# BME Design-Fall 2025 - AVERY SCHUDA Complete Notebook

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# **ORLA RYAN**

on

Dec 10, 2025 @05:45 PM CST

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LILLY MACKENZIE - Sep 12, 2025, 12:15 PM CDT

Last Name	First Name	Role	E-mail	Phone	Office Room/Building
Campagnola	Paul	Advisor	pcampagnola@wisc.edu		
		Client			
Schuda	Avery	Leader	aschuda@wisc.edu	6308008167	
Mackenzie	Lilly	Communicator	lfmackenzie@wisc.edu	7814349694	
Schroeder	Helene	BSAC	hschroeder4@wisc.edu	6127900434	
Ryan	Orla	BWIG	orryan@wisc.edu	6304019398	
Hutmaker	Corissa	BPAG	hutmaker@wisc.edu	7153708074	



AVERY SCHUDA - Sep 10, 2025, 9:04 PM CDT

Course Number: BME 400

Project Name: Intracranial EEG phantom for brain stimulation studies

Short Name: Neurosurgical Phantom

#### Project description/problem statement:

Intracranial electroencephalography (iEEG) is routinely used in surgical planning for individuals with uncontrolled seizures. Transcranial magnetic stimulation (TMS) may provide complementary information for mapping out critical brain regions that should be avoided during surgery, however, there are still safety concerns around the use of TMS in patients with iEEG. The major safety concerns are the induction of electrical currents, heating, and displacement of the implanted electrodes. The goal of this project is to develop a phantom that can be used to simulate the effect of TMS on electrode currents, temperatures, and changes in position.

#### About the client:

Dr. Raheel Ahmed, MD, is a UW Health Kids pediatric neurosurgeon and an associate professor in the Department of Neurological Surgery at the University of Wisconsin School of Medicine and Public Health. He treats children from birth to young adulthood who have neurological disorders that affect the brain and spine. Dr. Ahmed treats a wide variety of conditions such as hydrocephalus (fluid buildup in the brain), epilepsy (seizure disorder), movement disorders, brain tumors and spinal conditions that require surgery. He has a special clinical interest in pediatric epilepsy. In addition to his clinical practice, Dr. Ahmed conducts clinical research to improve pediatric epilepsy treatments.

Dr. Arun Karumattu Manattu, PhD, is a Scientist II at the Pediatric Neuromodulatory Lab at the Waisman Center, University of Wisconsin-Madison. His research is rooted in neuroimaging, biomechanics, and biomedical engineering, with a particular focus on understanding brain function and connectivity, especially in individuals with neurological impairments. Dr. Manattu utilizes multimodal neuroimaging techniques, including fNIRS, fMRI, and DTI, to explore the effects of cognitive load on postural control and brain health.

AVERY SCHUDA - Sep 12, 2025, 10:49 AM CDT

**Title: First Client Meeting** 

Date: 9/12/2025

Content by: Avery Schuda, Orla Ryan

Present: Avery, Orla, Helene, Corissa, Dr. Arun Manattu, Dr. Raheel Ahmed

Goals:

#### Content:

- · Both a clinical and research paradigm
- Epilepsy one or more than one area of the brain is hyperactive and results in overactivation of the entire brain
- Where are the seizures coming from and what are the risks of removing that area of the brain?
- Identify with pinpoint accuracy where the seizure are coming from
- · Electrode with 6-12 contacts
- · Leave electrodes in for about a week to capture required information about seizure location
- · TMS can potentially help patients to regain function
- Problem is it safe to do TMS on someone who has electrodes implanted in the brain?
- · Do not want the possibility of electrodes moving
- Are there any movements on a phantom with implanted electrodes and TMS applied
- Higher degree of responsibility in pediatric patients
- · Are there any thermal artifacts? do not want heating
- · Iowa group used gel-based phantom, also human skull-based phantom

# First

- · Availability/preference with client meetings
  - · Weekly? biweekly?
- · Semester vs year long goals
  - What do you want to see at the end of the semester, what do you want to see at the end of the year?
  - However long it takes, at the end of the day. Goals above timing!
    - As far as we can get
- · Remind him of our major due dates/familiarize him with the class format
  - Preliminary presentation: 10/3
  - o Poster presentation: 12/5

#### Project:

- Phantom from the paper: similarities/differences?
- What is the problem we are solving? How is it different from the problem the paper solved?

- One group has a similar study and had some success (group from lowa, research/put in LabArchives)
- · Safety concerns... induced current and displacement of electrodes
  - Testing for this before it is applied to children in-lab
- Budget, how to access/reimburse funds
  - Under \$500
    - Doesn't know how to access (lit)
    - Dept of neurosurgery?
- · PDS:
  - They will send us some info? TMS settings, etc.
    - Shared Teams folder
  - · Approximate size, weight limitations
    - Looking at a child-sized brain?
    - Does it need to be skull-based? Do they prefer that?
  - Material limitations
    - Iowa group was gel-based, with materials that mimicked brain properties
    - Used the long electrode strips Dr Ahmed showed us
    - Necrolic or gel phantom
  - Desired look/aesthetics
    - See second question under appropriate size
  - · Safety considerations, codes/standards that apply?
    - Standards on working with children
    - electromagnetic compatibility/safety (TMS and electrodes)
    - Clinical applications
  - · How often will it be used, overall shelf life desired
    - Should use Iowa study for a reference for this probably!
  - · Operating environment and ergonomics
    - Can find from literature (childhood EEG studies)
- · How does TMS/iEEG work in further detail?
  - See notes

# **NOTES** (orla)

- Localize where seizures are coming from utilizing iEEG (large focus on epilepsy patients)
  - Leads to possible removal of brain sections (where are the seizures coming from, and what are the consequences of removing that portion of the brain)
    - Is that part of the brain important? Can it be removed without disrupting normal functioning, etc?
- Electrodes with 6-12 units, inserted into the brain
  - · Left in to try and determine/monitor activity

- TMS!!
  - Studying connectivity and brain alterations via electromagnetic field manipulation
  - TMS hopefully should help:
    - Identify what portions of the brain are doing
    - Alter the circuitry to improve function
- Dr Gillick's lab → hopefully showing that young infants can recover motor function early on from TMS usage (iEEG can help with that too)
- · Can we do TMS on someone who has electrodes in their brain?
  - They are located deep within the brain, next to critical structures, etc.
  - Applying electromagnetic field changes... would that cause displacement??
- Going to be a long journey, but our phantom model could help with initial testing/framework for approval in the future
- · Each electrode has multiple contacts
  - As the electromagnetic field is activated, is the recording process disturbed?

## Conclusions/action items:

Avery to create shared Teams folder. Clients to send over more quantitative values for the PDS and future relevant research, upload info shared and lowa data into Teams. Circle back with Lilly and schedule follow up meeting in the next two weeks.

LILLY MACKENZIE - Oct 01, 2025, 9:43 AM CDT

Title: PNL Tour

Date: 10/1/2025

Content by: Lilly

Present: Lilly, Avery, Corissa, Helene

Goals: Tour PNL and discuss w client some of our ongoing questions

Content:

Intro

- · showed us the TMS device (Magstim)
- applications:
  - o single pulse TMS --> deliver a single pulse to the target and test how it affects the brain or end organ
  - not as often, use paired pulse --> after single pulse it gives a complementary pulse (higher or lower, depending if you want to inhibit or facilitate the given pulse)
  - o both test how the circuitry works
  - · commonly in clini c used as a treatment
    - repetitive TMS as psychiatric treatment, alter brain circuitry
    - not common in pediatric population, not used by PNL
  - · PNL uses single pulse, FDA approved treatment
- · PNL project
  - brain recovery project --> record infant brain activity right from 3 months to 2 years,
  - o longitudinal study come back every 6 months, three part study (TMS, MRI, motor assessment)
    - use TMS to assess activity from brain to arm, if that is predictive for development of CP
      - number of causes (hypoxia, infant stroke, seizure etc.) --> trying to determine if TMS can predict CP in infancy
    - MRI to image brain
    - motor assessments a bit older, evaluate for CP
- TMS
  - trying to send impulses to the brain non invasively --> thats where transcranial label comes from
  - o described the machine:
    - operator, machine coil, foot pedal
    - coils:
      - commonly used figure 8 coil
      - angle of tilt and position, direction are of consideration
      - physics: covered by Faraday's electromagnetism --> magnetic field induced when you send a current through a coil
    - Machine is basically a capacitor
    - you have different percentages that you can output a current on, depends on individual patient's motor threshold
      - also depends on activity --> active takes less stimulation (with slight contraction or muscle)
    - What will testing look like?
      - Duration
      - . .

MTS TESTING:

#### demoed on a fake head

- target mostly (here and other labs) the motor cortex.
- trying to identify response from hand area --> cortical mapping using TMS
  - move around that area and note where you get a response to a particular muscle
- common way: get an MRI of the subject and take the MRI, model the 3D head and then identify that target
  - neuro navigation (up on computer)
  - walked us through a testing demo
  - put EMG electrodes on the muscle to capture the muscle response
     --> easier than superficial, also quantitative
  - also use neuro navigation camera --> like motion capture, identify head in space
  - using the TMS:
    - best to not have electronics on while using
    - single pulse for testing use, we are not doing anything related to the treatment --> for psychiatric use
    - coil at 45 degree angle
    - try and get within 1mm of the target area (defined by the program)
      - this is very difficult to do with a child, especially with a brain injury
    - showed setup --> red dot inside the red circle (angle and coil orientation), green circle dictates the location (within 1 mm)

## This project:

- 0-2 years, plasticity era (phrasing confusing on my part) in the brain, want to make sure the plasticity is present
- use MRi when doing surgical intervention, but for them surgical scan is good
  - for their study, using non-sedated MRIs (natural sleep) --> typically at evenings or at night
    - sedation adds another component
- when they come back for TMS, you don't want them to be sleepy, you want them to be energetic

# TMS with IEEG

- will figure out later (with input from Dr. Raheel) on the clinical parameters, whether we'll ramp it up or just go just over threshold
  - could potentially get a graph based on input percent and then output parameters

- get a threshold where there could be damage to the tissue or heating increase
- When you have electrodes in place, we don't really know if the application has to change (it shouldn't but we have to test for safety)
- Temperature (room temp?)
  - heat generation before and after the pulse --> repeated pulses, generate some heat around the tissue
  - most of the coils we use it remains under the threshold --> primary concern then would be heat
  - don't need to heat hydrogel to body temperature
- Can we get electrodes (PLSPLSPLSPLS)
  - o ask Dr. Raheel if he's coming on Friday
- Funding string → can they please buy materials directly!
  - talk to Dr. Raheel about funding
- Will see if he has any questions after the presentation

## Conclusions/action items:

Will check back in after the presentation

AVERY SCHUDA - Oct 20, 2025, 11:09 AM CDT

**Title: Third Client Meeting** 

Date: 10/20/2025

Content by: Helene Schroeder, Avery Schuda

Present: Helene, Lilly, Corissa, Avery, Brooke, Dr. Manattu, Dr. Ahmed

Goals: To ask some questions to our clients regarding an age range and purchasing.

#### Content:

#### Age range:

- · can implant as young as 3 years, going up to adult
- · biophysical properties of skull are not too different after a certain age
- · 7-8 not much difference that will affect this pilot study
- 3 years to 18 years is broad range
- is there a way to do 3-7 years and 7-18 years?
  - would we need multiple phantoms? is the older demographic the same as the other study?
  - stick to younger kids, this is the novelty of the project
  - 3-7 years!!!!
- CT scans are already segmented and we can use those for our modeling
  - give us at least 3 scans for a few ages so we can average those values for our model
  - o share via teams or box folder
  - · be considerate about personal info that is given
- · we need specific age and volume for our phantom
  - o smaller range of 5-7 years old

## Funding/purchasing:

- · having someone look into it
- · specific person to contact about ordering? no...
- · dr. ahmed will look into it based on the email we sent

## Preliminary report:

- · will look at report in depth more later, specifically testing section
- research vs. clinical
  - · research: patient is sitting as is
  - clinical: patient's head is wrapped in compressive dressing so TMS cannot be directly placed on skull, several cm of dressing
- . TMS being further away from source: intensity of stimulation has to go up but not too high where it triggers seizure or causes harm
- · during treatment kids do not have seizure medication
- include this as a question that we can address after we answer some more preliminary questions
- question being, how to do TMS when you can't apply right onto skull because dressing is wrapped around head in a few cm thickness

## Contact method:

- any different contact we can talk to since everyone is busy?
  - o contact BOTH dr. ahmed AND dr. manattu
    - dr. manattu will probably be in more contact
- don't be afraid to double email
- What is the age demographic specifically for the 'pediatric population'?
  - o Brain size, etc

- · Bring up outside research again (if he has any idea of where we could look for SPECIFIC volumes, etc.)
- Implant as young as 3 years, want 3-18 years
- Make model that is applicable for 3-7 years
- Look at scans available and average it out
- Patient privacy
- Do you have a lab manager or scientist as a secondary contact for future ordering processes? (can just bring up to clarify whether or not he answers
  over email)
  - · Requested that they do ordering
  - · Once we have a better idea of volume discuss ordering agar
- Talk about report and ask for feedback
  - · Will look at it and get back to us
- . Mention the reagents we have tried to purchase and ensure he has seen this email
  - I don't think he read this email
- Trying to figure out if i should mention whether he has an alt contact (given he did not read prior email I think it's extra important to try and get a separate contact lol)

## His comments on report

- · Positioning of head is difficult during measurements
- · Head is wrapped in protective dressing, so TMS is several centimeters away from the dressing
- Might need to have higher thresholds because the distance between tms coil is greater. Have to worry about stimulation side effects or triggering a seizure (off meds)
- Might include this depth as something to address after initial studies
  - · Want to look at efficacy as well as safety in this case
  - · Arun will get more info on this

### Conclusions/action items:

This meeting was helpful in getting on the same page as our clients. We discussed that the age range we can focus on is 5-7 years. In the future we can broaden this range, but for feasability it will be 5-7 years. We will receive CT scans to create our phantom. Dr. Ahmed will look into the agar we need to order this week and hopefully order it this week. He also had not really looked at our report but will this week. He recommended to just email multiple times to get their attention, which is an ineffecient method.

AVERY SCHUDA - Sep 12, 2025, 1:16 PM CDT

**Title: First Advisor Meeting** 

Date: 9/12/2025

Content by: Avery Schuda

Present: Avery, Helene, Corissa, Lilly, Dr Campagnola

Goals: Introduce project and team to advisor

## Content:

- Won't be in this room for prelim presentations
- Poster session is in December good check in
- Don't need to split semesters continuous project for the whole year
- Flexible with deadlines if we need more time just ask
- Okay to send progress reports on Friday mornings
- Extra time to work on final deliverables into finals week
- Meet next week at 2pm in same room

## Conclusions/action items:

Work on PDS - due Thursday 18th at 11:59 pm. Continue research into problem. Schedule next client meeting.

LILLY MACKENZIE - Sep 19, 2025, 2:14 PM CDT

**Title: Second Advisor Meeting** 

Date: 9/19/2025
Content by: Lilly

Present: All

Goals: Discuss PDS with advisor

#### Content:

- . Discussed med student joining the team don't have a lot of information on it, will find out later today at the TECH team meeting
- Client meet once a month if possible, reached out to schedule lab tour
- One thing to do: start figuring out who's going to do what with the project -- who wants to focus on which part of the project (hydrogel, skull materials, testing protocols etc)
- Talk to Dr Wille about MTS validation of our materials come up with our own protocol probably
- · Protocols: conductivity measurements ask Dr. Numinkar:), can also look at the measurement protocols written in the standards
- · Start looking at outreach sooner rather than later
- No PDP time assignments yet, will find out later. NO PDP FOR SPRING SEMESTER, show and tell is giving advice to 301s.

#### Conclusions/action items:

Team will meet next week a couple of times to discuss the design matrices and preliminary presentation. Start working on material choices and try and meet with the clients to tour PNL

AVERY SCHUDA - Sep 26, 2025, 12:58 PM CDT

**Title: Third Advisor Meeting** 

Date: 9/26/2025

Content by: Avery Schuda

Present: Avery, Orla, Helene, Lilly, Corissa, Dr Campagnola

Goals: Talk about design matrices and update on progress

## Content:

- Add ease of use to skull material design matrix
- If you want to shape it want to do it photochemically
  - Can't do this with gelatin of the contenders it is probably the worst
- Consider base material only without crosslinker or saline/NaCl is design matrix
- Have them buy materials other than 3D prints directly

## Conclusions/action items:

Finish and send out design matrices. Work on prelim presentation.

HELENE SCHROEDER - Oct 14, 2025, 4:49 PM CDT

**Title: Fourth Advisor Meeting** 

Date: 10/14/2025

Content by: Helene Schroeder

Present: Lilly, Helene, Corissa, Orla, Dr. Campagnola

Goals: To discuss the preliminary report with Dr. Campagnola and ask about how we should go about ordering materials.

#### Content:

- · we turned in preliminary report last night and emailed it this morning
- · we are working on getting materials
  - · do this through clients, preferred methods
  - · we will not be authorized to use a funding string even if they give one to us
- advice for client who is less responsive, especially in terms of ordering materials:
  - email primary client
  - o are there scientists or post docs in his lab who can be a better direct contact for this stuff
  - o dr. manattu had no idea about funding stuff
  - o clients have to be the ones to order anything
- · need to figure out what exact materials we need
  - agar
  - saline
  - photopolymerization material
  - o give this info to our client
- · if client does not respond then he and Puccinelli will intervene
- · we have a meeting scheduled for next Monday (oct 20)
- · email him before the meeting to ask about more specific stuff
- · testing protocols
  - thermal conductivity/transfer line system
    - is there any transfer line system at the dept?
    - it measures thermal conductivity, usually used for soils but can be used for hydrogels
    - email Dr. Nimunkar!!
- let Dr. Campagnola know how meeting went after our meeting next monday (oct 20)
- deliverables
  - only comment was to consider tmtpa as a material
  - · does not have any other critiques
- · med student will attend the meeting on monday which will be very good
  - hopefully she will be able to get more invovled and get more context on the project
- no meeting on friday, next advisor meeting will be october 24

## Conclusions/action items:

This meeting we discussed our preliminary report, contact with our client, and what materials we may need. Dr. Campagnola did not have feedback for our deliverables besides to potentially consider another material, TMTPA. We are meeting with Dr. Ahmed next week (including Brooke) where we will hopefully learn more and all get on the same page. We will reach out to Dr. Campagnola after the meeting with any important updates. Materials must be ordered by our client, and we need to finalize which materials we need to place an order as soon as possible.

ORLA RYAN - Oct 24, 2025, 12:53 PM CDT

**Title: Fifth Advisor Meeting** 

Date: 10/24/2025

Content by: Orla Ryan

Present: Lilly, Orla, Avery, Corissa

Goals: Update Dr. Campagnola on our latest client meeting, agar order, and discussion with Dr. Nimunkar.

## Content:

- Went over the client meeting (takeaways, topics of discussion, etc.)
- Dr. Campagnola recommended to try emailing on Sunday nights (maybe more likely to get his attention)
  - o Since Dr. Ahmed has such a busy clinical schedule, don't want to email midday because it will get lost
- We will possibly try to make our own thermoline system (basic way to test heat transfer)
  - o For final temperature measurements, Dr. Nimunkar recommended using thermistors
- · Agar was received this morning.
- Debating printing the box phantom (would be 86 if we utilized planned material based on MakerSpace estimation)
  - some budget worries -- don't want to make low-budget decisions, Dr. Campagnola can maybe authorize us going over budget
  - o Dr. Campagnola approved of concept of making a cheaper box/holder in the meantime (for purposes of testing, etc.)
- · Skull portion of the project is pretty much cosmetic... but if we go over budget should likely be covered
- · Went over Feedback Fruits briefly, was pleased with all of our feedback for each other

## Conclusions/action items:

We will move now to fabricating and testing for the remainder of the semester (and will likely continue to do so next semester as well). We will look to reach out to Dr Ahmed on Sunday evenings or early mornings going forward, and won't worry as much about budget (or have some comfort in knowing that there will be support if we go over).

