|---|---|---|---|---|---|---|
| **Parameter** | **Abbreviation** | **Min** | **Max** | **Purpose** | **Description** | **Field display** |
| **TR** | **TR** | **(((2*1+[ES])+([FE]*(1/[RBW])/2))*[Num slices] * [ETL])+([fs]*([TR]/[ETL]/2))/[num acquisition]** | **10,000** | Use of grading | **Repetition time defines the period from one excitation pulse to the next. It refers to the cycle of repeating patterns of data collection. TR controls T1 contrast in our image. As we increase TR, we increase inherent signal to noise in our image, decrease T1 contrast, and increase scan time.** | **Number** |
| **TE** | **TE** | **(2*1+[ES]) + ([FE]*(1/[RBW]))** | **1000** | Use of grading | **Echo time defines the period from excitation to when our echo is collected. Most pulse sequences demonstrate our TE within our TR. This means that our TR will always be longer than our TE in most situations. TE controls T2 contrast. As we increase TE, we increase T2 contrast, decrease inherent signal to noise, and increase susceptibility in our image.** | **Number** |
| **TI** | **TI** | **–** | **–** | Use of grading | **Inverse time is used to suppress tissues based on their T1 recovery. This means that inverse sequences influence T1 contrast. By utilizing a 180-degree RF pulse prior to our TR, we can invert protons within a volume of our patient. If we wait a period of time that correlates with the T1 of a tissue we wish to suppress prior to excitation, that tissue will be removed from our image. Shorter inverse times will correlate with fat suppression. We call these short T1 inverse recovery sequences or STIR. Longer inverse times may correlate with cerebral spinal fluid, and these are called fluid attenuation inverse recovery sequences or FLAIR.** | **Drop Down If 1.5T show 160 2500 If 3T show 220 2500** |
| **Flip Angle** | **FA** | **If gradient echo=10 If spin echo =120** | **If gradient echo = 90 If spin echo = 180** | Use of grading | **A flip angle defines the amount of energy we deliver to our patient to tilt hydrogen away from longitudinal magnetization. A spin echo sequence always starts with a 90-degree RF pulse. It then is followed by one or more 180 degree refocusing pulses. Most of the time, we can change this number to lower patient heating. We should not decrease it below 120 degrees however Gradient echo sequences allow us to use a flip angle of 90 degrees or less. As we decrease are flip angle, we decrease T1 contrast in our image. We also decrease patient heating.** | **Number** |

| | | | | | | |
|---|---|---|---|---|---|---|
| **Slice Thickness** | **ST** | **0.1mm** | **50mm** | **Increase the coverage in the "slice direction"** | **Slice thickness controls how much tissue we will average into a 2-dimensional slice. The thicker our slice thickness, the more tissue we are averaging into our image. This can lead to image blurring called partial average volume artifact. Increasing our slice thickness can also promote higher SNR and increase coverage. As we increase coverage, we may be able to use less slices which leads to shorter scan times.** | **Number** |
| **Slice Gap** | **SG** | **0** | **5** | **Increase the coverage in the "slice direction"** | **Slice gap is a parameter that controls the spacing in between slices. The main benefit of this is to increase coverage so that we need less slices. This leads to shorter scan times. The issue with utilizing a slice gap is that pathology may be missed.** | **Number** |
| **Field of View** | **FOV** | **5** | **500** | **Increase the size of the "field of view" in viewer** | **The field of view controls the coverage included in our image. It acts as a frame around our image. Based on other parameters, we will have a fixed number of pixels in our image. As we decrease our field of view, we squeeze those pixels together making them smaller. If our pixels get smaller, our spatial resolution increases. This means that a decrease in field of view leads to an increase in spatial resolution. The downside of this is that our signal to noise ratio will decrease. This is because there is an inverse relationship between spatial resolution and SNR.** | **Number** |
| **Phase Encoding** | **PE** | **_** | **_** | Use of grading | **Phase encoding defines the number of lines in our data space or K space. As we increase our phase encoding, we increased the number of lines that need to be filled with echoes. This means we need to produce more echoes which leads to an increase in scan time. As we increase the number of lines however, we increase our spatial resolution. This parameter combined with our frequency encoding direction make up our image matrix or a grid of pixels which represent our patient. As we increase the number of phase encoding lines in our image, they are squeezed together due to a fixed field of view, and this leads to increased spatial resolution. There is an inverse relationship between spatial resolution and SNR which means that as we increase our phase encoding, we decrease our SNR.** | **Drop Down**<br>**128**<br>**192**<br>**224**<br>**256**<br>**320**<br>**384**<br>**448**<br>**512** |
| **Frequency Encoding** | **FE** | **_** | **_** | Use of grading | **Frequency encoding is a parameter that defines how many data points we will use to represent patient frequencies in the frequency encoding direction. As we increase our frequency encoding, we increase the number of data points used to replicate our patient signal. This can increase our echo spacing however it does not always increase our scan time. As we increase our frequency encoding, we increase the number of lines in our frequency encoding direction squeezing them together due to a fixed field of view. This means that we will increase our spatial resolution which leads to a decrease in SNR due too in inverse relationship between the two.** | **Drop Down**<br>**128**<br>**192**<br>**224**<br>**256**<br>**320**<br>**384**<br>**448**<br>**512** |
| **Number of Slices** | **#Slice** | | **80** | **Increase the coverage in the "slice direction"** | **The number of slices define how many pictures we need to cover in area of our patient. This is limited to how long our repetition time is and how many echoes we are collecting per repetition time.** | **Number** |
| **Phase Direction** | **Phase Dir** | **_** | **_** | **Determine if "Box 2" is covered properly.**<br><br>**The area represente d by the green box needs to be accounted for.** | **Phase encoding direction defines which orientation our phase encoding lines will be filled. This is important due to the many artifacts seen in this direction. The big artifacts to worry about in our phase direction is aliasing or wrap artifact and motion.** | **Drop Down**<br>**A-P (**Show if Sagittal or Axial)<br>**H-F** (Show if Sagittal or Coronal)<br>**R-L** (Show if Coronal or Axial) |
| **Anti-Aliasing** | **Alias** | **_** | **_** | | **Any tissue outside of our field of view in the phase encoding direction can lead to aliasing artifact. This parameter will compensate for this accounting for tissue outside our field of view in the phase encoding direction.** | |
| **RectFOV** | **RectFOV** | **_** | **_** | **This will increase or shorten the field of view in the "phase direction" by the percentage of our FOV defined in the drop down** | **Rectangular field of view is a parameter that will add or subtract information collected in the phase encoding direction. Is important to remember that we are not changing the number of lines in our k space and therefore this parameter will not influence our spatial resolution. It will however alter how much signal we collect from our patient and therefore as we decrease our rectangular field of view, we will decrease our SNR. Also, if we decrease our rectangular field of view, we no longer need to collect as many lines of k space to build an image and therefore can reduce our scan time.** | **Drop Down**<br>**200%**<br>**175%**<br>**150%**<br>**125%**<br>**100%**<br>**93%**<br>**85%**<br>**75%**<br>**68%** |
| **Number of Signal Averages** | **NSA** | **1** | **10** | Use of grading | **There are many situations where we have a signal deprived image. The number of signal averages can be increased so that we can increase our signal to noise ratio. What happens when we do this is that we collect multiple sets of information for the same slice depending on our signal averages we input. We can then average these data sets together to** | **Number** |