LILLY MACKENZIE - Nov 07, 2025, 2:51 PM CST

**Title: Sixth Advisor Meeting** 

Date: 11/07/2025
Content by: Lilly

Present: All

Goals: Discuss past couple of weeks of work

## Content:

- Discussed DICOM processing, plans for this weekend and rheometer testing
  - o got the DICOM files from Dr Ahmed
- Crosslinker
  - 10 kD or 25 kD PEG DA (PEG diacrylate)
  - LAP is a photocrosslinker (lithium something something, have it in the teaching lab)
  - Irgacare in teaching lab
  - ask Dr. JP for what's in the teaching lab to figure that out
  - crosslinking is pretty linear up to a point --> time of UV exposure increases crosslink density
    - play with parameters
    - amount of PEG-DA concentration and how much light --> two variables
    - versus Ergacare or LAP there is a standard time for light --> keep fixed
- Really quick measurement: shrink well measurements (not super quantitative)
  - measure thickness
  - o dehydrate it, measure (dehydrate w ethanol)
  - o rehydrate it, measure
  - o more crosslinkers, less it can shrink --> relative measurement. Can look at porosity

#### Conclusions/action items:

Email Dr. JP about teaching lab equipment and crosslinkers

Goal for end of semester: figure out final hydrogel concentration

AVERY SCHUDA - Nov 14, 2025, 12:56 PM CST

**Title: Seventh Advisor Meeting** 

Date: 11/14/2025

Content by: Avery Schuda

Present: Avery, Helene, Lilly, Corissa, Orla, Dr Campagnola

Goals: Discuss progress on testing and next steps

## Content:

- · Struggles with rheometer
- · Reached out to soft material characterization but would need to pay
- · Lilly to ask fellow students in lab about how they characterize hydrogels
- · Rougher MTS testing for next steps
- New BME faculty to get rheometer in late spring
- Dr Campagnola can reach out to faculty
- Email Christian Franck in this building, ME but works with BME students
- · Can just weight it for shrink swell
- · Hydrodynamic radius of agar should be known
- Can get information about crosslinking density and pore size
- · Use 100% ethanol for dehydration testing
- · For sanity check swell in DI water
- Flory Rehner analysis
- · Email client inviting them to poster and updating
- · Have CAD model up on a laptop during poster
- Send poster to Dr Campagnola a day or two before printing so he can proofread it
- Do quick post meeting after poster session

# Conclusions/action items:

Email Dr. Franck and CC Dr Campagnola. Work on testing and final deliverables.

ORLA RYAN - Nov 21, 2025, 12:48 PM CST

Title: Eighth Advisor Meeting

**Date:** 11/21/2025 **Content by:** Orla

Present: Orla, Avery, Corissa, Lilly, Helene

Goals: Fill in Dr Campagnola on our updates/get advice on switch to gelatin

## Content:

- filled Dr. Campagnola on our meeting with Dr. Franck and possible updates to our design
- · Avery turned a CT file into a CAD model, but we are looking into getting MRI scan(s) to get more specific brain gyration data
- Gelatin had been one of our four considered materials, but previously was ruled out (stable at room temperature? or not?)
  - · Melts eventually at room temperature, so have to contend with that
- Dr. Campagnola thoughts:
  - o still mechanically test our own gelatin rather than just using values gotten at the Franck lab
  - looking at options for this (MTS with smaller load cell? rheometer in the Franck lab?)
  - · gelatin cannot be photoactivated, instead physically crosslinks through setting
  - o overall, no problem with us switching to the different material (we'll have to adjust our approach)
- · Agar shrink-swell test notes:
  - · rehydrated overnight for agar
- · gelatin:
  - swelling in DI water until equilibrium
- Thermal conductivity testing --> baseline protocol in the works

# Conclusions/action items:

Complete testing and work on final deliverables to have the poster ready for the Tuesday before poster session.

ORLA RYAN - Sep 14, 2025, 1:31 PM CDT

Title: PDS Draft meeting

Date: 09/14/2025

Content by: Orla Ryan

Present: Orla, Lilly, Avery, Helene, Corissa

Goals: We are meeting today to revise our PDS draft and formulate a plan for starting design matrices.

## Content:

- We read through the work each team member had done (sections had been divided up).
- The document was reformatted, we discussed the references shared by the client, and did more literature searches to properly quantify several PDS statements.
- We were happy with the state of the document when the meeting finished, and will put a few more finishing touches before turning it in later this week.

## Conclusions/action items:

We will make the proposed changes to the document this week and be prepared to submit it for this Thursday. Additionally, we will be starting to focus on material/design choices next week as we form design matrices.

ORLA RYAN - Sep 19, 2025, 12:33 PM CDT

Title: Outreach 400 Meeting

**Date:** 9/19/2025 **Content by:** Orla

Present: Orla, Avery, Lilly, Corissa, Helene

Goals: learn about outreach opportunities/requirements for this semester

## Content:

- We went through some group discussion activities about the importance of outreach for BME within our community as well as the impact of diversity on engineering.
- Listened to past BME students' experiences with outreach.
- · Expectations:
  - putting together a short presentation to give at schools in the community, or the Children's Museum/WID
  - · having a draft by end of this semester, and a final description of our activity and how it went by spring semester!
- Opportunity to be mentors as well at Sun Prairie schools

## Conclusions/action items:

We will work this year to fulfill these outreach goals and give back to the community; additionally, we will keep diversity as a priority in this project and future engineering work.



AVERY SCHUDA - Sep 19, 2025, 3:47 PM CDT

Title: BME/TECH Kickoff

Date: 9/19/2025

Content by: Avery Schuda

Present: Avery, Corissa, Helene, Orla, Brooke

Goals: Learn about UWSMPH-TECH and meet the med student joining our team

## Content:

- Med students to attend team meetings w/client, BME faculty advisor, and team
- Med students to gather resources, background information, and connect with hospital resources
- Invite med student to team and client meetings
- · Have them help with additional background research
- Have the med student connect you with physicians for additional insight
- · Have them look over prelim or final presentation scripts
- UWSMPH-TECH Collaborative Innovation Award (spring)
  - Presentation should focus on the collaboration of the BME team and med student
- · Did neurobio undergrad
- · Full year commitment
- · Potential visit to the anatomy lab
- · Reach out with any questions

## Conclusions/action items:

Add Brooke to google drive, group chat, google drive.



# 2025/09/21 - Design Matrix/Prelim Presentation Meeting

AVERY SCHUDA - Sep 25, 2025, 12:44 PM CDT

Title: Design Matrix/Prelim Presentation Meeting

Date: 9/21/2025
Content by: Avery

Present: Avery, Helene, Corissa, Orla, Lilly

Goals: Divide sections of the preliminary presentation and work on design matrices

## Content:

- · Lilly emailing Dr Wille to ask about skull and brain materials
  - Initial thoughts are that we do not need to do MTS testing on the skull material, more care about conductivity than exact mechanical properties
  - Might care about mechanical properties of gel, definitely care about
- · Ask Dr. Campagnola about how to test hydrogel mechanical properties and conductive properties
- For hydrogels evaluate PAA, gelatin, agar, and agarose
  - · How to get access to materials? ordering/funding string from client
- For 3D printed material, evaluate PMMA, PLA, Formlabs BioMed clear, and Formlabs standard resin
  - PMMA not available in makerspace, so added accessibility issue, increased cost
    - Could buy a whole spool and use Jesse's FDM printers in TEAM lab (not preferred)
  - Thinking that Formlabs biomed will be best material, but expensive so may need to do test prints in cheaper material
- · Divided sections of the prelim report

## Conclusions/action items:

Work on individual sections of the design matrices, complete by Thursday evening. Talk to Dr Campagnola in design meeting about selecting a hydrogel. Complete individual sections of the prelim presentation by Monday 9/29 before meeting at 6pm.



AVERY SCHUDA - Sep 26, 2025, 1:41 PM CDT

**Title: Matrix Meeting** 

Date: 9/26/2025

Content by: Avery Schuda

Present: Avery, Orla, Helene, Lilly, Corissa

Goals: Finish the design matrices

Content:

Questions to ask client:

• What is the exact age that we are aiming for?

· Ordering materials?

.

# Conclusions/action items:

AVERY SCHUDA - Oct 05, 2025, 1:04 PM CDT

**Title: Preliminary Report Meeting** 

Date: 10/05/2025

Content by: Avery Schuda

Present: Avery, Helene, Corissa, Orla, Lilly

Goals: Divide up sections of the report to work on

## Content:

- Turn in by Sunday 10/12
- Lilly emailing Dr. P back about rheometer
  - · Okay to follow instructions giving without supervision?
  - · Look into ASTM methods for testing hydrogels
- Look into ordering materials
- Will need to fabricate hydrogel in teaching lab
- Chemical crosslinker or UV?
- · Divided sections of report

## Conclusions/action items:

Work on assigned sections of report. Look into outreach options after submitting preliminary deliverables.

# 2025/10/13 - Preliminary Report Finalization Meeting

AVERY SCHUDA - Oct 13, 2025, 8:29 PM CDT

**Title: Preliminary Report Finalization Meeting** 

Date: 10/13/2025

Content by: Avery Schuda

Present: Avery, Helene, Lilly, Corissa, Orla

Goals: Finish draft of preliminary report and enter citations

## Content:

- Advisor meeting tomorrow on Zoom from 4:30-5 pm
  - Avery missing advisor meeting tomorrow due to exam team remind Dr Campagnola please!
- · Issues with Zotero entering in text citations
  - · Lilly working on resolving
- · Adding section with DOE to determine electrical conductivity of saline
  - o 2 factor, 3 level design
  - Factors are % concentration of agar and % concentration of saline
- · Lilly found helpful paper that details rheological testing of pre-gelled hydrogel
  - Design of injectable agar/NaCl/polyacrylamide ionic hydrogels for high performance strain sensors ScienceDirect
- Avery/Corissa found thesis that gives a method for testing shear of gelled hydrogel
  - · Used parallel plates and glued to a piece of sandpaper
  - Rheometric measurement of hydrogel toughness
- · Can actually photopolymerize gelatin?
  - Mechanical properties still require some chemical modifications

## Conclusions/action items:

Goal to submit report tonight, if not then before advisor meeting. Go over report during advisor meeting.

# 2025/10/17 - Planning Next Steps Meeting

AVERY SCHUDA - Oct 17, 2025, 2:36 PM CDT

**Title: Planning Next Steps Meeting** 

Date: 10/17/2025

Content by: Avery Schuda

Present: Avery, Orla, Lilly, Corisa

Goals: Discuss ordering

#### Content:

- · Team updated Avery on Tuesday's advisor meeting
- · Discussed how to facilitate better client communication
- · Orla lead on grant for TMS
  - · Found out about it in PNL lab meeting
  - Dr Ahmed one of the people applying for grant
  - Asked for a copy to get more insight potential NDA?
  - Need more clarification on size likely under 2 years, but need specifics
- · Creating a doc of questions for Monday
  - Need to clarify the exact age they want us to fabricate because different ages in months before about 2 years can be different sizes
  - · Knowing final size will allow us to order correct volume of agar
- Lilly email Dr. Ahmed about ordering materials and a reminder about meeting Monday
  - Only client can order materials
  - · Asked if there is a lab manager/alternative point of contact that would be better to communicate purchasing with
- Main costs will be the 3D prints and the raw materials for the gel (namely agar)
- Found agar and NaCl in 1002 to begin fabricating while we wait for client to order materials
- · Looked at rheometer
  - · Seems like some fixtures may be missing?
- Link: Agar Solidifying agent

## Conclusions/action items:

Team meet next Thursday from 12:15-3 and/or Friday after advisor meeting to begin fabricating gels.

AVERY SCHUDA - Oct 24, 2025, 12:38 PM CDT

Title: Measuring Thermal Conductivity Discussion with Dr. Nimunkar

Date: 10/23/2025

Content by: Avery Schuda

Present: Avery, Corissa, Lilly, Dr, Nimunkar, Orla

Goals: Discuss methods for measuring thermal conductivity

## Content:

- · Conductivity based on NaCl ions
- Want to make sure our values of thermal conductivity
- · Use thermistors and thermocouple probes to collect temperature data
- · Create a mini version a Thermoline system using thermistors and thermocouples
  - Come back with a prelim design

## Conclusions/action items:

We need to talk about outreach next time. Some concerns about budget between expensive 3D prints, now needing electronic components, and ordering agar.



# 2025/10/27 - Discussing Testing and Deliverables

ORLA RYAN - Oct 27, 2025, 5:53 PM CDT

Title: Discussing Testing and Deliverables

Date: 10/27/2025

Content by: Orla Ryan

Present: Orla, Avery, Helene, Lilly, Corissa

Goals: We will be talking about how we can test our hydrogels by the end of the semester as well as starting to talk about deliverables.

#### Content:

- Filled in Helene on the hydrogel fabrication that was completed over the weekend
  - Initially on Friday, made 3 dishes of 2% agar and 3.67% NaCl weight by volume
  - o On Sunday, varied agar conditions (0.5, 1, 1.5%) while keeping the NaCl at 0.17% w/v
- To test for thermal conductivity (which we have been unsure on how to approach), we thought about taking Dr. Nimunkar's advice to construct a kind of thermal line
- Essentially, this will involve covering a hot plate with aluminum foil, creating hydrogels of KNOWN heights, and taking the temperature at their top end with the known thickness to solve for a conductivity constant
- video to watch for rheometer: Malvern Kinexus Rheometer
- Planning to meet on Thursday at 12:15 to experiment with the rheometer
- · Discussed outreach opportunities (lung idea)
- Can reach out to local elementary/middle schools with science clubs
- Made a tentative plan to work on final deliverables as we go (to be able to turn in around the same time as the poster)
  - Orla will hope to receive info about Family STEM Nights (filled out Qualtrics survey)
- Will work on an elevator pitch to have ready by show and tell
- Scooby gang

## Conclusions/action items:

Working on testing rheometer on Thursday and continuing to write fabrication plans to be used in final report as we go.

HELENE SCHROEDER - Oct 28, 2025, 3:59 PM CDT

Title: Meeting to Discuss Agar Fabrication Techniques

Date: 10/28/2025

Content by: Helene

Present: Lilly, Helene, TJP, Abbylee

Goals: Ask TJP about how we can efficiently crosslink agar

## Content:

- · crosslinking will increase mechanical properties, not ideal?
- want stable material? synthetic material perhaps
- look to research (not necessarily a brain phantom)
- · what about crosslinking for short time?
- · what about low conc. of agar and then crosslink?
  - tjp says "what's the point"
- our gels will hold shape but are fragile
  - o crosslinking helps
  - PEG diacrylate!!!!
  - try to acrylate agar!!!
- · agar and gelatin will become unstable at room temp
- call thermofisher and talk to rep about crosslinkers
  - ask about crosslinking agar, what are the options
- · search "crosslinked agar"
  - o ask chat!!
- · chemistry can get complicated, try to simplify by using these resources
- fragile
- · investigate if we need to actually mimic stiffness
- sprays for molds
  - can impact electrical conductivity
- scale down

## Conclusions/action items:

We have to do some more research into the materials and try to find preexisiting methods to crosslink the agar. TJP suggests we call ThermoFisher and ask a consultant/rep about what crosslinker to use.

LILLY MACKENZIE - Nov 19, 2025, 1:47 PM CST

Title: Meeting with Professor Franck about his brain models

Date: 11/19/2025
Content by: Lilly

Present: Lilly, Corissa, Avery, Orla

Goals: Meet w Professor Franck and discuss his research and how it pertains to our project

## Content:

- Prof Franck uses gelatin brain tissue mimics poured into silicone molds with gyration, and (will fact check w grad student) BioMed Clear resin to print his skull molds.
- · We saw Professor Franck's lab space and felt some of the brain models. He keeps his brains in 4C fridge in water
- · We will send a follow up email to Prof Franck to meet with a grad student of his
  - Avery has created a list of questions to ask the grad student which we will be sending ASAP
- Prof Franck prefers gelatin because has more straightforward mechanical properties that aren't frequency/testing condition dependent. He suggested we use gelatin, considering his lab has already characterized and published pretty much all of the information that we need. We will have to consider this and discuss w Dr. C to figure out how we will move forwar

#### Questions:

## Conclusions/action items:

We will send Prof Franck our questions and hope to meet with his grad student asap. We are currently considering using the agar data for this semester and then moving forward with gelatin in the future

LILLY MACKENZIE - Nov 19, 2025, 3:31 PM CST

Title: Meeting w Jesse

Date: 11/19/2025
Content by: Lilly

Present: Lilly, Corissa

Goals: Talk to Jesse at Design Hub about our proposed testing protocol for thermal conductivity

## Content:

- We very briefly talked to Jesse about our project and the idea to test using Lee's protocol. I didn't have diagrams or anything but basically asked him about using copper instead of brass and whether he thought the setup was feasible
- Based on the malleable nature of the gels, he suggested we just implant the temperature sensors into the material and make sure we control heat loss via insulators to make sure we trust the measurement
- In the interest of not purchasing more materials and spending time machining for the setup, I think this is a feasible way to sanity check the thermal conductivity of our gels when we create them. I will put a more detailed protocol in the protocols section of testing and results

#### Conclusions/action items:

I have to finish writing up a testing protocol and begin testing on either agar or gelatin. We can check against both of them potentially to validate the choice to chose one over the other

AVERY SCHUDA - Nov 24, 2025, 9:53 AM CST

Title: Meeting with Arvin

Date: 11/24/2025
Content by: Avery

Present: Avery, Helene, Lilly, Corissa, Arvin

Goals: Discuss questions about how the Franck lab creates their brain phantoms

## Content:

- Make sure to cover gels in DI water to prevent them from drying out
- Make their brains at 60C
- Dark part of MRI scan is the actual brain tissue, light part is skull
  - Separate the based on signal to noise ratio
- · Clear V5 resin
- · Agar microstructure organization is what makes it frequency dependent
  - Mainly have characterized mechanical, look into literature

## Conclusions/action items:

Reach out to Arvin with any further questions. Need to get gelatin and MRI scans from Dr Ahmed.

AVERY SCHUDA - Oct 26, 2025, 3:28 PM CDT

Title: Agar documentation

Date: 10/22/2026
Content by: Avery

Present: N/A

Goals: Order agar for use in making hydrogel brain

Content:

See attached documents

Conclusions/action items:

N/A

AVERY SCHUDA - Oct 26, 2025, 3:25 PM CDT



#### **Download**

#### Agar\_powder\_MTR\_AGHS\_EN.pdf (38.1 kB)

AVERY SCHUDA - Oct 26, 2025, 3:28 PM CDT





**Download** 

Life\_Technologies\_Order\_Confirmation\_-\_14811506SO\_Purchase\_Order\_-\_PO-00058566.pdf (337 kB)



## 2025/10/24 - Initial Agar Hydrogel Prototyping

LILLY MACKENZIE - Oct 24, 2025, 2:47 PM CDT

Title: Initial Agar Hydrogel Prototyping

Date: 10/24/2025

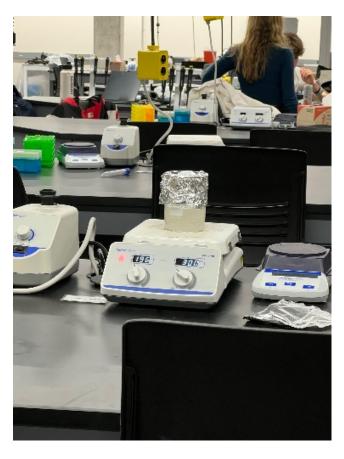
Content by: Orla Ryan

Present: Avery, Corissa, Lilly, Orla

Goals: Make a 2% Agar gel with 600 mM saline solution

#### Content:

- online protocols were referenced to facilitate beginning steps
- the following measurements were used:
  - o 2g of agar powder
  - ~5.5g NaCl
  - both measured using weighing boats
- · Stirred into 150mL of DI water gradually, with no heat at first
- · settings were changed on the hot plate: 300 RPM, covering the beaker and raising the temperature to 200 degrees C



- Mixture was stirred on hot plate for 40 minutes before decreasing temperature to 25 C and continuing to stir for another 20 minutes (modified from protocol below).
- Gels were set in petri dishes holding 50 mL of solution each, and left to self-assemble

#### Conclusions/action items:

We will continue to finetune our agar/saline mixture for use in future testing. This was a preliminary preparation meant to familiarize ourselves with the protocol and process of creating hydrogels with agarose and NaCl.

citation: Kinetically Frozen Rheology of Agar-agar Hydrogels Upon a Change of Anions in the Hofmeister Series

AVERY SCHUDA - Oct 26, 2025, 3:50 PM CDT

Title: Hydrogel fabrication - adjusting for mechanical properties

Date: 10/26/25

Content by: Lilly, Avery

Present: Lilly, Avery, Orla

Goals: Make more gels varying agar % to figure out ideal mechanical properties

#### Content:

- · We first gathered the three gel samples we fabricated on Friday afternoon
  - · Qualitative observations:
    - firmer than expected
    - relatively stiff
    - help up well for being kept at room temperature
- The NaCl % (w/v) was calculated to be 3.67% for these samples
- We cross-checked the procedure to make sure we approached fabrication appropriately this time, and made decisions on which conditions we wished to compare
  - for this iteration, we will be varying the AGAR concentration: 0.5%, 1%, and 1.5%
  - o each of these conditions will be represented by 3 replicates
  - the NaCl concentration will be kept the same, at 0.17%
- 0.255 g of NaCl was dissolved in 150 mL of DI water at 200 degC, 300 rpm, for 20 mins to batch create the 0.17% saline solution
- · Saline solution then divided us between 3 beakers, 50 mL of saline each
- The corresponding Agar was added (0.25, 0.5, and 0.75 grams)
- Agar was dissolved on hotplates at 200 degC, 300 rpm for 1 hour
- · The Agar/Saline solution was then divided into 3 petri dishes per condition, respectively
- · Gels left to set at room temperature

#### Conclusions/action items:

Need to look into UV crosslinking for a potential next step. Also need to figure out how to use the rheometer with our samples.