| | | | | | | |
|---|---|---|---|---|---|---|
| | | | | | produce in average data set. Since noise is random, we can decrease the noise in our image by this factor sqrt 2. | |
| Number of Acquisitions | NA | 1 | 10 | Use of grading | The number of acquisitions is a parameter that allows us to separate the echoes collected for a given TR into multiple measurements. The result is that we can use a shorter repetition time or utilize multiple breath holds when needed. | Number |
| Saturation | S | _ | _ | Use of grading | It is important to suppressed tissue in our image too optimize pathological processes. We can suppress fat, water, or silicone based on the unique frequencies They have. This is very sensitive to the homogeny or uniformity of our magnetic field at isocenter. Because we're not dependent on tissue relaxation to suppress tissues in our image, we can use this technique pre and post contrast. | Drop Down Fat Sat. or Water Sat. = 1 Off = 0 |
| Restore | R | _ | _ | Use of grading | | Check box |
| Half Fourier | Half Four | _ | _ | Use of grading | Half Fourier is a technique that relies on the fact that our k space is a mirror image of itself. This means that the top half of our k space is a mirror image of the bottom half, and the right half is a mirror of the left half. Because of this, if we fill a minimum of 53% of our k space with echoes and fill the rest with the zeros, we can produce a diagnostic image. By doing this, we can reduce the number of echoes we need to collect and therefore decrease our scan time. Since we are collecting less echoes from our patient, our SNR will decrease when implementing this technique. | Drop Down 100% 87% 75% 63% |
| Parallel imaging | PI | _ | _ | | Parallel imaging is a technique that can be used when we have two or more coil elements in the phase encoding direction. By using each coil element separately to collect data, we can produce multiple aliased images in a shorter scan time. By combining these datasets together, we can produce one full image in a shorter duration of time. This technique will shorten our scan time but also decrease our SNR. | Number On = 2 Off = 1 |
| Confirm Frequency | Con Freq | _ | _ | | Due to electron sharing throughout the electron cloud of fat molecules, it produces a slightly different magnetism than water and therefore processes different than water. This produces chemical shift between fat and water. Confirming our frequency allows us to isolate a frequency we want to focus on to either suppress a tissue or enhance a tissue. | Check Box |
| Cardiac Gating | Car Gating | _ | _ | Use of grading | There are two ways we can perform cardiac gating. Prospective gating will image during diastole. Retrospective gating will image throughout the entire cardiac cycle and produce images at different stages along it. This leads to a dataset which looks like a movie of the heart pumping. | Check Box Retrospective (CINE) Prospective |
| Segments | Seg | 1 | 20 | Use of grading | When performing retrospective cardiac gating, we have the option to select how many points along the cardiac cycle we want to produce an image in. In other words, how many echoes we want to collect throughout the cardiac cycle. Increasing this number will allow for more images of the cardiac cycle however it will lead to an increase in temporal resolution which can cause artifacts in our image. | Number |
| Calculated Phases | Car Cal Phas | 1 | 40 | Use of grading | This parameter will allow us to reconstruct additional phases of the cardiac cycle based on phases we've already collected. | Number |
| Trigger window | Trig W | 10ms | 500ms | Use of grading | When performing prospective gating, we need to identify an acquisition window which is optimal for imaging. We use our R-R peaks to trigger imaging. In order to isolate our acquisition window, we must add a delay Before our first R peak. This is our trigger window. | Number |
| Trigger Delay | Trig D | 10ms | 500ms | Use of grading | In order to appropriately identify or acquisition window, we utilize our R-R peak. In order to capture the point of our cardiac cycle where our heart is not moving for the longest duration of time, we must add a delay after our first peak. We call this the trigger delay. | Number |
| Acquisition window | Acq Win | [R-R] – ([Trig D] + [Trig W]) | | Use of grading | The period of time we collect data when using perspective gating is called our acquisition window. We identified this time using our trigger window and trigger delay. This period of time will always be less then the time it takes from one peak to the next. This causes an issue when trying to obtain T2 weighted images. When imaging T2 weighted images, we sometimes need to utilize more than one R-R peak. | Number |
| Measurements | Measure | 1 | 100 | Use of grading | The number of measurements defines how many times we will capture the same image per a given acquisition. This is utilized when performing a dynamic imaging. Temporal resolution becomes very important when we choose to use multiple measurements. | Number |
| Receiving Bandwidth | RBW | 10hz/px | 1700hz/px | Use of grading | Receiving bandwidth defines the rate that we sample our patient frequency at TE. Receiving bandwidth is tied closely with TE and our frequency encoding. As we increase our receiving bandwidth, we decrease our sample time which leads to possibly having the option to use shorter TR values. It also allows us to replicate our patient frequency more accurately and therefore decrease metal artifacts and blurring in our image. By decreasing our receiving bandwidth, we increase our sample time which increases our SNR and decreases our SAR. By doing this however we will decrease the contrast to noise ratio in our image. | Number |
| Echo Spacing | ES | ((1/bandwidth/ by acceleration factor (Parallel imaging)) * [GM] * [RFM])*100 | | Use of grading | Echo spacing refers to the period of time between echoes collected in a given repetition time. When multiple echoes are collected during a TR, there is a delay in between them. This is called echo spacing. | Only Show |
| Echo Train Length | ETL | 1 | [Pe] | Use of grading | Echo train length is a parameter utilized when performing spin echo sequences. It defines how many echoes we will collect within a given TR. As we increase our echo train length, we theoretically decrease our scan time and increase our SNR. The disadvantage of this parameter is that as we increase our echo train length, we increase the number of low-quality | Number |

| | | | | | | |
|---|---|---|---|---|---|---|
| | | | | | echoes collected which lead to image blurring. Echo train length also promotes T2 contrast when increased. | |
| **Gradient mode** | **GM** | _ | _ | Use of grading | **This parameter will change the way we ramp up our gradients. In other words, it changes our rise time rate. By doing this, we can potentially reduce artifacts in our image, reduced the loud noises produced from the MRI unit, and increase our echo spacing.** | **Drop Down**<br>**Fast**<br>**Normal** |
| **RF Mode** | **RFM** | _ | _ | Use of grading | **This parameter will change the way we perform our RF pulse. By increasing the duration of our RF pulse, we can decrease our SAR. We call this a soft pulse. This however can lead to increased scan times. On the contrary, if we decrease the duration of our RF pulse, we deliver a short burst of energy which can increase SAR.** | **Drop Down**<br>**Fast**<br>**Normal**<br>**Low SAR** |
| **Normal Mode** | **NM** | _ | _ | **Use for SAR** | **This is a mode of operation that controls the time-varying magnetic fields (RF and gradient coils). It is a mode that is meant to not cause physiological stress to our patient.** | **Default** |
| **First Level** | **FL** | _ | _ | **Use for SAR** | **This mode of operation also controls the time-varying magnetic fields (RF and gradient coils). It is a mode that may allow for physiological stress to be presented to our patient. Medical supervision is required to go into this mode.** | **Radial button** |
| **Pixel shift** | **PS** | [ | _ | **Use for grading** | **This describes how well we are able to represent chemical shift in our image. It defines how many pixels are needed to represent chemical shift. This is determined by field strength, receiving bandwidth, and frequency encoding.** | **Show Only** |
| **B-Value** | **BV** | **0** | **3000** | **Use for gradient** | **This parameter is unique to DWI. It determines how much diffusion we will see in our image. As we increase this parameter, we may will see more diffusion in our tissue. This will also reduce our SNR.** | **Drop Down**<br>**0**<br>**50**<br>**800**<br>**2000** |
| **VENC** | **VENC** | **0** | **500** | **Use for gradient** | **This parameter is unique to the phase contrast sequence. It determines the velocity of tissue we wish to be sensitive to. As we increase our VENC, we become more sensitive to faster moving tissue. It is important to identify the appropriate velocity of the tissue being imaged in order to accurately represent it.** | **Number field** |
| **Breath hold** | **BH** | _ | _ | **Use for calculation** | **When wishing to image our patient while they hold their breath, we need to use this parameter. It will allow us to image our patient over one or more breath holds. The number of acquisitions is a parameter that controls this.** | **Radial** |