## 2025/11/07 - Agar gel fabrication and rheology

AVERY SCHUDA - Nov 07, 2025, 4:38 PM CST

Title: Agar gel fabrication and rheology

Date: 11/07/2025

Content by: Avery Schuda

Present: Avery, Helene, Corissa

Goals: Fabricate gels with varying agar content and test them on the rheometer

#### Content:

- 0.255 g of NaCl was dissolved in 150 mL of DI water at 200 degC, 300 rpm, for 20 mins to batch create the 0.17% saline solution
- Saline solution then divided us between 3 beakers, 50 mL of saline each
- The corresponding Agar was added (0.25, 0.5, and 0.75 grams), rinse remaining agar into beakers, make sure total volume is at 50 mL (some water will have evaporated from the saline solution)
- · Cover beakers with foil
- · Agar was dissolved on hotplates at 200 degC, 300 rpm for 25 minutes

#### Conclusions/action items:

The rheometer software crashed while we were calibrating temperature, so we were not able to complete this part of the testing. We should potentially look into labs in ME or MSE that could give us more guidance in using a rheometer (or have a machine that has been serviced in the last 10 years). Instead, we poured the gels into 3 petri dished each, as done in the 10/26 fabrication. We should look into the swelling experiments that Dr. Campagnola described in the advisor meeting today as well.

HELENE SCHROEDER - Nov 07, 2025, 3:39 PM CST

- 0.2593 g NaCl
- 150 mL DI water
- 200 deg C, 300 rpm for 20 min
- 0.2528 g agar = 0.5%
- 0.4990 g agar = 1.0%
- 0.7519 g agar = 1.5%

•



## 2025/11/09-Agar fabrication and rheometer testing

LILLY MACKENZIE - Nov 09, 2025, 1:35 PM CST

Title: Agar Fabrication and Rheometer Testing

Date: 11/9/2025

Content by: Corissa Hutmaker, Avery Schuda

Present: Corissa, Lilly, Helene, Orla, Avery

Goals: Test agar gels at different concentrations using rheometer

#### Content:

#### Gel fabrication:

- . 0.2536g of NaCl was dissolved in 150 mL of DI water at 200 degC, 300 rpm, for 20 mins to batch create the 0.17% saline solution
- Saline solution then divided us between 3 beakers, 50 mL of saline each
- The corresponding Agar was added (0.2547, 0.5027, and 0.7540 grams), rinse remaining agar into beakers, make sure total volume is at 50 mL (some water will have evaporated from the saline solution)
- · Staggered start time by 10 mins each
- · Cover beakers with foil
- Agar was dissolved on hotplates at 200 degC, 300 rpm for 25 minutes
- · doing batches of cross-linked and non cross-linked
  - splitting into two 25 mL batches of 0.5%, 1%, and 1.5%
  - o one 25 mL beaker for cross link and one 25 mL for not cross link (each concentration)

#### Rheometer:

- · Calibration:
  - Performed a 2-minute torque map in air. "Calibration\_0105 Kinexus Torque Mapping.rseq".
  - Select to use temperature control, and set the temperature to the desired polymerization temperature in °C. (set to 18 degC). "General torque sequence.rseq".
  - Set the gap to 70 mm. "Set Gap.rseq" (there is also a shortcut button for this sequence).
  - Set the rheometer's absolute position to 3.142 radians. "Set rotational position.rseq". Repeat this step if the rheometer gets bumped at all during testing.
- Sample 1 0.5% agar in 0.17% saline
  - o Trial 1 gelled too quickly at 18 degC
  - Trial 2 gelled too quickly at 18 degC
- · Recallibrated at 25 degG
- Sample 2 0.5% agar in 0.17% saline
  - Trial 3 ran for about an hour before the rspace program froze, shut itself off and deleted all our data. This is when we decided to give up doing rheology for today.

#### Crosslinker:

Unsure about the amount. Going to make a 2.5% solution of irgacure 184 (2.5 g in 100mL) and then add 1 mL of solution to a 25 mL solution of agar gel. I am fairly sure this will get us to 0.1% final concentration of Irgacure in the gel. This is based off the paper references in my (Lilly's) research notes. The paper was unclear on the actual amount though, because it said the range was 0.05-0.2% for w/v while dissolving and also in the final gel, so I went with the 0.1% solute in the final gel. We will then cure it under the UVP CL-1000 Ultraviolet Crosslinker for 5 minutes at 5000 uJ/cm^2

- 0.5% samples were mixed up, so ratios are likely off (too much irgacure added for volume of 0.5% agar that was actually present) (my bad Lilly)
- 0.5% cross linked agar was almost fully solidified by the time it went under UV light

#### Conclusions/action items:

To-do:

- reach out to Anna Kiyanova (lab manager for a soft materials lab in Engineering Hall) about rheometer AND/OR crosslinking advice
- review outreach draft as a group
- look into articles sent by Dr. Dean on materials similar to brain tissue
- start deliverables and continue testing (once reaching out as described above)

LILLY MACKENZIE - Nov 19, 2025, 7:52 PM CST

Title: Gelatin hydrogel fabrication

Date: 11/19/2025

Content by: Avery and Lilly

Present: Avery and Lilly

Goals: Create 4%, 6%, 8% gelatin hydrogels tuned with 0.17% saline

#### Content:

- Weighed 4.057, 5.991, and 7.987 grams of gelatin
- Batch created a saline solution with 0.51g of NaCl in 300mL of DI water
- Dissolved at 80 C until no NaCl was visible.
- Added gelatin in measured amounts to 3 separate beakers and continued to heat/stir until completely dissolved, occasionally scraping
  down the sides of the beaker
- · poured into prepared and labeled containers and let set at 4 C overnight

detailed procedure will be under protocols, taken from the paper cited below

#### Conclusions/action items:

Test these gels for thermal conductivity over the weekend and discuss with advisor about potentially switching to gelatin

M. Navarro-Lozoya, M. S. Kennedy, D. Dean, and J. I. Rodriguez-Devora, "Development of Phantom Material that Resembles Compression Properties of Human Brain Tissue for Training Models," Materialia (Oxf), vol. 8, p. 10.1016/j.mtla.2019.100438, Dec. 2019, doi: 10.1016/j.mtla.2019.100438.

AVERY SCHUDA - Nov 24, 2025, 5:24 PM CST

Title: Gelatin and Agar Hydrogels with Varied NaCl Fabrication Date: 11/24/2025 Content by: Avery Present: Avery, Lilly, Corissa Goals: Fabricate gelatin and agar hydrogels with varied NaCl content for electrical conductivity testing Content: Reference paper: Comparison of electrical conductivities of various brain phantom gels: Developing a 'Brain Gel Model' - PMC Agar gels: 1.2 % agar based on the paper above NaCl: 0% 0.25 % 0.5% 0.75% Gelatin gels: 6% w/v gelatin because of Franck lab values, this is similar to brain tissue NaCl: 0% 0.25% 0.5% 0.75% 300 mL of each saline concentration was created by adding the corresponding grams of NaCl into DI water. 0.75 g - 0.25% 1.5 g - 0.5% 2.25 g - 0.75% NaCl was dissolved in DI water at 80 degC Saline solutions were divided into 2 beakers containing 150 mL each 9 g of gelatin or 1.8 g of agar was added to each saline concentration Gelatin solutions were mixed at 60 degC based on Franck lab protocol Agar solutions were mixed at 200 degC based on previous protocol Gels were poured into large weigh boats and cooled in a 4 degC fridge

### Conclusions/action items:

Electrical conductivity will be measure using the protocol Lilly wrote using a gel electrophoresis protocol and saline solutions corresponding to the percentage NaCl in each gel.

Sanity check: Conductivity should be increasing LINEARLY with NaCl percent so we can check that

LILLY MACKENZIE - Sep 23, 2025, 12:50 PM CDT

Title: Meeting w Dr. Wille to discuss Mechanical Testing

Date: 9/23/2025
Content by: Lilly

Present: Lilly, Helene

Goals: Chat w Dr. Wille to get a better idea of how we would go about testing our phantom material

#### Content:

- · Briefly explained our project to Dr. Wille -- super soft material testing for displacement of electrodes, low forces
  - She mentioned a rheometer as a tool of measurement -- has in the past been used by students for similar projects
    - will have to more clearly define the sort of forces that we're trying to measure (shear vs compressive)
    - define the magnitude of forces --> would mechanical forces be applied to the phantom? How would the phantom deform under these conditions
- Look for testing protocols for similar *and* dissimlar applications --> look for similar types of forces, human/viscoelastic tissue, but not necessarily brain phantom applications as starting points
  - o can use these protocols and test methods

#### Conclusions/action items:

We can discuss with Dr. P and Dr. Campagnola to help us better define our particular project and go about finding resources to test - Dr. Wille said she may defer us to students to learn about using rheometers



## 2025/11/16 - Thermocouple Circuit Design

CORISSA HUTMAKER - Nov 16, 2025, 12:31 PM CST

Title: Thermocouple Circuit Design

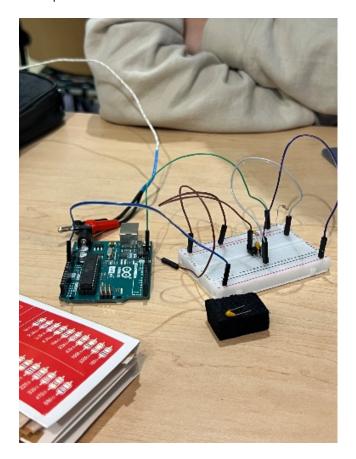
**Date:** 11/16/2025 **Content by:** Orla

Present: Orla and Corissa

Goals: To start building a thermocouple circuit for use in heat conductivity testing of the hydrogels.

#### Content:

- We started building a thermocouple circuit based off of a design we completed in BME 310.
- We found a UA741 op-amp in the BME blue room to use; I brought my Arduino kit and Corissa brought her multimeter with temperature probe capabilities.
- · We will start by utilizing the same circuit as in 310, but may consult with Dr. Nimunkar to see if any changes are necessary.
- Ideas for actual testing of heat conductivity:
  - set the hydrogel of choice on a hot plate (covered by layer of aluminum foil) and measure the temperature at its top BEFORE applying heat
  - o measure the thickness and surface area of the hydrogel as well
  - turn the hot plate to a specific temperature and record the time it takes to get the top of the hydrogel to that same temperature
  - o calculate "k" a thermal conductivity constant
  - see Orla's lab archives note within "Research Notes" --> "Materials and Methods" (the entry from 10/24/2025)
- · picture of current circuit:



Starter code:

```
int sensorPin = 0;
float tempSum = 0;
int readingCount = 0;
void setup() {
 // put your setup code here, to run once:
Serial.begin(9600);
}
void loop() {
 // put your main code here, to run repeatedly:
 int sensorValue = analogRead(sensorPin);
 float voltage = 1000*(sensorValue*(5.0/1023.0));
 float temperature = (voltage-96.188)/12.342;
 tempSum += temperature;
 readingCount++;
 if (readingCount >= 100){
   float averageTemperature = tempSum/100;
   Serial.print("Average Temperature: ");
   Serial.println(averageTemperature);
```

```
tempSum = 0;

readingCount = 0;
}

delay(100);
```

#### Conclusions/action items:

We may reach out to Dr. Nimunkar for help finishing off the circuit (or help locating cold junctions and/or needed op-amps).

## 2025/11/16 - Shrink Swell Testing Protocol

LILLY MACKENZIE - Nov 16, 2025, 5:48 PM CST

**Title: Shrink Swell Testing Protocol** 

Date: 11/16/2025
Content by: Lilly

Present: Lilly, Helene

Goals: Write formal protocol for shrink swell testing. The testing procedure and results are also outlined under the "experimentation" folder

#### Content:

#### Materials:

- · Agar hydrogels
- Punch
- · Weigh boats
- 50 mL beakers
- · 200 proof ethnol
- Tweezers
- Parafilm
- 1. Prepare 50 mL beakers with labels for replicate number and condition. We did three replicates of each condition (n=3).
- 2. Using a circular, clean punch, create three equal samples from the same gel to ensure equal thickness across samples.
- 3. Weigh each sample in a labeled weigh boat and record the initial weight.
- 4. Add each sample to its labeled 50 mL beaker and pour 10 mL ethanol (enough to cover the complete sample). Cover with parafilm to minimize ethanol evaporation.
- 5. After 20 minutes, remove samples from beakers and pat dry. Re-weigh in their labeled weigh boats and record measurements.
- 6. Once all samples have been weighed, place them back in their respective beakers and re-cover with parafilm.
- 7. Repeat measurements every 20 minutes for one hour.
- 8. Once measurements are complete, submerge hydrogel samples in DI water overnight. Re-weigh the following day.

#### Conclusions/action items:

We carried out this protocol and will re-measure weight of the re hydrated gels tomorrow

## 2025/11/21 - Thermal Conductivity Testing protocol

LILLY MACKENZIE - Dec 01, 2025, 11:51 AM CST

Title: Thermal conductivity testing protocol

Date: 11/21/2025
Content by: Lilly

Present:

Goals: Create and use testing protocol to get values for thermal conductivity of our hydrogels

Content:

$$k = \frac{m*c*\frac{dT}{dt}*\Delta x}{A\Delta T}$$

$$\mathrm{m} = \mathrm{mass} \ (\mathrm{kg})$$
 $\mathrm{c} = \mathrm{specific} \ \mathrm{heat} \ \mathrm{capacity} \ (rac{J}{kg*K})$ 
 $rac{dT}{dt} = \mathrm{rate} \ \mathrm{of} \ \mathrm{temperature} \ \mathrm{change} \ (\mathrm{K/s})$ 
 $\Delta x = \mathrm{separation} \ (m)$ 
 $\mathrm{A} = \mathrm{surface} \ \mathrm{area} \ (m^2)$ 
 $\Delta T = \mathrm{temperature} \ \mathrm{difference} \ (\mathrm{K})$ 

Before you begin:

Pour hydrogels at 4, 6, 8% gelatin, 0.17% NaCl

Allow gels to firm overnight. These gels were swelled with an excess of DI water to reach equilibrium overnight

Testing protocol:

Cut n>3 samples from the hydrogel mold. For consistency, they should all be approximately the same size. **Make these as close to rectangular as possible**. Weigh samples and take their dimensions, making sure you know which face of the sample will be in contact with the hot plate. This will be the surface area (A) dimension. Measure the length of the thermocouple you will be inserting into the sample. Mark this value, and subtract it from the height (measured as the dimension orthogonal to the face in contact with the hot plate) to get your  $\Delta X$  value.

Set the hot plate to 35 C and allow it to come to temperature. Wrap the sample in an insulating material and insert thermocouple. Measure and record starting temperature.

Allow the sample to sit on the hot plate for 10 minutes. Each minute, take a temperature measurement and record it. After 10 minutes, the sample at the location of the thermocouple will not be 35 C, but it should be increased by a number of degrees C.

Take the sample of the hot plate and calculate thermal conductivity from the equation above.

#### Conclusions/action items:

Modified from this protocol: https://asmedigital collection-asme-org. ezproxy. library. wisc. edu/electronic packaging/article/138/4/040802/384410/Measurement-Techniques-for-Thermal-Conductivity and the supplied of the protocol in the p

## 2025/11/19 - Gelatin Fabrication protocol

LILLY MACKENZIE - Dec 01, 2025, 11:54 AM CST

Title: Gelatin fabrication protocol for hydrogels in thermal conductivity tests

Date: 11/19/2025
Content by: Lilly

Present: Lilly, Avery

Goals: record the protocol we used to create the hydrogels for thermal conductiivty testing

Content:

Protocol for gels in thermal conductivity testing:

Dissolve .51 g of NaCl in 300 mL MilliQ at 80 C and 300 RPM until completely dissolved. Separate the saline into 3 batches for each condition, at 100 mL per batch

On separate hot plates at 80 C each, dissolve the following amounts of Knox unflavored gelatin powder:

- 4 g
- 6 g
- 8 g

Spin at 300 RPM until dissolved. Poor dissolved solution into molds. Molds are from 1080 electronics supply, cleaned with soap, water, and wiped down with ethanol. Each mold will yield 3 samples to test for thermal conductivity. Let set at room temperature overnight. Once set, pour an excess of DI water over the gels to allow to swell to equilibrium.

#### Conclusions/action items:

We will test these for thermal conductivity values after they set.



## 2025/11/30 - CT Processing in 3D Slicer Procedure

AVERY SCHUDA - Dec 03, 2025, 1:50 PM CST

Title: CT Processing in 3D Slicer Procedure

Date: 11/30/2025

Content by: Avery Schuda

Present: N/A

Goals: Outline the steps I used to process and clean DICOM files (from patient CT scans) in 3D Slicer

#### Content:

- 1. Open 3D Slicer → Load DICOM file
- 2. Go to "Segment Editor"
- 3. Add a new segment → choose "Threshold"
- 4. Use slider to find bone thresholds (~150-3000 HU) and apply
- 5. Preview model and refine using tools like:
  - 1. Smoothing
  - 2. Islands → Keep largest
  - 3. Scissors/Paint for manual cleanup
- 6. When satisfied: Segmentations → Export to 3D Model
- 7. STL for direct 3D printing
- 8. OBJ for editing in CAD software such as SolidWorks

#### Conclusions/action items:

This procedure will need to be slightly adapted for use with MRI files in the future, mainly the thresholds used to isolate a model of the skull and of the brain. This is the exact procedure I used to create the STL files from the 3 CT scans of 5-7 year old patients that Dr Ahmed provided.



## 2025/11/30 - Processing STL into a Workable CAD File

AVERY SCHUDA - Dec 03, 2025, 2:06 PM CST

Title: Processing STL into a Workable CAD File

Date: 11/30/2025

Content by: Avery Schuda

Present: N/A

Goals: Draft procedure for concerting an STL file (obtained by processing DICOM file from patient CT) into a workable CAD file

#### Content:

File processing from STL to CAD:

- 1. Obtain STL file or process DICOM file into STL (see procedure for doing this in 3D Slicer)
- 2. Import STL file into Fusion360
- 3. Manually remove any artifacts from scan (you can also do this in 3D slicer before exporting as STL)
- 4. Use repair mesh --> close holes, wrap, and stitch and remove
- 5. Compress model to smaller ratio to avoid crashing with larger file
  - 1. Generally, want less than 50k triangles, the smaller the better, but with more compression you lose detail
- 6. Convert mesh to solid body (prismatic)
- 7. Export as STEP file
  - 1. If you want to stay in Fusion360 to edit the CAD model stop here!
- 8. Import STEP file into SolidWorks
  - 1. This step can take around 30 minutes to import, especially if the file has a lot of triangles
- 9. Use internal repair tools to fill any remaining gaps
- 10. Save as a SLDPRT (part) file

#### To edit the CAD file:

- 1. Create sketch on surface
  - 1. Sometimes you need to create a plane along the surface by creating individual points and anchoring them to the surface
  - 2. SolidWorks is nice because it allows you to create 3D sketches, which is why we are using it over Fusion360
- 2. Extruded cut from shape to create top half of the skull
- 3. Save a separate copy of the same file
- 4. Reverse the extruded cut to leave the bottom half of the skull
- 5. Additional extruded cuts to remove any undesirable components
- 6. Save both files and exported at STL or STEP file for 3D printing

#### Conclusions/action items:

This procedure details both the file processing portion from Fusion360 to SolidWorks, as well as the creation of editable parts in SolidWorks. Minimizing the file size is best otherwise the programs will crash, but find the balance so that not too much detail is lost from the model.

HELENE SCHROEDER - Oct 30, 2025, 1:32 PM CDT

Title: Rheometer Testing of Hydrogels

Date: 10/30/2025

Content by: Helene

Present: Helene, Lilly, Avery, Orla, Corissa

Goals: To test the shear modulus and other mechanical properties of the agar hydrogels at different concentrations using the rheometer in ECB 1002.