| **High level parameters** | | |
|---|---|---|
| Parameter | Abbreviate | Calculate |
| SNR | | ((((FOV*1.71)*(1/PE*1.71)*(1/FE*1.71)*(Slice thickness*1.71)*Half Fourier*RectFOV*(1/RBW)*(NSA*1.71)*(1+OS))/2.5)/PI)*1000*Field Strength |
| CNR | | (144-(ETL+(Slice Thickness*2.5) + (((1/RBW)*1000)*9) - ((Half Fourier * 100-100)/2) |
| Resolution | | (FOV/PE) X (FOV/FE) X Slice thick |
| Scan time | | (((FS*(TR/ETL)) +TR) * (PE * averaged * half Fourier * rectfov) * (1 + phase oversampling)) / (ETL * Accelerate factor) |
| Temporal Resolution | | TR*Segments<br><br>Only Show when Retrospective button in the cardiac tab is selected |
| SAR | | Field strength^2 * B1+rms*(WARP)*RECTFOV +(oversampling)))/(ES))/15<br><br>Popup a prompt: “SAR too High” If<br>Normal Mode = (See SAR Table)<br>First Level = (See SAR Table) |
| SED | | Simulation 1: (SAR * Scan Time in sec.)<br>+<br>Simulation 2: (SAR * Scan Time in sec.)<br>+<br>Simulation 3: (SAR * Scan Time in sec.) |

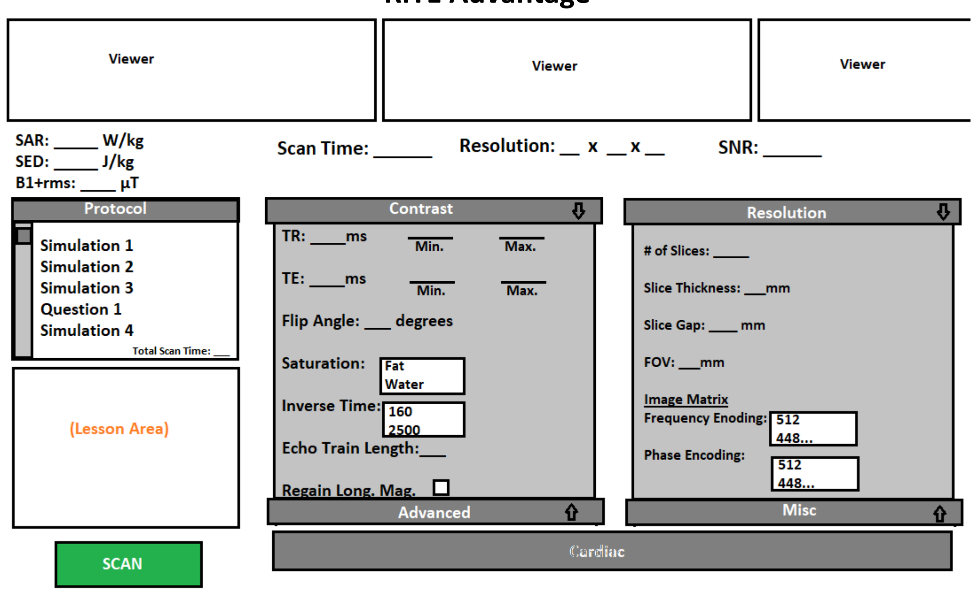
| | | |
|---|---|---|
| | | + Etc. |
| B1+rms | | Flip angle^2 * ((((Slices*(PE*Half Fourier))*RBW/100)/(TR)))/100000 |
| PNS | | |

**If SAR limit is met (See SAR Table), Show Pop up “SAR Limit Met” and give option to go to First Level Mode or adjust calculations again (retry)**

| SAR Table | | |
|---|---|---|
| **Coil** | **Normal Mode Limit** | **First Level Limit** |
| Body RF Coil | 2 W/kg | 4 W/kg |
| Knee T-R | 20 W/kg | 40 W/kg |
| Brain R-only | 3.2 W/kg | 3.2 W/kg |
| Brain T-R | 10 W/kg | 20 W/kg |
| Surface R only | 2 W/kg | 4 W/kg |
| Foot R only | 2 W/kg | 4 W/kg |
| Breast R only | 2 W/kg | 4 W/kg |
| Shoulder R only | 2 W/kg | 4 W/kg |