#### Content:

#### Rheometer set up:

- · follow instructions given by Dr. P (see attached)
- initialization process
  - o turn on air
  - o open rSpace software
  - · turn on machine
  - · insert cone and plate geometry into machine
  - let it do initialization process
- · torque mapping calibration
  - close hood around the plate
  - · let calibration run
- · general torque sequence calibration
  - ambient (room temp)
- · set gap
  - o 70 mm
- gels are approx 8.75 mm tall

## What we did:

- · use piece of gel
- 2% gel, 600 mM NaCl
- · rheometer squished the gel
- · gel kinda slid out of the gap because it was too stiff and slippery
- · did another flatter section
- these results are not to be used for analysis as they used gelled sections, not liquid

#### Notes:

- · our understanding of using the rheometer is as follows:
- · have gel in liquid form and place on the flat plate
- · the cone will lower and sandwich the liquid gel
- you set it to a temperature where the agar will gel
- the cone spins while it has sandwiched the gel
- · measures while it gels?
- the mixture can be partially gelled when you put it on the rheometer (liquid enough to be pipetted)

#### Conclusions/action items:

Although we had some trouble figuring out how to turn on and intialize the rheometer, we eventually figured it out! We did not have any liquid or partially gelled pieces of agar, so we used gelled pieces of agar at 2% concentration to ensure the rheometer works as intended. We will do this process again in the future with the correct agar.



**Download** 

Rheometer\_instructions\_general.rtf (6.94 MB)



## 2025/11/16: Shrink Swell Testing on Agar Hydrogels

LILLY MACKENZIE - Nov 16, 2025, 5:44 PM CST

Title: Shrink Swell Testing on the Agar Hydrogels

Date: 11/16/2025

Content by: Helene

Present: Helene, Lilly

Goals: To test the agar hydrogels by submerging them in 200 proof ethanol.

#### Content:

#### Materials:

- · 200 proof ethanol
- · weigh boats
- · gels at diff concentrations
- · punch to cut the hydrogels to small circles/cylinders
- scale
- · beaker and parafilm to submerge the gels in and cover them for airtight seal
  - · each gel gets its own labeled beaker

#### Methods:

- · prepare gels by punching out even circular sections from the gels
- · weigh each of them
- submerge each gel in ethanol (enough to cover it fully)
- · cover beaker with plastic wrap (or something) to seal it
- check gels every 20 mins for 1 hour by removing them from ethanol, blotting them dry, and weighing them in a weigh boat
- · do calculation to find percent decrease in swelling
- also overnight, resubmerge dehydrated gels in DI water to calculate swelling
- we also submerged 1 1.0% agar gel (that had not been dehydrated) in ethanol overnight
- this was at about 5:15 PM
- · tomorrow, we will re-weigh gels
- attached is a photo of our results

#### Conclusions/action items:

This testing was a success in showing a percent decrease when we dehydrated the gels using ethanol. We will check on the gels tomorrow to see how they swelled and also to check on the gel that we let dehydrate overnight.

		weight (g)					
Time Point	n	0.50%	1.00%	1.50%			
initial	1	1.004	1.216	1.192			
	2	1.005	1.25	1.17			
	3	1.003	1.158	1.07			
	Addition	of 10 mL 200 pro	of EtOH				
20 min	1	0.9131	0.9087	0.9031			
	2	0.8386	0.9341	0.921			
	3	0.6335	0.9061	0.9096			
40 min	1	0.876	0.8928	0.8742			
	2	0.806	0.9262	0.9062			
	3	0.592	0.9	0.8688			
60 min	1	0.8274	0.8821	0.871			
	2	0.7502	0.9261	0.8865			
	3	0.5211	0.8959	0.8489			
% decrease	1	17.58964143	27.45888158	26.9295302			
	2	25.17412935	25.92	24.23076923			
	3	48.04586241	22.63385147	20.6635514			



## 2025/11/23 - Thermal Conductivity Testing

ORLA RYAN - Nov 23, 2025, 5:09 PM CST

Title: Thermal Conductivity Testing

Date: 11/23/2025 Content by: Orla

Present: Orla, Helene, Corissa, Lilly, Avery

Goals: Make headway on completing thermal conductivity testing using our thermocouple circuit and/or a thermometer.

#### Content:

- · Utilizing Lilly's thermal conductivity protocol found from previous experiments
- · Measuring conductivity of multiple gelatin concentrations
- using Arduino code/a simple cold junction op-amp set up
  - calibrated/made note that the thermocouple was measuring different temperatures than the thermometer (made note for possible calibration curve)
- Removed gels from containers, cut into portions for individual mass measuring and size measurements (separated by percentage gelatin

   4,6,8%)
  - measurements below were also copied into a spreadsheet for future reference
    - 4% gels:
      - Sample 1: 3.6cm length, 2.2cm width, 1.4cm height
        - mass: 10.12g
      - Sample 2: 3.8cm length, 2.3cm width, 1.2cm height
        - mass: 10.98g
      - Sample 3: 4cm length, 2.2cm width, 1.5cm height
        - mass: 11.51g
      - Sample 4: 4.1cm length, 2cm width, 1.5cm height
        - mass: 12.39g
      - Sample 5: 3.1cm length, 1.8cm width, 1.2cm height
        - mass: 6.23g
    - 6% gels:
      - Sample 1: 2.6cm length, 1.6cm width, 1.2cm height
        - mass: 5.11g
      - Sample 2: 1.7cm length, 2.1cm width, 1.2cm height
        - mass: 6.81g
      - Sample 3: 3.5cm length, 2.8cm width, 1.6cm height
        - mass: 6.4g
      - Sample 4: 2.8cm length, 1.2cm width, 1.4cm height
        - mass: 5.57g
      - Sample 5: 2.4cm length, 1.6cm width, 1.5cm height
        - mass: 6.16g
    - 8% gels:
      - Sample 1: 3.4cm length, 2cm width, 1.5cm height
        - mass: 10.61g
      - Sample 2: 3.3cm length, 2.2cm width, 1.5cm height
        - mass: 10.52g
      - Sample 3: 3.4cm length, 2cm width, 1.5cm height
        - mass: 8.44g
      - Sample 4: 3.5cm length, 1.8cm width, 1.4cm height
        - mass: 7.52g
      - Sample 5: 3.4cm length, 1.9cm width, 1.4cm height
        - mass: 8.63g

Conclusions/action items:



## 2025/11/24 - Thermal Conductivity Testing

AVERY SCHUDA - Nov 24, 2025, 5:07 PM CST

**Title: Thermal Conductivity Testing** 

Date: 11/24/2025

Content by: Avery

Present: Avery, Lilly, Corissa

Goals: Continue the thermal conductivity testing

#### Content:

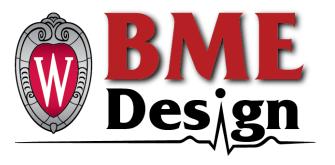
- · Utilizing Lilly's thermal conductivity protocol found from previous experiments
- · Measuring conductivity of multiple gelatin concentrations
- using Arduino code/a simple cold junction op-amp set up
  - calibrated/made note that the thermocouple was measuring different temperatures than the thermometer (made note for possible calibration curve)
- Removed gels from containers, cut into portions for individual mass measuring and size measurements (separated by percentage gelatin

   4,6,8%)
  - o measurements below were also copied into a spreadsheet for future reference
    - 4% gels: (already completed)
      - Sample 1: 3.6cm length, 2.2cm width, 1.4cm height
        - mass: 10.12g
      - Sample 2: 3.8cm length, 2.3cm width, 1.2cm height
        - mass: 10.98g
      - Sample 3: 4cm length, 2.2cm width, 1.5cm height
        - mass: 11.51g
      - Sample 4: 4.1cm length, 2cm width, 1.5cm height
        - mass: 12.39g
      - Sample 5: 3.1cm length, 1.8cm width, 1.2cm height
        - mass: 6.23g
    - 6% gels: (started here)
      - Sample 1: 2.6cm length, 1.6cm width, 1.2cm height
        - mass: 5.11g
      - Sample 2: 1.7cm length, 2.1cm width, 1.2cm height
        - mass: 6.81g
      - Sample 3: 3.5cm length, 2.8cm width, 1.6cm height
        - mass: 6.4g
      - Sample 4: 2.8cm length, 1.2cm width, 1.4cm height
        - mass: 5.57g
      - Sample 5: 2.4cm length, 1.6cm width, 1.5cm height
        - mass: 6.16g
    - 8% gels:
      - Sample 1: 3.4cm length, 2cm width, 1.5cm height
        - mass: 10.61g
      - Sample 2: 3.3cm length, 2.2cm width, 1.5cm height
        - mass: 10.52g
      - Sample 3: 3.4cm length, 2cm width, 1.5cm height
        - mass: 8.44g
      - Sample 4: 3.5cm length, 1.8cm width, 1.4cm height
        - mass: 7.52g
      - Sample 5: 3.4cm length, 1.9cm width, 1.4cm height
        - mass: 8.63g

## Conclusions/action items:

Thermal conductivity is complete with this round of gelatin gels. Lilly to compute final values for thermal conductivity using MATLAB and the equation previously calculated.

# Intracranial EEG Phantom for Brain Stimulation Studies Product Design Specifications (PDS)



BME 400 18 September 2025

Clients: Dr. Raheel Ahmed, Dr. Arun Manattu
UW School of Medicine and Public Health
Neurosurgery

Advisor: Dr. Paul Campagnola
University of Wisconsin–Madison
Department Chair of Biomedical Engineering

Section 303

Avery Schuda (Team Leader) - aschuda@wisc.edu
Lilly Mackenzie (Communicator) - lfmackenzie@wisc.edu
Orla Ryan (BWIG)- orryan@wisc.edu
Helene Schroeder (BSAC) - hschroeder4@wisc.edu
Corissa Hutmaker (BPAG) - hutmaker@wisc.edu

## **Function**

Intracranial electroencephalography (iEEG) is routinely used in surgical planning for individuals with uncontrolled seizures, such as those with epilepsy. Utilizing  $\epsilon$  this method provides high spatiotemporal resolution [1]. Transcranial magnetic stimulation (TMS) assesses brain circuit excitability through electromagnetic induction, ind networks [2]. While this neuromodulation technique may provide complementary information for mapping out critical brain regions that should be avoided during surgery, of secondary electrical currents, heating of the implanted electrodes, and electrode array displacement, all of which would have severe consequences for the affected indivistudied on children with epilepsy, but instead on adult patients; dissimilar physiology and comparative higher resting motor thresholds might require higher levels of stimul project, therefore, is to develop a pediatric brain phantom model that can be used to simulate the main effects of TMS on iEEG electrodes: currents, temperatures, and chan

#### Client requirements

- 1. The phantom should represent the physiology of the pediatric brain in terms of overall matter volume, between 50 and 100 mm³, and circumference of the surround
- 2. The material should have efficient conductivity to allow for proper current testing; to represent brain tissue conductivity, this value should lie between 0.2 and 0.5 S
- 3. The device must be able to withstand a minimum of 50 magnetic pulses, as is common in TMS sessions for human participants [1].
- 4. The phantom must not physically interfere with TMS coil application to allow for adequate testing. To allow for optimal orientation, the TMS operator should be at
- 5. The budget must not exceed \$500.

#### **Design requirements**

#### 1. Physical and Operational Characteristics

#### a. Performance requirements

- i. The phantom must withstand magnetic pulses up to a frequency of 0.5 Hz, as performed in a previous TMS study on patients with implanted electrodes [1].
- ii. To reflect the higher motor threshold present in a pediatric nervous system, as the corticospinal tract continues to develop, the phantom should tolerate pulses up to
- iii. Similar physiological properties to the young child brain are ideal, including an overall brain matter volume between 50 and 100 mm<sup>3</sup> and appropriate conductivity
- iv. The shape and structure of the model must be maintained despite implantation of electrode arrays up to 90 mm [1].
- v. The construction of the phantom and any necessary container must allow for measurements of displacement, temperature change, and induced current; as such, the each of the embedded electrodes.

#### b. Accuracy and Reliability

- i. After treatment with TMS, the implanted electrodes should experience <1°C of heating [10].
- ii. The iEEG electrodes should experience displacement of less than 20 mm, as some deformations of the brain can naturally occur [11]. Ideally, there will be no signif
- iii. Charge density must be less than 30  $\mu$ C/cm<sup>2</sup> when TMS is being administered at full power [1].

#### c. Life in Service

- i. The phantom will be used to ensure the safety of TMS being used with iEEG technology.
- ii. The phantom must be constructed from material that will not degrade over the entire testing period, such as a 3D printed acrylic polymer. The client will define the
- iii. Each round of TMS testing will last approximately 350 seconds [12].

#### d. Shelf Life

- i. The shelf life necessary for this phantom will extend for the duration of client testing. After in vitro testing is complete, the client will begin clinical trials with pedia
- ii. To ensure minimal material degradation, the phantom will be stored at room temperature and humidity, 22-24 °C and 40-60%, respectively [13].
- iii. Depth electrodes will be used. They will not be permanently implanted but should be used within approximately 3 years [14].

#### e. Operating Environment

- i. The phantom will be used in conjunction with TMS and iEEG technology. Materials must be compatible with this technology.
- ii. The phantom will be used in a sterile environment and handled by neurosurgeons during testing.
- iii. The phantom will be used at average room temperature, 22-24 °C, and humidity, 40-60% [13].

#### f. Ergonomics

- i. Neurosurgeons handling the phantom must be able to safely use and replace components of the phantom, such as the gel and electrodes, between testing.
- ii. The phantom will be placed on a table for the duration of testing, approximately 1 meter (m) off the ground.

#### g. Size

- i. The phantom should mimic the size of an average pediatric brain and skull.
- ii. The approximate volume of the phantom will be 50-100 mm<sup>3</sup> [4].
- iii. The approximate circumference of the skull of the phantom will be 50-54 cm [5].

#### h. Weight

i. The phantom will ideally be less than 2 kg to ensure the phantom is easy to transport and lift without causing strain to the user.

#### i. Materials

- i. The base of the phantom will be constructed from a 3D printed acrylic polymer. Acrylic based filament or resin for 3D printing has good optical clarity for viewing polymethyl methacrylate (PMMA) parts showed minimal degradation over 5 years [15].
- ii. 6-12 contact EEG electrodes will be embedded in silicone for precise positioning of the implanted electrodes [1]. Depth arrays (platinum macro contacts) are implaced cortical surface [12].
- iii. A hydrogel will be used to approximate brain tissue. Similar phantoms have used a polyacrylic acid saline gel [1], agar, gelatin, or agarose. The addition of NaCl is conductivity [16].
- iv. Fiberoptic fluorescent temperature sensors can be connected perpendicular to the electrodes to measure changes in temperature [12].
- v. Ferromagnetic materials will be avoided so as to not interfere with the TMS induced magnetic field [17].

## j. Aesthetics, Appearance, and Finish

- i. The base of the phantom should be 3D printed from a clear filament/resin so that the implanted electrodes and internal components can be easily viewed.
- ii. A replaceable hydrogel brain mimics the texture and conductive properties of the brain. However, a gel with greater optical clarity is desired for positioning and vie
- iii. A gel-based phantom housed in a rectangular box is better for calibration testing and can be used to evaluate temperature changes and basic electromagnetic effects
- iv. A skull-based phantom would provide greater anatomical accuracy and more complex geometry is important to evaluate TMS induced fields more realistically [19] simpler gel-box phantom will be created for initial testing, before moving onto a more complex skull-based phantom.

#### 2. Production Characteristics

#### a. Quantity

i. The client desires one gel based phantom housed in a 3D printed rectangular box to first be created for preliminary testing before progressing to a skull-based phant

#### b. Target Product Cost

i. The total production cost must not exceed the budget of \$500.

#### 3. Miscellaneous

#### a. Standards and Specifications

- i. MTR Standards 2.4 and 3.3 require pediatric patients with implanted electrodes to have an inter-electrode impedance of up 10 kOhms maximum, and that electroen microvolts (uV), respectively [20].
- ii. CFR Standard 882.5802 defines the use of TMS coils for treatment of neurological and psychiatric disorders as Class II medical devices with specific controls. The pulse output, magnetic and electrical field, built in device safety features, and patient exposure to sound during device use [21].
- iii. The testing of the phantom must follow ASTM standard F2182, which details a test procedure for measuring temperature change due to induced current during mag

#### b. Customer

i. The customers for this project are pediatric patients with intracranial implanted electrodes who will need to undergo neurosurgery.

#### c. Patient-related concerns

i. Patient-related concerns during simultaneous iEEG and TMS include heating of electrodes, induced electrical current, and displacement of electrodes. This phanton concerns on a pediatric patient.

#### d. Competition

i. A similar phantom used to test the safety of combined iEEG and TMS was recently made at the University of Iowa [1]. This phantom used a polyacrylic acid (PAA) representing the brain and skull tissue, respectively. This phantom was successfully used to verify safety of concurrent iEEG and TMS use in adult patients undergo phantom addresses many of the current project's concerns, it fails to account for more stringent safety standards and physiological differences required when considerable to the current project of the c

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ORLA RYAN - Oct 05, 2025, 12:45 PM CDT

Title: Design Matrices

Date: 10/5/2025

Content by: Orla Ryan

Present: n/a

Goals: I am uploading a copy of our initial design matrices.

Content:

See the attached PDF for our constructed tables.

#### Conclusions/action items:

We will be moving on with material orders and fabrication methods.

ORLA RYAN - Oct 05, 2025, 12:41 PM CDT

#### HYDROGEL DESIGN MATRO

Design Orlivrio	Weight	Gelotin		Polytocrylic suicil		Agor		Approce	
Thermal Canductivity	20	9:6	a	316	10	5)5	20	1/6	4
Pettert	210	2/5	8	4(5	12	5/5	20	45	18
Tundolity	20	1/5	6	5/5	20	9/5	12	3/5	12
Heactivity	. 15	405	12	305	9	2/5	6	3/5	- 9
shelfulfe	. 15	105	3	4(6	12	3/6	9	3/6	12
Cost	10	5:5	10	215	4	415	B	2/5	4
Total	100	46		09		70		57	

Table t Design matrix for brain phantom hydrogol materials.

#### SKULL BASE DESIGN MATRIX:

Design Criteria	Weight	Pelyliberic scale (ALA)		Pulytrae nyl metropnykriej (PhtMA)		Pormicts BerHed Clear		Ponntaby Hiteratord Route	
Prescrivity and Shell title	25	9/5	15	5/6	25	4/5	20	3/5	10
Transparency	20	1/5	4	6/6	-90	2/2	20	2/6	12
remittivity:	201	2/6	И	20/24	12	h(h	20	N/h	38
Accessibility	10	6/6	15	1/9	1	4/6	12	4/6	12
Properties	10	2/3	4	55	10	5/5	10	2/5	4
Cost	10	9/9	10	1/6	2	8/9	9	4/6	8
Telal	700	- 5	đ	7	2	8	8	7	3

Table It Design motivis for 30 printed phantom base material.

**Download** 

PDF\_DESIGN\_MATRICES\_for\_LabArchives.pdf (205 kB)

ORLA RYAN - Oct 24, 2025, 8:48 PM CDT

**Title: Outreach Brainstorm** 

Date: 10/24/2025

Content by: Orla Ryan

Present: n/a

Goals: Writing down some ideas for the team's outreach for next semester

#### Content:

- Since our project is very central nervous system-focused (the brain, development, connectivity, epilepsy disorder, etc.), it would make the most sense to focus on this area for our outreach as well
  - can look into after-school science clubs/put together some kind of display or presentation on how different areas of the brain function
- Describe epilepsy, maybe! Especially since Dr. Ahmed specializes in pediatric patients
- Would we involve Brooke?
- How to best describe the brain to middle or high schoolers -->
  - not too complicated (especially depending on age range)
  - lobes and basic functions (occipital, parietal, etc.)
- OR go into a little bit of depth on our project and how we are making it ... aka hydrogels
- Come up with an activity for making hydrogels of a kind? Jello? Play-doh for shaping?
- What would be needed:
  - · Graphic presentation
  - o Props
  - Interactive activity kids to do (depends on our subject choice)

#### Conclusions/action items:

I'll bring these ideas up with the team at our next whole-group meeting. It is not too urgent to get this formalized, but would be nice to have a general plan/agreement!

ORLA RYAN - Oct 30, 2025, 12:37 PM CDT

Title: Elevator Pitch

Date: 10/30/2025

Content by: Orla Ryan

Present: Avery, Lilly, Helene, Orla

Goals: Writing up an elevator pitch for the group to use tomorrow as we go through show and tell, along with ideas for questions to ask other BME

students.

#### Content:

Show and Tell Elevator Pitch:

Epilepsy is a prevalent neurological condition marked by the occurrence of repeated, uncontrollable seizure that commonly manifests in children. One main treatment method is that of surgical intervention, in which neurosurgeons identify and disconnect cranial regions involved in seizure generation. Prior to these operations, brain mapping techniques such as intracranial electroencephalography (iEEG) and transcranial magnetic stimulation (TMS) are utilized to provide a neurological "map". We are planning to create a brain phantom model composed of a hydrogel solution and encased in clear resin that can be used to simulate the main effects of TMS on iEEG electrodes. At this stage, we have decided to use agar for our hydrogel. Next semester, we will print a casing out of BioMed Clear Resin to hold the hydrogel. For now, we are focusing on tuning the hydrogel properties (using different concentrations of agar, NaCl, and via crosslinking) to achieve a close match to human brain tissue properties. Subsequently, testing methods for measurements of temperature changes, electrical conductivity, and electrode displacement will be refined and followed to overall simulate accurate pediatric brain tissue behavior.

What feedback are we looking for?

Ideas on future testing set-up (i.e. how can we detect possible electrode displacement, current build-up, etc.?)

Any experience working with agar/advice on processing and crosslinking?

Currently, we will just be calling ThermoFisher on the advice of Dr. TJP

Can ask about the process of generating mold/3D print from CT scans (especially for the bougie group... they utilized MRI scans to 3D print part of their current project)

#### Conclusions/action items:

We will try and get some constructive criticism and/or ideas from our peers during tomorrow's show and tell session.

## 2025/11/7 - Tong Lecture, Kristin Myers

ORLA RYAN - Nov 07, 2025, 12:42 PM CST

Title: Tong Lecture, Kristin Meyers

**Date:** 11/7/2025 **Content by:** Orla

Present: Helene, Lilly, Orla, Avery, Corissa

Goals: Learn from Kristin Myers (a past BME graduate) on the connections between healthcare and engineering.

#### Content:

- · Three career journey chapters:
  - "the foundation", "the growth curve", "build and transform"
- · College years/early 20s:
  - had 4 co-ops/internships (Abiomed, BAIRD, etc.)
  - Medtronic
  - o got MBA at Harvard
  - was an investor in healthcare startups
- · "Growth curve"/later 20s:
  - · worked at Aetna (chief of staff for the CEO president)
    - led a very large team
    - in the meantime, started a cycling studio
  - · Unified Women's Healthcare (president/chief operating officer)
    - working through teams and making a bigger impact by combining IQ and EQ
- · "Build and transform":
  - o making systematic change, not just through a job/company
  - · Hopscotch Health
    - working on primary care for rural communities
  - BCBS
    - affordability/improving the experience for more of the country
- · How much do we spend on healthcare in the US?
  - \$\$: 5.3 trillion
  - %GDP: 18
  - spend 2x more than other first world countries, BUT ranked last on equity, access, and outcomes
- underlying healthcare challenges --> misaligned incentives, inequities between zip codes, federal/state/employer contradictions in financing and regulation
- · Building an integrated system that enables health and wellness for ALL
  - · 'Integrated ecosystem'
  - Some things we would need: human centered design, connected care delivery platforms, simplified/automated infrastructure
  - · Engineers do systems best!
- · Five takeaways:
  - work hard and build range take on hardest projects possible
    - look for offices WITH other people (not fully remote)
    - getting ONE professional job may help in future (about taking that first chance)
  - $\circ\hspace{0.1cm}$  seek diverse exposure different sectors, teams, and geographies
  - choose your people wisely surround yourself with high-integrity people
  - know your values, protect them
  - embrace challenge, keep growing

#### Conclusions/action items:

We can consider the advice and outlook Kristin offered during this speech to shape our work ethic and career considerations going forwards.

ORLA RYAN - Dec 03, 2025, 10:08 PM CST

Title: Final Poster Upload

Date: 12/3/2025
Content by: Orla

Present: n/a

**Goals:** To upload the final poster for reference within the team's notebook.

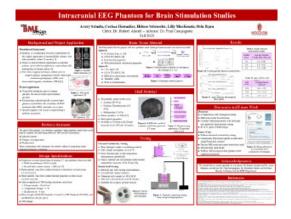
Content:

See attached files!

#### Conclusions/action items:

The group will present this coming Friday.

ORLA RYAN - Dec 03, 2025, 10:09 PM CST



**Download** 

BME400BrainPhantomFinalPoster.pdf (377 kB)

ORLA RYAN - Dec 10, 2025, 12:09 PM CST

Title: Outreach Activity Guide

**Date:** 12/10/2025 **Content by:** Orla

Present: n/a

Goals: Uploading the team's planned outreach activity.

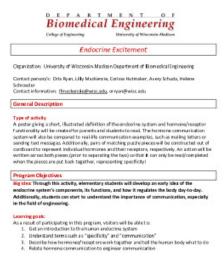
Content:

· See attached file!

#### Conclusions/action items:

The team will meet with Dr. TJ Puccinelli early next week to go over our draft and get feedback.

ORLA RYAN - Dec 10, 2025, 12:09 PM CST



#### **Download**

Ryan-MacKenzie-Hutmaker-Schuda-Schroeder-outreach-draftactivityguide.pdf (1.01 MB)

# 2025/09/10 - "Effects of transcranial magnetic stimulation on the human brain recorded with intracranial electrocorticography"

AVERY SCHUDA - Sep 11, 2025, 11:43 PM CDT

Title: "Effects of transcranial magnetic stimulation on the human brain recorded with intracranial electrocorticography"

Date: 9/10/2025

Content by: Avery Schuda

Present: N/A

Goals: Read the article provided by the client to better understand the project and learn about a similar device

Link: Effects of transcranial magnetic stimulation on the human brain recorded with intracranial electrocorticography | Molecular Psychiatry

Citation: J. B. Wang et al., "Effects of transcranial magnetic stimulation on the human brain recorded with intracranial electrocorticography," Mol Psychiatry, vol. 29, no. 5, pp. 1228–1240, May 2024, doi: 10.1038/s41380-024-02405-y.

#### Content:

- · Intracranial Electroencephalography (iEEG) measures neural activity with high spatiotemporal resolution
  - · Recorded from neurosurgical epilepsy patients using electrodes either implanted within the brain or on its surface
  - Has been used following intracranial electrical stimulation to delineate temporal dynamics and spatial spread
  - · Promising tool to provide similar resolution following noninvasive neuro modulatory techniques
    - Recent work w/ noninvasive transcranial direct and alternating current stimulation (tDCS and tACS) and iFFG
    - Higher stimulation amplitude than what is typically used may be needed to reliably induce intracranial effects
    - No supporting evidence in protocols presumed to drive specific oscillation frequencies

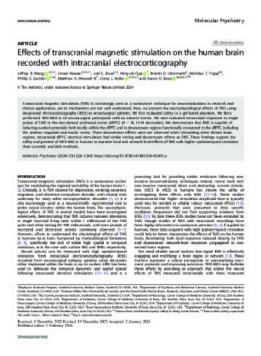
0

- Transcranial Magnetic Stimulation (TMS) noninvasive neuromodulation technique of regional excitability
  - · Research and clinical applications
  - · Mechanisms not well understood motivation for project
  - FDA cleared for depression, smoking cessation, migraines, and OCD
  - · Clinical trials underway for several other neuropsychiatric disorders
  - Experimental tool to probe neural circuitry within the human brain
  - In animal models, TMS proven to induce transient alterations in single neuronal firing rates within 1 millisecond of the TMS pulse, often lasting 40-100 ms
  - · Periods of increased and decreased activity commonly observed
  - Lack of high spatial or temporal resolution with surface EEG and fMRI hampers understanding the physiological effects of
- · Current TMS safety guidelines include intracranial hardware as a contraindication to TMS administration
  - Emerging safety data and animal studies have demonstrated that TMS can be applied safely in the presence of iEEG
  - This technique had not been evaluated in humans
- This study used a gel-based phantom to perform safety testing of TMS at clinically relevant intensities while recording iEEG
  - Following the success of these experiments in vitro, combined TMS and iEEG was performed on 22 patients
- Testing with the gel phantom evaluated three concerns: electrodes heating, electrode displacement, and induction of secondary electric currents
- · Delivered TMS to the gel phantom with intracranial electrodes placed within the gel and on its surface
- · Distance between the TMS coil to the electrode contacts was set to 10 mm
  - Represents the smallest distance possible between the coil and the iEEG electrodes in human experiments
  - Smallest distance means the highest amplitude in magnetic field
  - TMS must cross the skin, skull, and CSF space prior to reaching the electrodes

#### Conclusions/action items:

This article was helpful in getting a background on TMS and iEEG technologies, as well as an example of a phantom used for a similar study to what this design project hopes to achieve. Next steps will be to meet with the client and discuss if they desire a gel-based phantom as well and what other specifications may apply from this article.

AVERY SCHUDA - Sep 11, 2025, 11:44 PM CDT



#### **Download**

Effects\_of\_transcranial\_magnetic\_stimulation\_on\_the\_human\_brain\_recorded\_with\_intracranial\_electrocorticography.pdf (2.36 MB)



# 2025/10/02 - "Can We Deliver TMS to Patients With Implanted Devices? A Practical Summary of the Recent Safety Recommendations"

AVERY SCHUDA - Dec 04, 2025, 2:54 PM CST

Title: "Can We Deliver TMS to Patients With Implanted Devices? A Practical Summary of the Recent Safety Recommendations"

Date: 10/02/2025

Content by: Avery Schuda

Present: N/A

Goals: Learn about safety considerations of using TMS with a variety of implanted devices

Citation: A. Tendler, Y. Roth, and C. A. Hanlon, "Can We Deliver TMS to Patients With Implanted Devices? A Practical Summary of the Recent Safety Recommendations," J. Clin. Psychiatry, vol. 84, no. 4, p. 23l14857, Jul. 2023. doi: 10.4088/JCP.23l14857.

Link: "Can We Deliver TMS to Patients With Implanted Devices?" A Practical Summary of the Recent Safety Recommendations

#### Content:

- Objective provide a practical summary of updated safety recommendations for transcranial magnetic stimulation (TMS) in patients with implanted devices
- · Original TMS safety guidelines were highly conservative, recent consensus updates allow broader use
- FDA and device IFU documents have not yet aligned with updated expert recommendations
- Theoretical Risks
  - Heating of conductive implants
  - Mechanical movement of ferromagnetic implants
  - · Demagnetization of permanent magnets
  - · Induced currents in wires/electrodes (especially if aligned with coil)
  - · This aligns closely with the considerations of our project
- · Risk Mitigation
  - · Arrange electrode wires close together, twisted in alternating directions to reduce induced currents
  - · Avoid loops in wire bundles
  - Use handheld ferromagnetic detectors for unknown implant materials
- · MRI vs TMS Comparison
  - MRI fields: 1.5-3 Tesla (static)
  - TMS: ~2 Tesla but very brief (under 1 ms)
  - TMS effect on ferromagnetic materials is weaker than MRI
  - · MRI safe or MRI-conditional devices are generally TMS safe
- Recommendations
  - · Avoid placing ferromagnetic material within 10 cm of coil
  - · Anchored implants (plates, screws) do not move under TMS
  - · Remove hearing aids for protection
- · Vagal and hypoglossal nerve stimulators safe with TMS, no damage reported
- · Cochlear implants MRI-conditional ones are safe, others need evaluation
- Older programmable type CSF shunts unaffected by TMS
- · Only use deep brain stimulators if medically justified, avoid lead loops
- Follow updated consensus guidelines rather than outdated manufacturer IFUs
- · Consider risks vs. benefits for each patient
- Push for FDA and manufacturer updates to reduce confusion and improve compliance

#### Conclusions/action items:

This article did not address EEG at all, but some of the information that applies to other implanted devices may still apply to TMS with iEEG. This furthers the idea that the combination of the two have not been looked at as much, hence the need for the creation of our phantom.

# 2025/09/18 - "Comparison of electrical conductivities of various brain phantom gels: Developing a 'Brain Gel Model'"

AVERY SCHUDA - Sep 18, 2025, 9:53 PM CDT

Title: "Comparison of electrical conductivities of various brain phantom gels: Developing a 'Brain Gel Model"

Date: 9/18/2025

Content by: Avery Schuda

Present: N/A

Goals: Research options for gel materials used for the brain of the phantom

Search term: hydrogels used in brain phantom (google)

Citation: M. A. Kandadai, J. L. Raymond, and G. J. Shaw, "Comparison of electrical conductivities of various brain phantom gels: Developing a 'Brain Gel Model," Mater Sci Eng C Mater Biol Appl, vol. 32, no. 8, pp. 2664–2667, Dec. 2012, doi: 10.1016/j.msec.2012.07.024.

Link: Comparison of electrical conductivities of various brain phantom gels: Developing a 'Brain Gel Model' - PMC

#### Content:

- · Goal of the study: develop a brain phantom using hydrogels that mimic brain tissue's electrical conductivity
- Focused on conductivity at 37 deg F and in the 100-500 Hz frequency range
- Agar
  - Moldable and structurally rigid at 37 deg C
  - · Conductivity increases with NaCl concentration and temperature
  - Used in MR/NMR studies due to similar proton density and relaxation times to soft tissue
  - · Contains multiple charges
  - · Less pure than agarose
- Agarose
  - Electrically neutral and highly pure
  - Moldable and suitable for infusion studies
  - · Mimics mechanical properties and pressure profiles of brain tissue
  - · Conductivity also increases with NaCl concentration and temperature
- Gelatin
  - Easy to prepare and has the highest conductivity at room temperature
  - · Loses structural integrity at 37 deg C unless used at high concentrations
  - · High concentrations reduce its similarity to brain tissue
  - · Low cost
- · Conductivity is nearly independent of frequency in the 100-500 Hz range
- Conductivity increases linearly with NaCl concentration and temperature
- Formulas were derived to predict the conductivity for each gel type

#### Conclusions/action items:

Gelatin is best for room temperature use, while agar and agarose are better at physiological temperature. All of these gels could be options for the phantom and should be evaluated in a design matrix against PAA gel.



# 2025/09/18 - "Development of anatomically accurate brain phantom for experimental validation of stimulation strengths during TMS"

AVERY SCHUDA - Sep 18, 2025, 11:10 PM CDT

Title: "Development of anatomically accurate brain phantom for experimental validation of stimulation strengths during TMS"

Date: 9/18/2025

Content by: Avery Schuda

Present: N/A

Goals: Learn about the advantages of a skull-based phantom for use with TMS

Search term: skull based phantom for TMS (google scholar)

Citation: H. Magsood and R. L. Hadimani, "Development of anatomically accurate brain phantom for experimental validation of stimulation strengths during TMS," Materials Science and Engineering: C, vol. 120, p. 111705, Jan. 2021, doi: 10.1016/j.msec.2020.111705.

Link: Development of anatomically accurate brain phantom for experimental validation of stimulation strengths during TMS - ScienceDirect

#### Content:

- · Created a skull based phantoms for use with TMS
- · Developed patient-specific 3D models from MRI data
- · Fabricated a conductive brain phantom using PDMS-MWCN composite polymer
- · Phantom mimics anatomical geometry and electrical conductivity of brain tissues
- · Used for experimental validation of TMS induced stimulation strengths
- · Mimics real brain geometry and surface topography, improving the realism of electric field distribution
- · Polymer conductivity tuned to match grey matter, white matter, and CSF
- · Allowed researchers to conduct repeated TMS procedures without the ethical concerns of testing on real patients
- · Useful for testing new TMs coil configuration and stimulation protocols
- · Can be adapted for other neuromodulation techniques like deep brain stimulation and tDCS
- · Voltage induced by TMS shoes predictable linear behavior with coil intensity and rapid decay with distance
- The model uses uniform conductivity, while real brains have region-specific variations
- Electric field mapping is more difficult due to probe induced distortions in complex geometries
- · Air bubbles during molding can effect the conductivity and anatomical fidelity
- PDMS-MWCNT composite has limitations in conductivity enhancement and mechanical properties
- · Slight anatomical deviations in CT scans due to phantom placement errors

#### Conclusions/action items:

Skull-based phantoms are also a viable option for use with TMS. While more difficult to construct and complex to model, there is a greater accuracy when compared to the box only phantom. I think taking a combination approach, first creating a box phantom for initial testing and work on creating a skull based phantom after.



# 2025/09/17 - "Effect of artificial aging on mechanical and physical properties of CAD-CAM PMMA resins for occlusal splints"

AVERY SCHUDA - Sep 17, 2025, 5:22 PM CDT

Title: "Effect of artificial aging on mechanical and physical properties of CAD-CAM PMMA resins for occlusal splints"

Date: 9/17/2025

Content by: Avery Schuda

Present: N/A

Goals: Learn about the shelf life of 3D printed acrylic materials such as PMMA

Search term: "shelf life of 3d printed acrylic parts" (google scholar)

Link: Effect of artificial aging on mechanical and physical properties of CAD-CAM PMMA resins for occlusal splints - PMC

**Citation:** J. C. Raffaini et al., "Effect of artificial aging on mechanical and physical properties of CAD-CAM PMMA resins for occlusal splints," J Adv Prosthodont, vol. 15, no. 5, pp. 227–237, Oct. 2023, doi: 10.4047/jap.2023.15.5.227.

#### Content:

- 3D printed PMMA showed minimal changes in surface roughness and color after aging
- · Maintained high flexural strength, especially after thermomechanical cycling (TMC)
- · Simulated 5 years of aging under load
  - o 1.2 million cycles, 2 Hz frequency, 1.4 kg/f
  - Temperature conditions during cycling were 5, 37 and 55 deg. C (+/- 2 deg C), each maintained for 30s, with an intermediate pause of 12s
  - o 73,000 brushing cycles
- · Aging had negligible impact on its mechanical properties high durability
- After TMC 3D printed PMMA had the lowest increase in surface roughness compared to milled PMMA and heat cured acrylic resin
- · 3D printed PMMA had the lowest surface roughness alteration of the materials tested
  - Greater resistance to surface degradation compared to the other acrylic resin type
  - Surface brushing actually reduced the surface roughness of 3D printed PMMA, likely due to low filler content and smoother finish
- · 3D printed PMMA showed less color change compared to milled and heat-cured PMMA, especially after brushing
- Milled PMMA had the highest flexural strength overall
  - · 3D printed resin matched the flexural strength after TMC shows good resistance to mechanical stress
  - UV polymerization and post curing enhanced structural integrity
- 3D printed PMMA resin showed the best longevity compared to the other resins
  - Shelf life of at least 5 years with minimal degradation

#### Conclusions/action items:

This article showed that 3D printed acrylic resin such as PMMA has good durability and a shelf life of at least 5 years. This will help to inform specifications for the PDS and provide a starting point for a material selection design matrix.



# 2025/09/18 - "Safety and recommendations for TMS use in healthy subjects and patient populations, with updates on training, ethical and regulatory issues: Expert Guidelines"

AVERY SCHUDA - Sep 18, 2025, 9:29 PM CDT

**Title:** "Safety and recommendations for TMS use in healthy subjects and patient populations, with updates on training, ethical and regulatory issues: Expert Guidelines"

Date: 9/18/2025

Content by: Avery Schuda

Present: N/A

Goals: Learn more about TMS safety considerations and what materials can be used with it

Serach term: "what materials cannot be used with TMS" (google scholar)

Citation: S. Rossi et al., "Safety and recommendations for TMS use in healthy subjects and patient populations, with updates on training, ethical and regulatory issues: Expert Guidelines," Clin Neurophysiol, vol. 132, no. 1, pp. 269–306, Jan. 2021, doi: 10.1016/j.clinph.2020.10.003.

Link: Safety and recommendations for TMS use in healthy subjects and patient populations, with updates on training, ethical and regulatory issues: Expert Guidelines - PMC

#### Content:

- · Update of 2009 safety guidelines for TMS
- · Focuses on new devices, protocols, and ethical considerations
- · Seizure risk remains the most serious risk
  - · Most common in patients using CNS-active drugs when using traditional parameters
  - Still relatively rare complication
- · Safety of new TMS devices must be evaluated independently
  - Require full risk analysis
  - · Can't rely on equivalence to existing devices
- · Technical safety concerns
  - Coil heating
  - Acoustic noise
  - · Electromagnetic interference
  - Mechanical stress
  - Avoid with ferromagnetic materials
- · Dose safety varies by individual, coil type, and brain region
- · Risk analysis essential for new protocols
- Preclinical animal studies
  - Showed TMS can affect neuroplasticity, intracellular signaling
  - · Can affect blood brain barrier permeability
  - · Limited translation to humans
- Manufacturers must ensure device safety and quality
- · Users must follow guidelines and monitor for faults or misuse
- Devices like cTMS and FlexTMS allow more control over pulse shape and duration potentially enhancing neuromodulation
- New Double-cone and H-coils penetrate deeper but are less focal
  - Safety data is promising but limited.
- Low-field and static magnetic stimulations show neuromodulatory effects with minimal risk but require caution due to strong magnetic forces
- MRI and EEG (!!) can improve targeting and safety, especially in patients with brain lesions
- Robot-guided TMS enhances precision and reduces operator exposure; safety concerns include mechanical and software reliability
- · TMS can interact with implants
  - · e.g. DBS, cochlear implants
  - Requires careful risk assessment to avoid heating or induced currents
- · Despite theoretical risks, no significant increase in seizure rates has been observed in patients on psychotropic medications
- · Adverse effects

- Seizures
- Headaches
- Scalp discomfort
- Transient hearing changes (proper hearing protection is essential)
- · No lasting cognitive impairments reported; effects are generally mild and short-lived in both healthy and clinical populations
- TMS alone is considered safe in children (with hearing protection) and during pregnancy
  - More data is needed for very young children and fetal safety.
- · Ethical use in research and clinical settings requires informed consent, risk-benefit analysis, and adherence to regulatory standards

#### Conclusions/action items:

This article helps to highlight safety concerns with what methods and materials should not be used with TMS. I found it relevant that the article mentioned that TMS was generally safe for kids, but more data is needed for young children and infants, which is partially what this project aims to address.