**Template layout**

**RITE Advantage**




Viewer
Viewer
Viewer
SAR: _____ W/kg
SED: _____ J/kg
B1+rms: ____ µT
Scan Time: ______
Resolution: __ x __ x __
SNR: ______
Protocol
Simulation 1
Simulation 2
Simulation 3
Question 1
Simulation 4
Total Scan Time: ___
(Lesson Area)
SCAN
Contrast
Advanced
Phase Encoding Direction:
A-P
L-R
Oversampling: _____ %
Number Averages: ___
Receiving Bandwidth: ___ Hz/px
Parallel Imaging:
Half Fourier
100%
87% ..
RectFOV
100%
90%...
Confirm Frequency:
Resolution
Misc
Echo Spacing: ____ms
RF Mode:
Fast
Normal
Low SAR
Gradient Mode:
Fast
Normal
Normal Mode
First Level
MARS
Measurement: ___
Temporal Resolution: ___
Breath holds:
Cardiac
Viewer
Viewer
Viewer
SAR: ____ W/kg
SED: ____ J/kg
B1+rms: ____ µT
Scan Time: ______
Resolution: __ x __ x __
SNR: ______
Protocol
Simulation 1
Simulation 2
Simulation 3
Question 1
Simulation 4
Total Scan Time: ___
(Lesson Area)
SCAN
Contrast
Advanced
Resolution
Misc
Retrospective
Prospective
Trigger Window: _____
Segments: ____
Trigger Delay: _____
Calc. Phase: ___
Acquisition Window:
+- _______
Temporal Resolution: ____
Cardiac
R-R
Trigger Delay
Acquisition Window
If Prospective Show
If Retrospective Show
R-R
Equally distribute number of segments
Segments

# Part 3: Grading

Based on the data the user entered grades will be presented to them. The grade scale is:

| Fail | Average | Pass |
|---|---|---|
| 0-69% | 70-85% | 86-100% |

This will be based on the following.

| Parameter | Calculate | Fail Message | Average Message | Pass Message | Filter |
|---|---|---|---|---|---|
| **SNR** | = SNR Percent<br>If pulse sequence all except spin echo and TR*2/FA = Less than 1, subtract 20% SNR | Your SNR was not sufficient enough to produce a diagnostic image. | Your SNR was acceptable | Great SNR | Noise filter = % |
| **CNR** | = CNR Percent | Your CNR was not sufficient enough to produce a diagnostic image. | Your CNR was acceptable | Great CNS | Gaussian filer = % |
| **Resolution** | = pixel size (FOV/PE x FOV/FE)<br>PE = 100%< +-.3 default > 0%<br>FE = 100%< +-.3 default > 0% | Your resolution was not sufficient enough to produce a diagnostic image. | Your resolution was acceptable | Great resolution | Sharpness filter = % |
| **Breath hold** | If breath hold button is selected and breath hold time is >30s=Fail 0%<br>Breath hold time 20-29s=Average 80%<br>Breath hold time <19s=pass 100% | Your breath hold was too long. Patient could not hold their breath for the entire sequence | Your breath hold was acceptable for the average patient. | Your breath hold was great and tolerable for most patients. | |
| **Temporal Resolution** | If retrospective is selected in the cardiac tab, show grade<br>If >50ms Fail 0%<br>If 40-49ms=Average 80%<br>If <39ms=pass 100% | Your temporal resolution was too long. This will poorly represent moving tissues | | Your temporal resolution was great | |
| **Image Contrast** | Uses Parameter vs Admin Selected | You have created the incorrect image contrast | | | = Assigned photo |
| **Image Size** | Filter only | Filter only | | | Zoom = User FOV / Admin FOV |
| **Scan Time** | < default input = pass | Your scan time was too long for this exam. | Your scan time was acceptable | Excellent scan time | |
| **SAR** | < default input when apply = pass | The patient exceeded their RF limit | | SAR Limit Met | |
| **SED** | <limit when apply = pass | The patient exceeded their total RF dose | | | |
| **B1+rms** | < default input when apply = pass | The patient exceeded the B1+rms limit | | B1+rms Limit Met | |
| **Artifacts** | = Average of<br>Chemical shift, aliasing, partial volume | | | | |
| *Chemical shift* | =Pixel shift<br>If pixel shift is > 2.3, user fails. Otherwise they pass | Your technique presented a large pixel shift which lead to chemical shift artifact. Given your field strength, you should have used a larger receiving bandwidth or increased your frequency encoding in your image matrix | | | |
| *Aliasing* | Phase direction=RectFOV+FOV+Aliasing<br><br>If phase direction (formula above) < box 2 size, use fails. Otherwise they pass | You have not taken consideration of tissue outside your field of view in the phase direction. You presented aliasing artifact | | | |
| *Partial Volume* | If slice thickness is > 8, user fails. Otherwise they pass | Your slice thickness was too thick and partial volume artifact was seen. | | | |

**Image Filtering**

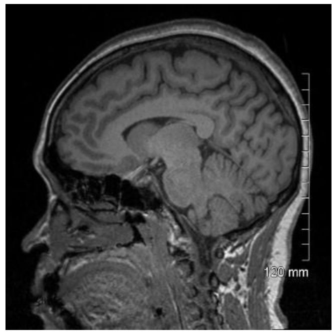
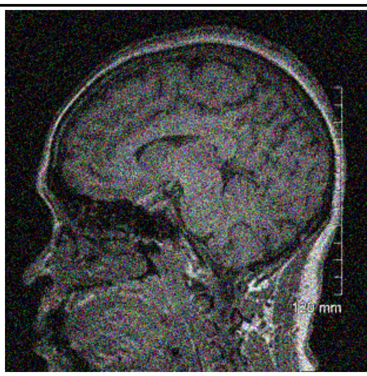
<table>
<tr><td colspan="2">Stock Photo  (image contrast user performed)<br><br></td></tr>
<tr><td><br></td><td>Noise Filter</td></tr>
<tr><td></td><td>Gausian Filter</td></tr>
<tr><td><br></td><td>Sharp Filter</td></tr>
<tr><td><br></td><td>Zoom Filter</td></tr>
</table>

Image contrast will also be graded: If the selected parameters by the user = the image contrast defined in the builder, then this area is correct. The table below define the correct parameter for each given image contrast.

The image displayed and filtered to the user should be the image contrast they created.

| If Spin echo | | | | | |
|---|---|---|---|---|---|
| **Parameters** | **T1** | **T2** | **PD** | **IR** | **Hide Parameters** |
| TR | 400-900ms | >2000 | >2000 | STIR = >5000<br>FLAIR = >9000 | VENC<br>B value |
| TE | <30 | >80 | <30 | - | |
| Flip Angle | >120 | >120 | >120 | >120 | |
| TI | | | | 1.5T<br>TI = = STIR<br>T1= = FLAIR<br><br>3.0T<br>T1 = 220 = STIR<br>T1 = 2500 = FLAIR | |

| If Gradient Echo | | | | |
|---|---|---|---|---|
| **Parameters** | **T1** | **T2** | **PD** | **Hide Parameters** |
| TR | <250 | >251 | >251 | ETL<br>VENC<br>B value |
| TE | <20 | >21 | <20 | |
| Flip Angle | >45 | <45 | <45 | |

| If DWI | | | | | |
|---|---|---|---|---|---|
| **Parameters** | **EPI** | **Low Diffusion** | **Medium Diffusion** | **High Diffusion** | **Hide Parameters** |
| TR | >3000 | >3000 | >3000 | >3000 | Change name ETL to Filling Factor<br>VENC<br>Flip Angle |
| TE | <200 | <200 | <200 | <200 | |
| B Value | 0 | <100 | 101-700 | >701 | |

| If Phase Contrast | | | | |
|---|---|---|---|---|
| **Parameters** | **Too Low** | **Just Right** | **Too High** | **Hide Parameters** |
| TR | <10000 | <10000 | <10000 | B Value<br>Half Fourier<br>RectFOV<br>ETL |
| TE | <50 | <50 | <50 | |
| Flip Angle | >10<90 | >10<90 | >10<90 | |
| Venc | <set amount | Set amount | >set amount | |

| If SSFP | | |
|---|---|---|
| **Parameters** | **T2** | **Hide Parameters** |
| TR | <20 | B value<br>Half Fourier<br>VENC<br>ETL |
| TE | <10 | |
| Flip Angle | >20 | |

| If TOF | | |
|---|---|---|
| **Parameters** | **Good** | **Hide Parameters** |
| TR | <50 | VENC<br>B Value<br>ETL |
| TE | <10 | |
| Flip Angle | >5 | |