# 2025/09/18 - "MR relaxation times of agar-based tissue-mimicking phantoms"

AVERY SCHUDA - Sep 18, 2025, 10:56 PM CDT

Title: "MR relaxation times of agar-based tissue-mimicking phantoms"

Date: 9/18/2025

Content by: Avery Schuda

Present: N/A

Goals: Learn about the advantages and disadvantages of a box-gel phantom made using agar

Search term: rectangular box gel based skull phantom (google)

Citation: A. Antoniou et al., "MR relaxation times of agar-based tissue-mimicking phantoms," Journal of Applied Clinical Medical Physics, vol. 23, no. 5, p. e13533, 2022, doi: 10.1002/acm2.13533.

Link: MR relaxation times of agar-based tissue-mimicking phantoms - Antoniou - 2022 - Journal of Applied Clinical Medical Physics - Wiley Online Library

#### Content:

- · Mimic acoustic, thermal, and MR relaxation properties of biological tissues
- T1 and T2 values can be tuned by adjusting ingredients.
- · Produce tissue-like MR signals
- · T2 influenced by agar concentration, T1 modifiable with additives like silicon dioxide
- · cost effective and accessible, made from inexpensive, widely available materials
- Easy to prepare without specialized equipment
- · Durable and can be reshaped
- Do not undergo irreversible changes when heated (unlike PAA-based phantoms)
- · Agar is a natural, biodegradable substance
- · Safer than synthetic gels like PAA, which may have toxic effects
- · Can be molded into various shapes and compartments
- Suitable for complex phantom configurations (e.g., multi-insert box phantoms)
- Agar not visually clear like PAA gels, difficult to visually detect coagulated regions
- · No inherent color change upon heating
- Used rectangular container specifically engineered to hold multiple compartments of tissue-mimicking materials
- Allows simultaneous testing of various phantom compositions under identical imaging conditions
- · Facilitates comparative analysis of MR relaxation times (T1 and T2) across different formulations
- · Supports standardization and repeatability in experiments
- Enables parallel evaluation of multiple phantom types
- · Reduces time and resource consumption in experimental setups
- Ensures uniform imaging conditions for all samples
- · Minimizes variability due to external factors
- · Inclusion of reference liquids (e.g., water, oil) helps calibrate MR imaging and validate results
- · Compartments can be tailored to specific experimental needs
- · Supports testing of additives
- Requires precise construction to avoid leakage or cross-contamination between compartments if using multiple different sample types
- · Adjacent compartments may influence each other during focused ultrasound exposure
- The container material must be MR-compatible and acoustically neutral to avoid imaging artifacts.

#### Conclusions/action items:

A box phantom could be a viable option for initial calibration testing. It is what they used in the paper that the client provided which most closely matches this project. Further research is needed into potential advantages of constructing a more complex skull-based phantom.



### 2025/09/25 - Formlabs biomed clear resin

AVERY SCHUDA - Dec 04, 2025, 3:06 PM CST

Title: Formlabs Biomed clear resin

Date: 9/25/2025

Content by: Avery Schuda

Present: N/A

Goals: Document the material properties of Formlabs biomed clear resin

Link: BioMed Clear Resin | Formlabs

#### Content:

See attached SDS and technical data sheet

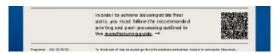
- · SP Class VI certified, ISO 13485, FDA-registered facility
- Transparent, hard, strong, wear-resistant, suitable for biocompatible applications
- Approved for long-term skin contact (>30 days), breathing gas pathways (>30 hours), short-term bone/tissue contact (<24 hours)</li>
- · Common uses: medical devices, prototypes, molds, jigs, fixtures, visualization models, implant sizing
- · Key properties
  - Tensile strength 52 MPa
  - o Young's modulus 2080 MPa
  - Elongation at break 12%
  - o Flexural strength 84 MPa
  - o Flexural modulus 2300 MPa
  - hardness Shore D 78
  - Impact resistance 35 J/m
  - · Heat deflection temp 67 degC
- · Post-processing wash with alcohol, cure as per IFU for biocompatibility
- · Properties vary with geometry, orientation, print settings, and sterilization method

#### Conclusions/action items:

This will likely be our final material choice for 3D printing the skull portion of the final phantom. Its material properties are very similar to that of cranial bone and it is clear as an added aesthetic benefit.

AVERY SCHUDA - Dec 04, 2025, 3:05 PM CST

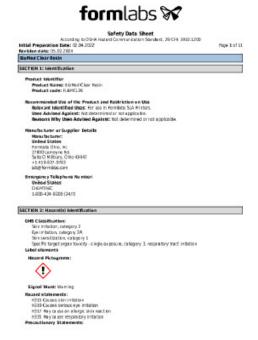




#### **Download**

#### Formlabs\_biomed\_clear\_Technical\_Data\_Sheet.pdf (595 kB)

AVERY SCHUDA - Dec 04, 2025, 3:05 PM CST



**Download** 

Formlabs\_biomed\_clear\_SDS.pdf (148 kB)



## 2025/10/05 - "Rheometric measurement of hydrogel toughness"

AVERY SCHUDA - Dec 04, 2025, 2:27 PM CST

Title: "Rheometric measurement of hydrogel toughness

Date: 10/05/2025

Content by: Avery Schuda

Present: N/A

Goals: Find a test method for measuring mechanical properties of hydrogels

Citation: H. E. Read, "Rheometric measurement of hydrogel toughness," S.B. thesis, Dept. Mech. Eng., Massachusetts Institute of Technology, Cambridge, MA, USA, May 2020. [Online]. Available: https://hdl.handle.net/1721.1/127870

Link: 1196830587-MIT.pdf

#### Content:

- · Thesis objective
  - Develop a novel method to measure fracture energy of soft hydrogels using a rheometer
  - · Compare results with traditional pure shear tensile tests
  - o Target application characterization of soft, transient, and self-healing gels
- Non-covalent gels: Physical crosslinks → reversible, low-energy bonds → useful for bioengineering/self-healing
- Traditional tensile tests fail for soft gels (need alternative methods)
- Fracture energy (G) resistance to failure, critical for material design
- Gel Synthesis
  - Material polyacrylamide (PAA)
    - Components: Acrylamide (AA), Bis-acrylamide (BAA), APS (initiator), TEMED (catalyst), water.
  - BAA/AA ratios tested: 0.17%, 0.34%, 0.51%
  - · Degassing 2.5 hrs to reduce bubbles
  - · Acrylic + glass mold (later added PTFE for easier removal)
  - · Notched gels Polyester/PTFE inserts for circumferential notch
- · Tensile Tests
  - Pure shear method compare notched vs. un-notched samples
  - · Metrics elastic modulus (Neo-Hookean fit), critical stretch, fracture energy
  - · Elastic modulus increased with crosslink density
  - Fracture energy decreased non-linearly with BAA/AA ratio
- Rheometer Tests
  - o Geometry: 20 mm parallel plates, sandpaper + superglue for adhesion
  - · Controlled normal force: 1 N
  - Used constant shear rate to avoid fatigue
  - · Notched sample dimensions chosen for "deep crack" regime
  - · Calculated fracture energy using Gent's model
  - Rheometer fracture energy was ~5x tensile test value
  - $\circ$  Discrepancy likely due to Poynting effect (torsion  $\rightarrow$  axial stretch  $\rightarrow$  extra normal force
  - Demassieux et al. model separates Mode I & III contributions.
  - Requires normal force compensation

#### Conclusions/action items:

This thesis was helpful in narrowing down some parameters for testing a hydrogel on a rheometer. However, I don't want to glue anything to the shared rheometer in the teaching lab, so will look into other protocols for testing hydrogels on the rheometer.

Rheomet	ric Measurement of Hydrogel Toughness
	hy
	Helen E. Bead
	Submitted to the Department of Mechanical Engineering diffilment of the Requirements for the Degree of
Buch	clor of Science in Mechanical Engineering
	at the
	Massachusetts Institute of Technology
	May 2020
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ignature of Author.	Department of Mechanical Engineering May 8, 2020
betified by:	Gareth H. McNaley Professor of Mechanical Sugiesering Thesis Supervisor
coupled by:	Maria Yang Professor of Mechanical Engineering

#### **Download**

1196830587-MIT.pdf (7.01 MB)

## 2025/11/20 - "Ballistic and Blast-Relevant, High-Rate Material **Properties of Physically and Chemically Crosslinked Hydrogels**"

AVERY SCHUDA - Nov 20, 2025, 5:21 PM CST

Title: "Ballistic and Blast-Relevant, High-Rate Material Properties of Physically and Chemically Crosslinked Hydrogels"

Date: 11/20/2025

Content by: Avery Schuda

Present: N/A

Goals: Understand the testing and results of Dr. Franck's characterization of various hydrogels

Link: Ballistic and Blast-Relevant, High-Rate Material Properties of Physically and Chemically Crosslinked Hydrogels | Experimental Mechanics

Citation: E. C. Bremer-Sai, J. Yang, A. McGhee, and C. Franck, "Ballistic and Blast-Relevant, High-Rate Material Properties of Physically and Chemically Crosslinked Hydrogels," Exp Mech, vol. 64, no. 4, pp. 587-592, Apr. 2024, doi: 10.1007/s11340-024-01043-3.

#### Content:

- In the article Dr Franck's team looked at high strain rate mechanical properties of 3 hydrogels polyacrylamide, gelatin, and agarose
  - Relevant to ballistic and blast scenarios
- Hydrogels mimic soft tissue properties so they are good for both biomedical and defense applications
- · Accurate prediction of mechanical response requires knowledge of high strain rate properties (scarce in literature)
- Used IMR (inertial microcavitation rheometry) at high strain rates (>10^3 s^-1)
- Goal: show how physical vs. chemical crosslinking informs the choice of constitutive model
- Laser-induced cavitation experiments analyzed via IMR
- Compared two constitutive models:
  - · Neo-Hookean Kelvin-Voight (NHKV) for dynamic, physically crosslinked gels
  - Quadratic Kelvin-Voight (gKV) for chemically crosslinked gels with strain-stiffening
- · Gelatin (dynamic physical bonds) fits best with NHKV model
- Polyacrylamide (static chemical bonds) requires qKV model due to strain-stiffening
- Agarose is technically physically bonded but behaves more like static networks due to its fibrillar structure
  - · qKV model slightly better
- Microstructure knowledge significantly improves model selection and accuracy
  - Understanding polymer network structure, bond type and mobility, is critical for selecting appropriate viscoelastic models
  - Saves time in IMR analysis and ensures physically meaningful material properties
- Gelatin most closely represented brain tissue under high strain rate conditions
  - It is physically crosslinked with dynamic hydrogen bonds --> similar to the weak, reversible interactions in biological tissues like the brain
  - Gelatin exhibited viscoelastic properties that align well with soft tissue response, particularly under rapid deformation
  - The NHKV model accurately captured gelatin's behavior, consistent with brain tissue mechanics
  - Polyacrylamide is chemically crosslinked, strain-stiffening, and much less representative of brain tissue
  - · Agarose, while physically crosslinked, has a rigid fibrillar structure that makes it behave more like a static network, so it is not as close to brain tissue

#### Conclusions/action items:

We should make a decision whether it would be better to switch to a gelatin-based hydrogel brain. Based on this study it more accurately represents brain tissue, the rheological characterization has already been completed for us, and Dr Franck would be able to guide us through the process his lab uses to create brain phantoms.

AVERY SCHUDA - Nov 20, 2025, 4:56 PM CST



### **Download**

11340\_2024\_1043\_MOESM1\_ESM.pdf (226 kB)

# 2025/11/19 - "How to Easily and Automatically Convert a CT Scan (DICOM Data) Into a 3D Printable Medical Model (STL File) in Minutes With Free Software and Online Services"

AVERY SCHUDA - Dec 03, 2025, 1:35 PM CST

Title: "How to Easily and Automatically Convert a CT Scan (DICOM Data) Into a 3D Printable Medical Model (STL File) in Minutes With Free Software and Online Services"

Date: 11/19/2025

Content by: Avery Schuda

Present: N/A

Goals: Learn how to process CT files in DICOM format into an STL that can be 3D printed

Citation: Instructables, "How to Easily and Automatically Convert a CT Scan (DICOM Data) Into a 3D Printable Medical Model (STL File) i...," Instructables, Feb. 18, 2017. Available: https://www.instructables.com/How-to-Easily-and-Automatically-Convert-a-CT-Scan-/. [Accessed: Nov. 19, 2025]

Link: How to Easily and Automatically Convert a CT Scan (DICOM Data) Into a 3D Printable Medical Model (STL File) in Minutes With Free Software and Online Services: 11 Steps (with Pictures) - Instructables

#### Content:

#### 1. Install Required Software

- · Download 3D Slicer from slicer.org (free, cross-platform).
- Download Autodesk Meshmixer from meshmixer.com (free mesh editing tool).

#### 2. Obtain CT Scan Data

- · Register for a free account at embodi3D.com.
- · Download the sample anonymized CT scan (DICOM format) or use your own CT scan CD/DVD from a hospital.
- Ensure the scan is CT only (not MRI or ultrasound).

#### 3. Convert DICOM to NRRD in 3D Slicer

- Open 3D Slicer and drag the DICOM folder into the window.
- · Accept prompts to copy data into the database.
- · Load the study into the active scene via the DICOM Browser.
- Save the study as NRRD (.nrrd) format.
- 4. Upload NRRD to Online Conversion Service

#### Log into embodi3D.com.

- · Launch democratiz3D app.
- · Drag and drop the NRRD file into the upload window.

#### 5. Configure Processing Parameters

- · Provide title, description, tags, and privacy settings.
- Enable processing and select CT NRRD to Bone STL (or muscle/skin).
- Set threshold (default 150) and quality (High).
- · Agree to terms and submit.

#### 6. Download STL Model

- Wait 5–15 minutes for processing.
- · Receive email notification or check "My Files" on embodi3D.
- Download the generated STL file.

#### 7. Clean STL in Meshmixer

- Use Select → Expand to Connected → Invert to remove unwanted table parts.
- Run Analysis → Inspector → Auto Repair All if needed.
- Export the cleaned STL file.

#### 8. Finalize for 3D Printing

- Verify the model is error-free.
- Save/export STL for use on any 3D printer.

#### Conclusions/action items:

I will use this procedure to complete the file processing of CT into STL. The STL model can also be converted into a CAD file using Fusion360, which would allow the file to be edited.

AVERY SCHUDA - Oct 13, 2025, 8:33 PM CDT

Title: Gel box phantom

Date: 9/28/2025

Content by: Avery Schuda

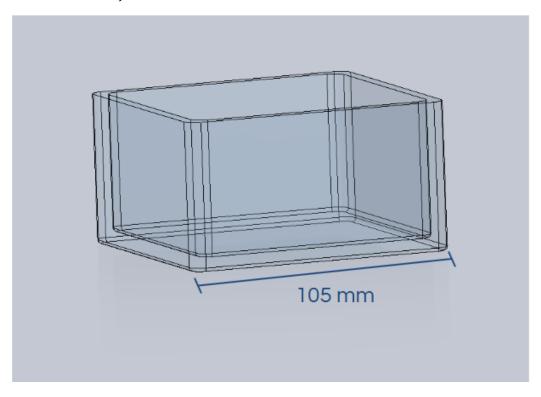
Present: N/A

Goals: Create a SolidWorks model of a pediatric sized gel box phantom

Content:

Based on the procedure used in the University of Iowa paper (LINK)

Based volume on a 2 year old - this is the smallest that we would need



#### Conclusions/action items:

When we tried to 3D print this at the Makerspace it was \$86, so reevaluation of dimensions is needed to make sure this cost is necessary. I think that the wall thickness could be reduced, as it is based on the adult lowa phantom.



# 2025/09/28 - Step wedge for presentation

AVERY SCHUDA - Dec 04, 2025, 2:37 PM CST

Title: Step wedge for presentation

Date: 9/28/2025

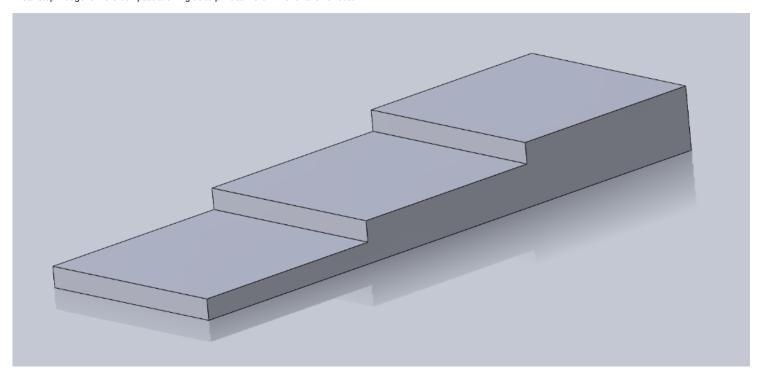
Content by: Avery Schuda

Present: N/A

Goals: Create a material swatch as an example for the preliminary presentation

#### Content:

This was adapted from a similar design from last semester. I created a linear array of  $1 \times 1$  in squares and extruded them from 0.1 to 0.3 in, in 0.1 in increments. This design of the linear step wedge is more compact allowing us to print at more infills for a lower cost.



#### Conclusions/action items:

This will be 3D printed at the Makerspace in Formlabs biomed clear resin to give us an idea of the material's optical properties and be brought to the preliminary presentation/



# 2025/11/19 - File processing of CT Scans

AVERY SCHUDA - Dec 03, 2025, 1:27 PM CST

Title: File Processing of CT Scans

Date: 11/19/2025

Content by: Avery Schuda

Present: Avery, Lilly

Goals: Convert CT scans into anonymized files and process them into STL files that can be 3D printed

#### Content:

I was able to process all three DICOM files into NRRD in 3D slicer. It seems like Dr. Ahmed was able to properly remove patient information, but converting to an NRRD file is a good extra safety guard. I was also able to successfully upload the files to embodi3D, but they never completed processing.

Procedure adapted from: How to Easily and Automatically Convert a CT Scan (DICOM Data) Into a 3D Printable Medical Model (STL File) in Minutes With Free Software and Online Services: 11 Steps (with Pictures) - Instructables

#### 1. Install Required Software

- Download 3D Slicer from slicer.org (free, cross-platform).
- · Download Autodesk Meshmixer from meshmixer.com (free mesh editing tool).

#### 2. Obtain CT Scan Data

- · Register for a free account at embodi3D.com.
- Download the sample anonymized CT scan (DICOM format) or use your own CT scan CD/DVD from a hospital.
- Ensure the scan is CT only (not MRI or ultrasound).

#### 3. Convert DICOM to NRRD in 3D Slicer

- Open 3D Slicer and drag the DICOM folder into the window.
- · Accept prompts to copy data into the database.
- · Load the study into the active scene via the DICOM Browser.
- · Save the study as NRRD (.nrrd) format.
- 4. Upload NRRD to Online Conversion Service

#### Log into embodi3D.com.

- Launch democratiz3D app.
- Drag and drop the NRRD file into the upload window.

#### 5. Configure Processing Parameters

- Provide title, description, tags, and privacy settings.
- Enable processing and select CT NRRD to Bone STL (or muscle/skin).
- Set threshold (default 150) and quality (High).
- · Agree to terms and submit.

#### 6. Download STL Model

- Wait 5-15 minutes for processing.
- Receive email notification or check "My Files" on embodi3D.
- · Download the generated STL file.

#### 7. Clean STL in Meshmixer

· Import STL into Meshmixer.

- Use Select → Expand to Connected → Invert to remove unwanted table parts.
- Run Analysis → Inspector → Auto Repair All if needed.
- · Export the cleaned STL file.

#### 8. Finalize for 3D Printing

- · Verify the model is error-free.
- Save/export STL for use on any 3D printer.

#### Conclusions/action items:

Use the internal process in 3D Slicer to convert the CT scans to an STL directly. Files can be cleaned up in 3D Slicer directly; other post-processing can be done in Meshmixer or Fusion 360.

AVERY SCHUDA - Dec 03, 2025, 1:29 PM CST



**Download** 

4\_Monday\_November\_3\_2025\_41817\_AM\_CST.nrrd (83.1 MB)

AVERY SCHUDA - Dec 03, 2025, 1:29 PM CST



**Download** 

302\_Monday\_November\_3\_2025\_35800\_AM\_CST.nrrd (75.8 MB)

AVERY SCHUDA - Dec 03, 2025, 1:30 PM CST



**Download** 

302\_Monday\_November\_3\_2025\_34550\_AM\_CST.nrrd (71 MB)

# 2025/11/24 - Half size skull for 3D printing

AVERY SCHUDA - Dec 03, 2025, 1:44 PM CST

Title: Half size skull for 3D printing

Date: 11/24/2025

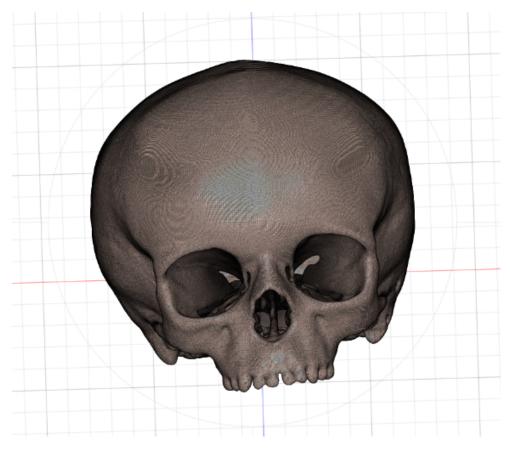
Content by: Avery Schuda

Present: N/A

Goals: Create a half size skull model that can be 3D printed as a prop for poster presentation

#### Content:

I used the patient file that I processed previously in 3D slicer to create an STL file. I then used Bambu Studio (3D printer app) to scale the model down to 50%. I used tree supports for 3D printing, 100% rectilinear infill, and printed the model in PLA.



#### Conclusions/action items:

This model will serve as a representation of the high-quality skull model that can be created through processing real CT scans of 5–7-year-old patients and give a preview of the full-size model that will be 3D printed next semester.

AVERY SCHUDA - Dec 03, 2025, 1:38 PM CST



Download

Segmentation.stl (113 MB)



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Screenshot\_2025-11-30\_173226.png (146 kB)

AVERY SCHUDA - Dec 03, 2025, 1:42 PM CST



<u>Download</u>
Screenshot\_2025-11-30\_173111.png (132 kB)



# 2025/02/05 - Design + Innovation Labs Training Documentation

AVERY SCHUDA - Feb 05, 2025, 12:38 PI

Title: Design + Innovation Labs Training Documentation

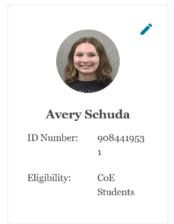
Date: 2/5/2025

Content by: Avery Schuda

Present: N/A

Goals: Complete training at the UW Makerspace and TEAM labs for design fabrication

Content:



My Memberships						
Membership Type	Start Date	Expiry Date	Renew	Card Info		
Access Fee	Mon, May 22 2023	Sun, Dec 31 2023	Not Renewable	N/A		
Machining	Sun, Jan 1 2023	Permanent	Not Renewable	N/A		
Lab Orientation	Sun, Jan 1 2023	Tue, Dec 30 3000	Not Renewable	N/A		
Laser Cutter	Sun, Jan 1 2023	Tue, Dec 30 3000	Not Renewable	N/A		
Shop Tools	Sun, Jan 1 2023	Tue, Dec 30 3000	Not Renewable	N/A		

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AVERY SCHUDA - Feb 05, 2025, 12:36 PM CST



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Design\_Innovation\_Lab\_Permits.pdf (214 kB)



## 2025/02/05 - Biosafety/OSHA Chemical Safety Training Documentation

Title: Biosafety/OSHA Chemical Safety Training Documentation

Date: 2/5/2025

Content by: Avery Schuda

Present: N/A

Goals: Complete biosafety training to be able to work safely in the tissue engineering lab.

Content:



This certifies that Avery Schuda has completed training for the following course(s):

Course	Assignment	Completion
Biosafety Required Training	Biosafety Required Training Quiz 2024	3/2/2024
Chemical Safety: The OSHA Lab Standard	Final Quiz	3/2/2024

Data Last Imported: 02/05/2025 12:39 PM

AVERY SCHUDA - Feb 05, 2025, 12:41 PM CST



**Download** 

Biosafety\_and\_OSHA\_Chemical\_Training\_Records.pdf (42 kB)

Δ١



# 2025/10/30 - CITI Human Subjects Research Documentation

AVERY SCHUDA - Oct 30, 2025, 3:29 PM CDT

Title: CITI Human Subjects Research Documentation

Date: 10/30/2025

Content by: Avery Schuda

Present: N/A

Goals: Complete training for human subjects testing

Content:

See attached.

Conclusions/action items:

N/A

AVERY SCHUDA - Oct 30, 2025, 3:29 PM CDT



**Download** 

citiCompletionCertificate\_15027183\_73267016.pdf (77.4 kB)

# 2025/09/12-Initial Client Meeting Research

ORLA RYAN - Sep 12, 2025, 9:37 AM CDT

Title: Initial Client Meeting Research

Date: 09/12/2025

Content by: Orla Ryan

Present: n/a

Goals: To obtain an initial base of knowledge so as to approach our team meeting with Dr. Ahmed with proper questions and context.

#### Content:

- Intracranial EEG (iEEG) is used in many regions of the neuroscience field
- It shows a lot of promise for understanding the brain, but presents limitations at the same time
- it utilizes "strips or grids of electrodes" to sample/monitor neurons across the brain
- "Direct electrical stimulation of the brain has a great therapeutic potential specially when coupled with real-time recordings from the surface of the brain or from a subcortical structure in a closed-loop circuits."
- an interesting potential future direction is the development of wireless iEEG!
- [1 J. Parvizi and S. Kastner, "Human Intracranial EEG: Promises and Limitations," *Nat Neurosci*, vol. 21, no. 4, pp. 474–483, Apr. 2018, doi: 10.1038/s41593-018-0108-2.

#### Conclusions/action items:

I will brainstorm questions and meet over Teams with both my team and the client later today.

## 2025/09/13 - Utilizing Client Research

ORLA RYAN - Sep 13, 2025, 2:13 PM CDT

Title: Utilizing Client Research

Date: 09/13/2025

Content by: Orla Ryan

Present: n/a

Goals: Working through the documents shared with our team by the client to further my understanding.

#### Content:

- · this document appears to describe previous study methods for testing gel-implanted electrodes
  - this could guide how we approach materials testing!
- · measured temperature changes via fluorescent temperature sensors, making sure to maintain direct physical contact
- measured electrode displacement was observed via a high-speed camera (which touted resolution that allowed for displacements as small as 1mm to be viewed)
- voltage measurements were taken with an oscilloscope probe
  - parallel and perpendicular orientations of the electrodes were tested, along with different positions on the TMS coil surface and induced voltage in cables/connectors
- · arrays of electrodes manufactured by "Ad-Tech Medical" were used
- TMS location and pulse trajectory was recorded using Brainsight
- SKULL PHANTOM:
  - · used acrylic polymer for material
  - · electrodes were fixated with a volt and nut/O-ring



#### Conclusions/action items:

I will be working on the PDS this week, and will incorporate some of what I have learned into rewriting our problem statement.

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#### **Download**

**Supplementary\_information.pdf (47.6 MB)** Information that was put in our shared Teams folder by the alternate contact, Dr. Arun Manattu

ORLA RYAN - Sep 13, 2025, 9:09 PM CDT

Title: Physiology of Child Brain

Date: 09/13/2025 Content by: Orla Ryan

Present: n/a

Goals: Get some statistics/background data on the average size and volume (and other relevant characteristics) of pediatric brains and skulls.

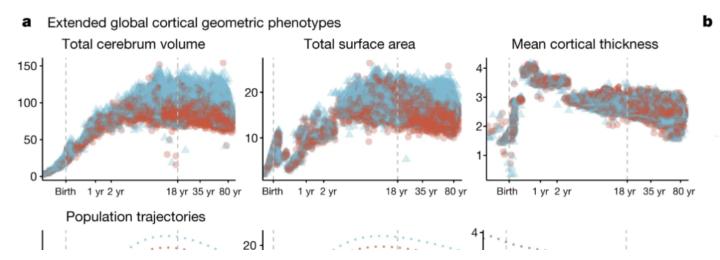
Content:

I investigated two sources to find metrics on how large the average child's brain is.

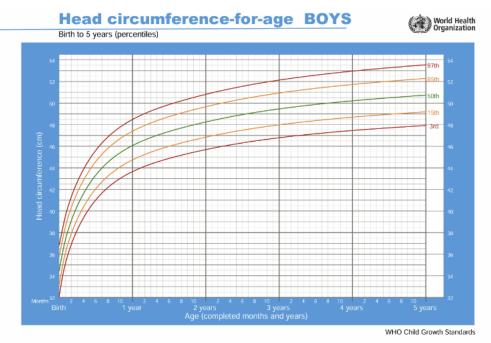
One gave more information on the average brain matter volume for different ages, with a graphic shown below:

# Fig. 2: Extended global and regional cortical morphometric

### From: Brain charts for the human lifespan



The other described average circumference of a child's head, separated by gender (below is the chart for boy's average circumference).



[2] "Head circumference for age." Accessed: Sept. 13, 2025. [Online]. Available: https://www.who.int/tools/child-growth-standards/standards/head-circumference-for-age

#### Conclusions/action items:

I will use these metrics to help inform me as I write sections of the PDS.

ORLA RYAN - Sep 14, 2025, 4:25 PM CDT

Title: TMS in Children

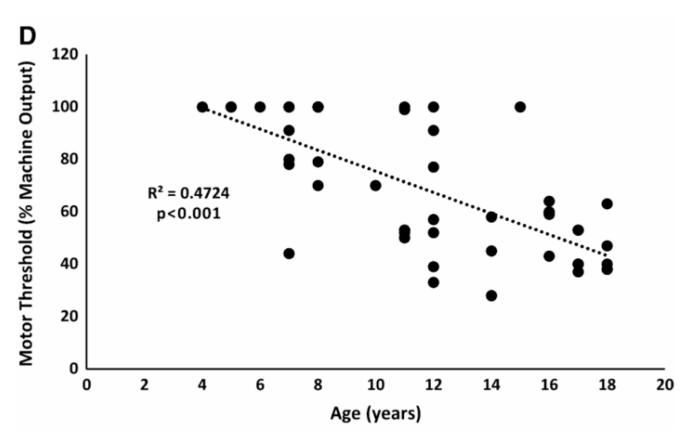
**Date:** 09/14/2025 **Content by:** Orla

Present: n/a

Goals: I am investigating the relative safety of and protocols associated with TMS in children.

#### Content:

- TMS has been used frequently in the study of neurophysiology as well as the treatment of several psychiatric disorders, but less is known about its impacts on children.
- · the regional cortical excitability that is modulated by TMS appears to be well-tolerated by both adults and children
- · higher stimulation intensity is typically needed in pediatric patients to initiate a motor evoked potential (MEP)
  - limited corticospinal tract development/this process is still on going in the child brain
- generally, the therapeutic effects and minimal adverse reactions support the idea that TMS is safe in children, but more work should be done



[1] M. Q. Hameed et al., "Transcranial Magnetic and Direct Current Stimulation in Children," Curr Neurol Neurosci Rep, vol. 17, no. 2, p. 11, Feb. 2017, doi: 10.1007/s11910-017-0719-0.

#### Conclusions/action items:

I will use this information to aid in writing the PDS and determining safety standards we should strive for.

# 2025/09/14-TMS application literature values

ORLA RYAN - Sep 14, 2025, 4:28 PM CDT

Title: TMS application literature values

**Date:** 09/14/2025 **Content by:** Orla

Present: n/a

Goals: I am finding more reference values for TMS; namely, the magnet strength/common frequencies.

#### Content:

- the use of a magnetic coil in TMS is considered noninvasive
- the area of the TMS magnetic field is smaller than that of an MRI, and generates a field of similar strength
  - o "1.5-2 Teslas"
- low-frequency pulses are around 1 Hz, and higher frequencies of 5 to 10 Hz are also used
  - different pulse patterns are used depending on the type of TMS treatment/neuromodulation intention
- · variety of coil shapes are available as well

[1] "TMS (Transcranial Magnetic Stimulation): What It Is," Cleveland Clinic. Accessed: Sept. 14, 2025. [Online]. Available: https://my.clevelandclinic.org/health/treatments/17827-transcranial-magnetic-stimulation-tms

#### Conclusions/action items:

I will use these values in constructing expectations for the design of our phantom.

ORLA RYAN - Sep 25, 2025, 11:44 AM CDT

Title: Methodology for Modeling the Human Skull in EEG Analysis

Date: 9/21/25
Content by: Orla

Present: n/a

Goals: I would like to understand the physiology of the human skull and its mechanical/electrical properties.

#### Content:

- · an in-depth series of computer simulations was used to investigate the layered human skull structure
  - conductivity and anisotropy considerations
- · effect of the skull conductivity mainly comes from its "radial component"
  - · these authors noted that previous studies did not take varying layer thickness into account when determine skull properties
- several models were developed to account for both spongy and compact portions of the skull as well as isotropic vs anisotropic conductivity properties
- · overall, this paper offered a couple parameters to consider

# TABLE I. Conductivities of the reference volume conductor [Akhtari et al., 2002; Fuchs et al., 2007; Ramon et al., 2006]

Head tissue	Isotropic conductivity (S/m)		
Skin	0.43		
Compact bone	0.0064		
Spongy bone	0.02865		
Brain	0.33		

M. Dannhauer, B. Lanfer, C. H. Wolters, and T. R. Knösche, "Modeling of the human skull in EEG source analysis," *Human Brain Mapping*, vol. 32, no. 9, pp. 1383–1399, 2011, doi: 10.1002/hbm.21114.

#### Conclusions/action items:

I will use what I've learned here to inform my design matrix descriptions and justifications.



# 2025/09/25 - More Mechanical Properties of the Skull

ORLA RYAN - Sep 25, 2025, 11:54 AM CDT

Title: More Mechanical Properties of the Skull

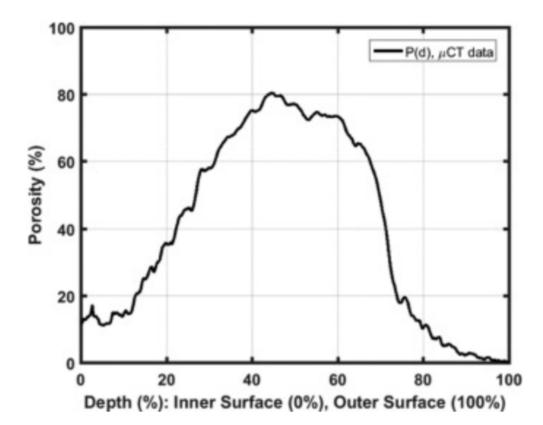
Date: 09/25/2025
Content by: Orla

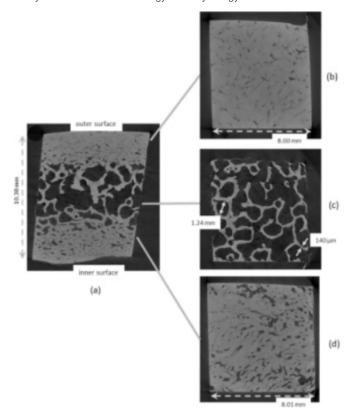
Present: n/a

Goals: I am getting more literary background surrounding the physiology and mechanical properties of the bones that make up the skull.

#### Content:

- This study focused on bone specimens from the frontal/parietal bones of adult human skulls
- The researchers distinguished between three layers: outer table, diploe, and inner table
  - · each layer has a different thickness and average porosity
  - the two bone types (frontal and parietal) had different makeups of these three layers
- Using micro-CT scans, they observed the porous structural arrangement
- for our purposes, we are less concerned with the mechanical loading that the skull bones can withstand; force will not be applied to our phantom
  - o instead, we will likely focus on the porosity of various skull layers
  - we may not be able to replicate the changing levels of porosity throughout the various layers (as shown in the two images below taken from the study), but could focus on recreating the LEAST porous layer (which would theoretically provide the most resistance to magnetic pulse), MOST porous layer (to apply the strongest magnetic pulse possible to the electrodes), or aim for somewhere in between





[1 S. L. Alexander, K. Rafaels, C. A. Gunnarsson, and T. Weerasooriya, "Structural analysis of the frontal and parietal bones of the human skull,"

] Journal of the Mechanical Behavior of Biomedical Materials, vol. 90, pp. 689–701, Feb. 2019, doi: 10.1016/j.jmbbm.2018.10.035.

#### Conclusions/action items:

I will touch base with my team on these findings, especially as we move into selecting materials and methods of fabrication.



# 2025/10/08 - Epilepsy Surgical approaches

ORLA RYAN - Oct 08, 2025, 7:35 AM CDT

Title: Epilepsy Surgical approaches

Date: 10/8/25

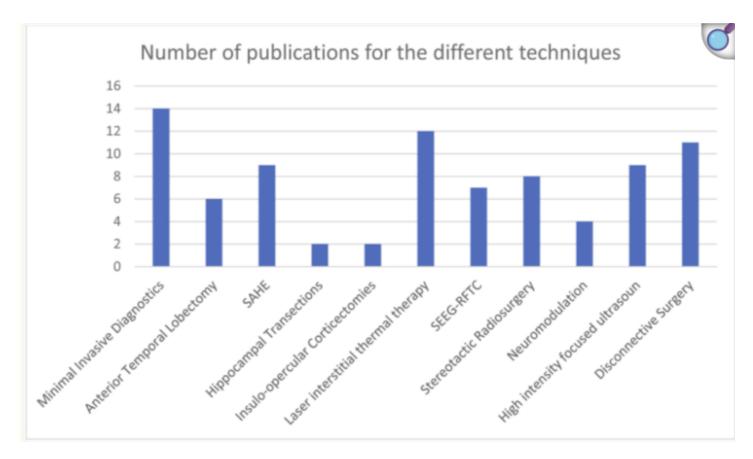
Content by: Orla Ryan

Present: n/a

Goals: Getting more background on the different approaches to epileptic surgery and seeing where brain mapping techniques might assist.

#### Content:

- quality standards in epilepsy surgery are VERY high
- · requires precise diagnostics to delineate the epileptogenic zone
  - also includes a patient-specific approach
- · Prioritizes minimal invasiveness
- Prevalent surgical approach is an anterior temporal lobectomy (targets temporal lobe epilepsy, which is the most prevalent form of drugresistant epilepsy)
  - some other types include selective amygdalohippocampectomy and corticoamygdalohippocampectomy
- · Laser techniques are utilized more frequently recently, as well as neuromodulation (delivering electrical energy to neural targets)



[1] F. Winter et al., "Current state of the art of traditional and minimal invasive epilepsy surgery approaches," Brain and Spine, vol. 4, p. 102755, Jan. 2024, doi: 10.1016/j.bas.2024.102755.

#### Conclusions/action items:

I will use this source to inform my preliminary report sections and better communicate with the client about his specific preferred approaches/needs.



# 2025/10/13 - Reporting Dielectric Values of Human Tissue

Title: Reporting Dielectric Values of Human Tissue

Date: 10/13/2025 Content by: Orla Present: n/a

Goals: Finding a table that displays literature values for permittivity in various human tissues.

#### Content:

- see the table added below!
- These values are used to compare permittivities of different skull material options (with the hope of finding the option closest to physiological values)

Tissue	Source	Permittivity
Skull (Cancellous)	Bone Cancellous	2.49E+2
Skull (Cortical)	Bone (Cortical)	1.45E+2

<sup>[1 &</sup>quot;Dielectric Properties » IT'IS Foundation." Accessed: Oct. 13, 2025. [Online]. Available: <a href="https://itis.swiss/virtual-population/tissue-properties/database/dielectric-properties/">https://itis.swiss/virtual-population/tissue-properties/database/dielectric-properties/</a>
Conclusions/action items:

I will use these values as a reference point for choosing base materials.



# 2025/09/13 - Notes from Iowa's Previous Study

ORLA RYAN - Sep 13, 2025, 6:22 PM CDT

Title: Notes from Iowa's Previous Study

Date: 09/13/2025

Content by: Orla Ryan

Present: n/a

Goals: I am combing through the study performed at Ulowa, which was shared with us by the client, to get inspiration for my team's approach.