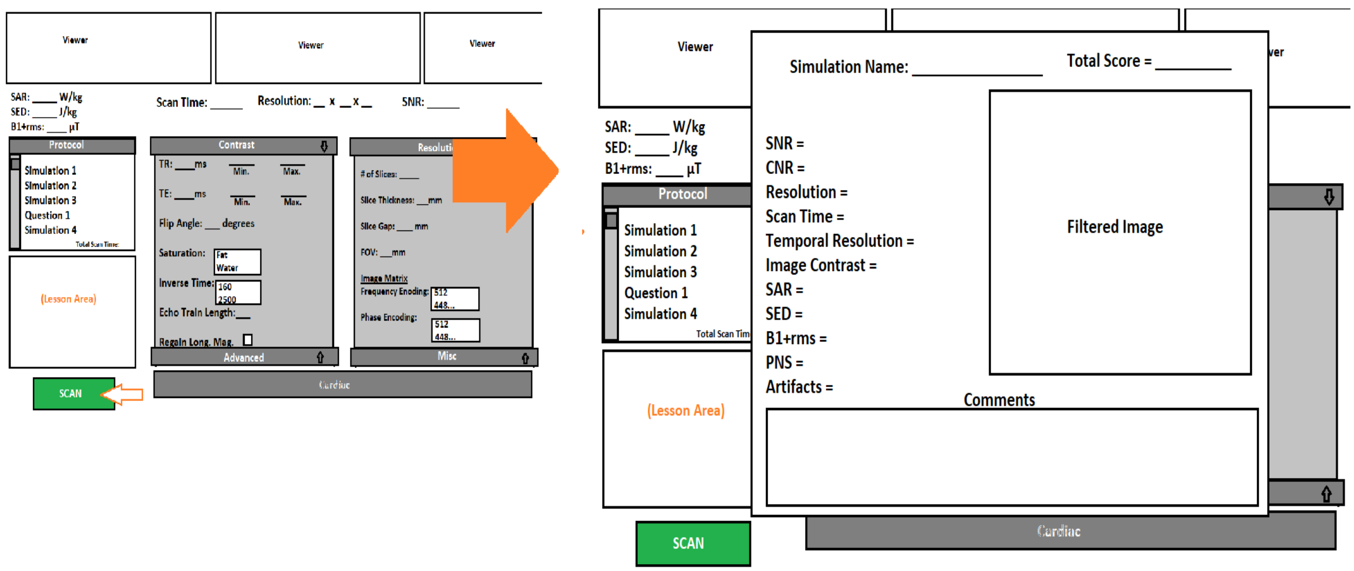
# Grade Display

After every simulation submitted the user would get a popup of a score card.

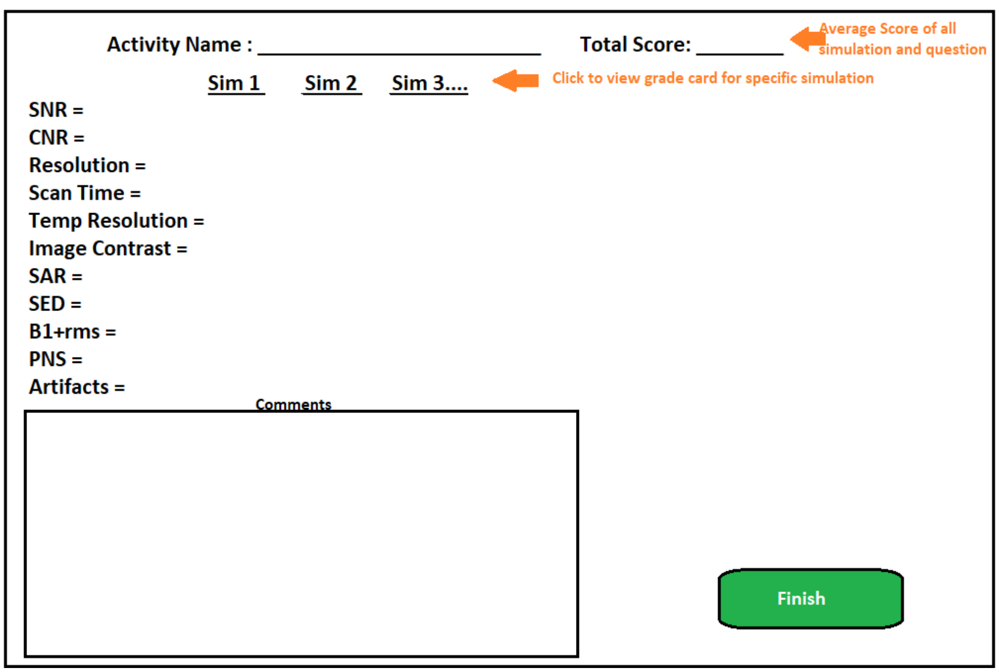
- Grades should be set up to be exported
- Image result should be saved with images for (1 year).

## Frontend

After the user clicks "scan" on the controls, a grade card of that sequence will be presented as a popup.



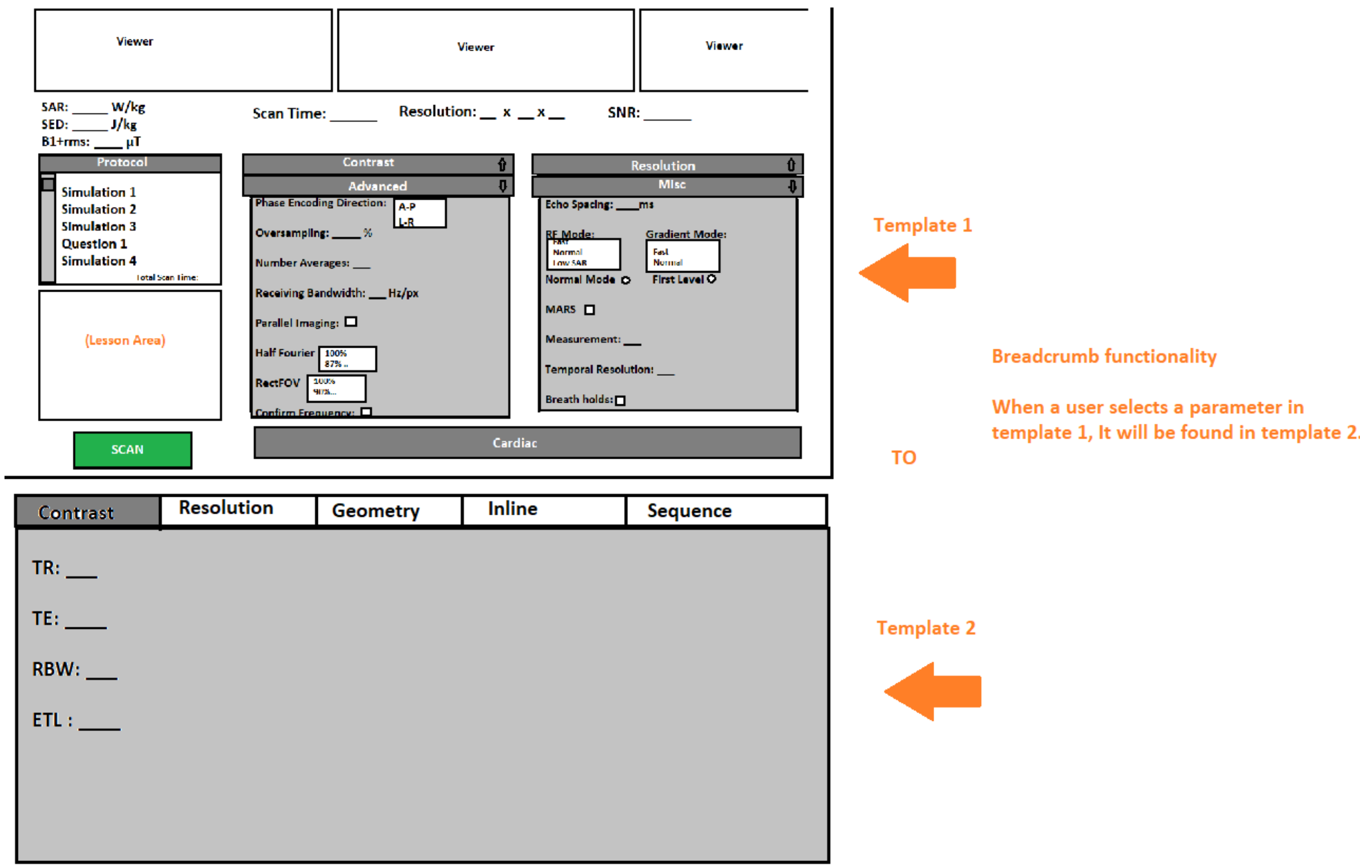

When the activity is complete, a total score card will be demonstrated and saved under their dashboard. "Activity Results"



## Future Plans

1. Export Grades to Learndash
2. Dashboard for simulators: Show Completed activities and score
3. Free Play: have user control some of the conditions that build and exercise (Template, Field Strength, Pulse sequence, Image contrast, SAR limits, B1+rms limits, Scan Time limits)
4. Have a list of required activities that need to be completed with a pass score
5. Parameters displayed on different templates. (Template layout coming later) (Vendor to Vendor)
6. Multiple template view at once with breadcrumb to parameter.

### Vendor to Vendor Example




| Terminology changes between templates (Send Filled Out Later) | | | | |
|---|---|---|---|---|
| **Parameters** | **SIEMENS** | **GE** | **PHILIPS** | **Toshiba** |
| TR | | | | |
| TE | | | | |
| TI | | | | |
| Flip Angle | | | | |
| Slice Thickness | | | | |
| Slice Gap | | | | |
| Field of View | | | | |
| Phase Encoding | | | | |
| Frequency Encoding | | | | |
| Number of Slices | | | | |
| Phase Direction | | | | |
| Anti-Aliasing | | | | |

| | | | | |
|---|---|---|---|---|
| **RectFOV** | | | | |
| **Number of Signal Averages** | | | | |
| **Number of Acquisitions** | | | | |
| **Saturation** | | | | |
| **Restore** | | | | |
| **Half Fourier** | | | | |
| **Parallel imaging** | | | | |
| **Confirm Frequency** | | | | |
| **Cardiac Gating** | | | | |
| **Segments** | | | | |
| **Calculated Phases** | | | | |
| **Trigger window** | | | | |
| **Trigger Delay** | | | | |
| **Acquisition window** | | | | |
| **Measurements** | | | | |
| **Receiving Bandwidth** | | | | |
| **Echo Spacing** | | | | |
| **Echo Train Length** | | | | |
| **Gradient mode** | | | | |
| **RF Mode** | | | | |
| **Normal Mode** | | | | |
| **First Level** | | | | |
| **Pixel shift** | | | | |
| **B-Value** | | | | |
| **VENC** | | | | |
| **Breath hold** | | | | |