#### Content:

During our client meeting with Dr. Ahmed on Friday, he referenced this study performed by researchers in Iowa that explored a very similar concept to what we will be tackling this year. The main difference he discussed was focusing on pediatric populations rather than adults. I will take notes below:

- TMS can modulate regional excitability in the brain, but understanding the physiological effects has been difficult with a lack of spatial or temporal resolution
  - this high resolution can come from iEEG electrodes (implanted in the brain or on its surface)
- the focus of the study was to start finding "reliable neural markers that signal TMS is effectively engaging and modifying a brain region or network "
  - · safety and efficacy
- the study's conclusion was that: "TMS-iEEG is a viable tool for studying the electrophysio logical effects of TMS on the human brain and that 2) TMS is capable of inducing responses both locally and in functionally connected downstream neuronal populations in humans"
- · Study methods:
  - o gel-based phantom to evaluate heating, displacement, and secondary currents
  - o intracranial electrodes placed within the gel and on the surface (mimicking human experimental conditions)
  - distance between the TMS coil and electrode contacts was 10mm, approximating the smallest possible distance between the coil and electrodes in human experiments
- · Materials:
  - o gel phantom with polyacrylic acid saline gel
  - 3/16-inch polymethyl methacrylate wall
  - electrodes included a 32-contact grid electrode and an 8-contact penetrating arrays
- additional:
  - o 22 human participants with iEEG received TMS
  - o no significant adverse effects
- proof-of-concept all together:
  - o physiological effects of TMS can be recorded
  - o some initial safety data in the phantom brain and human participants found in the article
- [1] J. B. Wang et al., "Effects of transcranial magnetic stimulation on the human brain recorded with intracranial electrocorticography," Mol Psychiatry, vol. 29, no. 5, pp. 1228–1240, May 2024, doi: 10.1038/s41380-024-02405-y.

#### Conclusions/action items:

I will reference this note in the future when discussing material choices, testing, and other project considerations with the team for our design this year.

ORLA RYAN - Sep 13, 2025, 5:56 PM CDT

www.histor.com/mp	Molecular Psychiatry
ARTICLE	R. Cont trustee
Effects of transcranial magnetic recorded with intracranial elec	stimulation on the human brain trocorticography
Jeffrey B. Wango <sup>1231</sup> , Umair Wassan <sup>23A,11</sup> , Jod E. Snue <sup>1,6</sup> , Hiro Philip E. Gander <sup>1,18</sup> , Wathew A. Woward W <sup>2</sup> , Corey J. Keller <sup>1</sup>	y uti Oye 🐧 finands D. Utermarki <sup>a</sup> , Nicholas T. Trapp <sup>er</sup> . 1 <sup>35(1)</sup> and Amon D. Boen <sup>©</sup> MARLIN <sup>(1)</sup>
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Iowa\_TMS-iEEG.pdf (2.36 MB)



# 2025/09/14 -TMS applications for children in the future

ORLA RYAN - Sep 14, 2025, 4:32 PM CDT

Title: TMS applications for children in the future

**Date:** 09/14/2025 **Content by:** Orla

Present: n/a

Goals: I am looking for referential information on TMS applications in a children population (and how it may move forward in the future/our device could propagate that change).

#### Content:

- once again, the efficiency of utilizing TMS is noted: "Its minimal risk, excellent tolerability and increasingly sophisticated ability to interrogate neurophysiology and plasticity make it an enviable technology for use in pediatric research with future extension into therapeutic trials"
  - use in children populations is only just emerging
- single and paired pulse methods are most common
  - pulses can also be paired with peripheral stimulation
- "When applied repetitively, TMS can also modulate cortical excitability."
- the magnetic field volume applied by TMS is small and decreases exponentially with distance... so tissues located centimeters from the application point are unaffected
- · possible adverse effects include headaches, scalp tenderness, and (very rarely), seizures

[1] T. Rajapakse and A. Kirton, "Non-invasive brain stimulation in children: applications and future directions," Transl Neurosci, vol. 4, no. 2, p. 10.2478/s13380-013-0116–3, June 2013, doi: 10.2478/s13380-013-0116-3.

#### Conclusions/action items:

It might be worth discussing with our client what the expected TMS protocol will be (i.e. what pulse pattern, range of intensities, and any other factors that may play into the application).

ORLA RYAN - Sep 28, 2025, 9:17 AM CDT

Title: iEEG Functioning

**Date:** 9/28/25

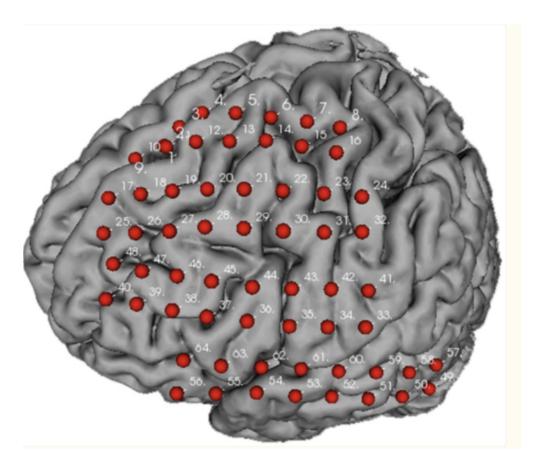
Content by: Orla

Present: n/a

Goals: To get a thorough description of how intracranial electroencephalography (iEEG) can be used by neurosurgeons.

#### Content:

- · before neurosurgery, which can be performed as treatment for patients with epilepsy, iEEG is often used to map out brain function
- The implanted electrodes provide crucial information for epileptogenic zone resection
  - These subdural/deep electrodes offer a frontal cortex activity view and can help pinpoint affected regions of the brain
- · These epileptogenic zones specify which regions of the brain are involved in generating seizures
  - the ultimate goal for neurosurgeons, then, is to remove these damaged/involved tissues without harming the normallyfunctioning or important parts of the brain



[1 Y. Wang, J. Yan, J. Wen, T. Yu, and X. Li, "An Intracranial Electroencephalography (iEEG) Brain Function Mapping Tool with an Application to Epilepsy Surgery Evaluation," *Front Neuroinform*, vol. 10, p. 15, Apr. 2016, doi: 10.3389/fninf.2016.00015.

#### Conclusions/action items:

I will update the preliminary presentation with this information and be prepared to discuss expectations with the client given my deeper understanding.

# 2025/10/08 - Children in Research Studies

ORLA RYAN - Oct 08, 2025, 7:28 AM CDT

Title: Children in Research Studies

Date: 10/8/2025

Content by: Orla Ryan

Present: n/a

Goals: To learn more about the limitations/challenges associated with research focused on child participants.

#### Content:

- there are a lot of complex ethical sensitivities that come up when focused on utilizing children and adolescents in human research
  - · ex: bioethics, informed consent, risk assessment
- to consider the rights of the children/adolescents themselves, it is necessary that proper consent is obtained from either the individuals or their guardians (due to the inherent vulnerability)
- it is important to continue striving for research involving children, as it is BEST SUITED to address their needs!
- · Researchers need to prioritize respect, benefit, and justice
  - · consider autonomy in decision making, the level of safety/risk associated with the type of research, and informed consent

[1] G. Askari, M. Vajdi, S. Jafari-Nasab, and S. Golpour-Hamedani, "Ethical guidelines for human research on children and adolescents: A narrative review study," J Res Med Sci, vol. 29, p. 53, Aug. 2024, doi: 10.4103/jrms.jrms 610 23.

#### Conclusions/action items:

I will use this information to better prepare our preliminary report; additionally, I will be mindful of these obstacles as we attempt to help the client with initial testing stages for a child-centered research problem.

ORLA RYAN - Nov 04, 2025, 8:13 PM CST

Title: TMS Phantom Model

Date: 11/4/2025

Content by: Orla

Present: n/a

Goals: Investigating another TMS phantom model that was created (for different circumstances) to see if they have any relevant resources.

#### Content:

- The lab I work at on campus, Pediatric Neuromodulation Lab (PNL), has recently purchased a TMS phantom model
  - they are hoping to use it for training purposes, as it is set up to show skill in finding motor hotspots
- "consists of a 3D printed head-shaped shell which encloses a cluster of 16 pairs of orthogonal sensing coils"
  - The sensing coils are oriented tangentially to the skull and are engineered to measure the intensity/direction of TMS pulses
- · Essentially, this phantom is purely focused on testing TMS operators' ability to accurately target hotspots with the TMS coil
  - a simulated EMG response is then displayed to show feedback
- · Little information was given on the assembly/fabrication of the phantom itself, but I will look into their cited sources for more input

[1 C. Finetto, C. Glusman, J. Doolittle, and M. S. George, "Presenting ERIK, the TMS phantom: A novel device for training and testing operators," ] *Brain Stimul*, vol. 12, no. 4, pp. 1095–1097, 2019, doi: 10.1016/j.brs.2019.04.015.

#### Conclusions/action items:

I can take a look at the physical phantom when it arrives at my lab. Additionally, I will look into the cited sources of this study to see if there are any helpful resources I can take advantage of.

#### 2025/09/20 - Brain Tissue Model Material

ORLA RYAN - Sep 21, 2025, 12:39 PM CDT

Title: Brain Tissue Model Material

**Date:** 09/20/2025 **Content by:** Orla

Present: n/a

Goals: I am doing some research on prior brain models to contribute to the team's design matrices.

#### Content:

- I found an article on the creation of a brain phantom for the purpose of measuring shifts during neurosurgery
  - the main focus was the mechanical properties, as a result
  - "The phantom, made of a composite hydrogel, was designed to reproduce the dynamic mechanical behaviour of the brain tissue in a range of strain rates suitable for surgical procedures"
- given how complex brain tissue is, the group proposed a "hybrid poro-hyper-viscoelastic material formulation"
- not all of these conclusions may be applicable for our purposes, as our intent is to focus on conductive/thermal properties (although displacement will also be a factor)
- the phantom they created was homogenous and made of the following materials:
  - o PVA, PHY, deionized water, and gelatin powder
  - · more detailed fabrication details can be found linked!

[1 A. E. Forte, S. Galvan, and D. Dini, "Models and tissue mimics for brain shift simulations," *Biomech Model Mechanobiol*, vol. 17, no. 1, pp. 249– ] 261, Feb. 2018, doi: 10.1007/s10237-017-0958-7.

#### Conclusions/action items:

I can reference this source when adding to the brain material design matrix; in constructing the entire model (skull and all), this may also be useful to come back to. Finally, there is a further source detailing the phantom material which I will link here to come back to: <u>A composite hydrogel for brain tissue phantoms - ScienceDirect.</u>

ORLA RYAN - Sep 20, 2025, 9:17 PM CDT



s10237-017-0958-7.pdf (2.36 MB)

ORLA RYAN - Sep 21, 2025, 9:59 PM CDT

Title: Skull Material tests

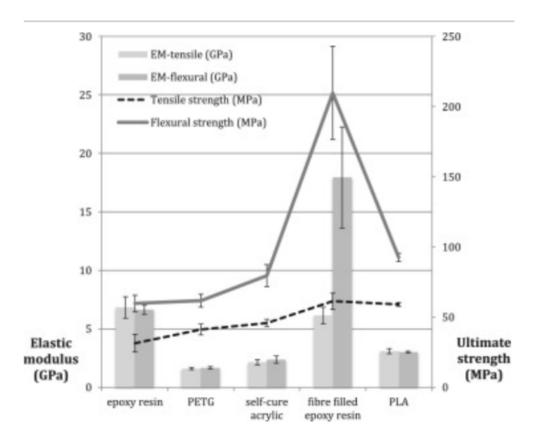
Date: 9/21/2025
Content by: Orla

Present: n/a

Goals: Find literature values for common polymers/materials to compare to that of brain skull tissue.

#### Content:

- · several materials were put in a universal testing machine to measure properties such as tensile/flexural elastic modulus and strength
- · resin was found to have similar values to that of the mean human skull reported in literature
- · previous skull models have used substances such as polyurethane, glass/epoxy resin, polycarbonate, and fiberboard
- the skull is anisotropic with different mechanical properties depending on the direction tangent to the skull surface
  - note: it is unlikely that we will be able to replicate this with such intense specificity, but hopefully we can find a suitable range of reported values to aim for
- this study compared PLA, PETG, 3D printing filament, and several resin examples
- for mechanical considerations, it seems that resin could be a suitable skull simulant for 'lower impact forces' (which is what applies to our scenario)



[1 L. Falland-Cheung, J. N. Waddell, K. Chun Li, D. Tong, and P. Brunton, "Investigation of the elastic modulus, tensile and flexural strength of five ] skull simulant materials for impact testing of a forensic skin/skull/brain model," *Journal of the Mechanical Behavior of Biomedical Materials*, vol. 68, pp. 303–307, Apr. 2017, doi: 10.1016/j.jmbbm.2017.02.023.

#### Conclusions/action items:

I will use what I learned from this source to inform my team moving forward in fabricating a realistic/suitable skull model for our phantom.



# 2025/09/25 - 3D Printing Guidelines from MakerSpace

ORLA RYAN - Sep 25, 2025, 11:58 AM CDT

Title: 3D Printing Guidelines from MakerSpace

Date: 09/25/2025
Content by: Orla

Present: n/a

Goals: I am trying to get an idea of what our options and limitations are for utilizing the 3D Makerspace printers.

#### Content:

- The Grainger Engineering Design Innovation Lab offers a basic guide to considerations for 3D printing
- Some of the main noted advantages/capabilities include:
  - · forming complex geometries
    - (ex: the human skull is not a perfect sphere, and requires some porosity... hence 3D printing will be a good option to recreate this shape)
  - o internal/organic geometries
  - o testing different models or tolerances, and scaling
    - relatively cheap as well (and quick to make), which are both positive aspects for prototyping
  - prints are notably 'porous' --> again, good for our purposes
- [1 "3D Print Guide," Grainger Engineering Design Innovation Lab. Accessed: Sept. 25, 2025. [Online]. Available: <a href="https://making.engr.wisc.edu/3d-printing-di-lab/">https://making.engr.wisc.edu/3d-printing-di-lab/</a>

#### Conclusions/action items:

In our search for material options, as well as our journey to narrow down final dimensions and other geometrical measures, the team will likely look to use the 3D printing space offered at UW-Madison quite often.



# 2025/09/27 - Water-Soluble Polymer/Blend Properties

ORLA RYAN - Sep 27, 2025, 5:39 PM CDT

Title: Water-Soluble Polymer/Blend Properties

Date: 9/27/25

Content by: Orla

Present: n/a

Goals: I am trying to get a better understanding of the various properties of water-soluble polymers.

#### Content:

This source gave a comprehensive guide of various synthetic polymers and their characteristics/mechanical properties. I mainly utilized figures such as that added below. Water-soluble polymers tend to have higher thermal conductivities than those that are not water-soluble. Additionally, this figure is helpful to see the properties of *crosslinked* PAA, as that is a likely method of fabrication we would use should we decide on PAA as the final material.

Table 1. Summary of Measurement Results: Thermal Conductivity ( $\Lambda$ ), Heat Capacity (C), Longitudinal Elastic Constant ( $C_{11}$ ), Transverse Elastic Constant ( $C_{44}$ ), Longditudinal Speed of Sound ( $V_I$ ), and Transverse Speed of Sound ( $V_I$ )

polymer	$\Lambda~(W~m^{-1}~K^{-1})$	$C  (MJ  m^{-3}  K^{-1})$	C <sub>11</sub> (GPa)	C <sub>44</sub> (GPa)	<i>V<sub>I</sub></i> (nm ps <sup>-1</sup> )	$V_T$ (nm ps <sup>-1</sup> )
PVA	0.31 ± 0.02	1.62 ± 0.15	13.0 ± 1.4	2.5 ± 0.2	3.21 ± 0.15	1.41 ± 0.05
PAA	0.37 ± 0.02	1.49 ± 0.15	17.0 ± 1.9	3.6 ± 0.1	3.74 ± 0.18	1.72 ± 0.05
PVP	0.27 ± 0.02	1.85 ± 0.16	12.6 ± 1.2	2.2 ± 0.1	3.18 ± 0.13	1.33 ± 0.05
PAM	0.38 ± 0.02	1.67 ± 0.16	24.5 ± 3.0	4.3 ± 0.2	4.34 ± 0.24	1.82 ± 0.06
PSS	0.38 ± 0.02	1.96 ± 0.17	15.7 ± 1.8	2.0 ± 0.1	3.64 ± 0.19	1.30 ± 0.05
MC	0.21 ± 0.01	2.20 ± 0.23	10.5 ± 1.3	1.9 ± 0.1	2.77 ± 0.16	1.15 ± 0.05
РММА	0.20 ± 0.01	1.65 ± 0.14	9.6 ± 0.9	2.0 ± 0.1	2.85 ± 0.12	1.30 ± 0.05
PAP	0.16 ± 0.01	1.67 ± 0.14	7.4 ± 0.7	1.8 ± 0.1	2.64 ± 0.10	1.30 ± 0.05
PAA (cross-linked)	0.28 ± 0.02	1.62 ± 0.24	11.9 ± 1.5	2.7 ± 0.1	3.45 ± 0.19	1.64 ± 0.06

<sup>[1</sup> X. Xie, D. Li, T.-H. Tsai, J. Liu, P. V. Braun, and D. G. Cahill, "Thermal Conductivity, Heat Capacity, and Elastic Constants of Water-Soluble Polymers and Polymer Blends," *Macromolecules*, vol. 49, no. 3, pp. 972–978, Feb. 2016, doi: <a href="https://doi.org/10.1021/acs.macromol.5b02477">10.1021/acs.macromol.5b02477</a>.

#### Conclusions/action items:

I will help finalize the design matrix and material choice before this week's presentation.

ORLA RYAN - Sep 27, 2025, 5:48 PM CDT

Title: Design Mechanisms/Applications of Degradable Hydrogels

Date: 9/27/25

Content by: Orla

Present: n/a

Goals: Understanding the degradation of hydrogels, especially the differen

#### Content:

- Physical hydrogels can experience the reversible gel—sol transition under the application of external stimuli, such as temperature, light intensity, electric fields, ionic groups, pH, and pressure
  - The most relevant for us to consider is likely temperature and pressure in this case
- Degradable hydrogels can be either synthetic or natural based
  - o synthetics are most resistant to degradation but can be bioincompatible
  - the derivation process for natural polymers that includes separation and purification negatively influence its mechanical features via the destruction of natural cross links
- · Overall, hydrogels can degrade along their backbone, at chain links, or along pendant chains
- · Another main form of degradation is hydrolytic:
  - "The hydrolytic degradation in the presence of water is realized by incorporating such groups along polymer chains or at
    crosslinking junctions. Various parameters, including the polymer's length, nature, chemical composition, pH, crosslinking
    density, and crystallinity, are prominent elements in controlling the rate of hydrolytic degradation"
- This will be important to consider in our fabrication process

[1 B. Hosseinzadeh and M. Ahmadi, "Degradable hydrogels: Design mechanisms and versatile applications," *Materials Today Sustainability*, vol. 23, p. 100468, Sept. 2023, doi: 10.1016/j.mtsust.2023.100468.

#### Conclusions/action items:

I will bring these items up as we move into the product ordering and overall fabrication phase of the design project.

ORLA RYAN - Sep 27, 2025, 5:55 PM CDT

Title: Hydrogel Overview

Date: 9/27/25

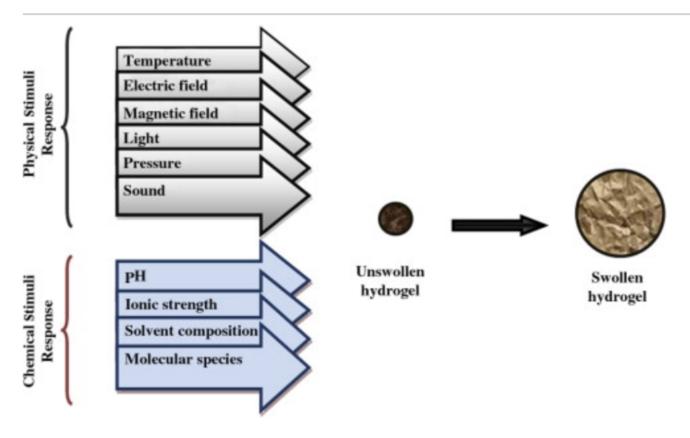
Content by: Orla

Present: n/a

Goals: I am finding a library of sources to reference as we start working with hydrogels.

#### Content:

- some key takeaways I took from this article are as follows:
  - dramatic changes in volume can occur in response to a variety of physical and chemical stimuli (as pictured below)



- I thought this was an important quote as well: "In general, hydrogels can be prepared from either synthetic polymers or natural polymers. The synthetic polymers are hydrophobic in nature and chemically stronger compared to natural polymers. Their mechanical strength results in slow degradation rate, but on the other hand, mechanical strength provides the durability as well"
  - Durability is more important for our purposes!
- Hydrogel preparation can be accomplished in a number of ways, and their applications are growing:
  - It appears that the process for forming natural polymers might take a lot of effort for our purposes

[1 E. M. Ahmed, "Hydrogel: Preparation, characterization, and applications: A review," *Journal of Advanced Research*, vol. 6, no. 2, pp. 105–121, Mar. ] 2015, doi: 10.1016/j.jare.2013.07.006.

#### Conclusions/action items:

I will also bring this information to my group when we next meet to decide on final materials.

Title: Thermal Conductivity Methods

Date: 10/24/2025 Content by: Orla Present: n/a

Goals: Looking into possible methods of measuring the thermal conductivity of our hydrogel prototype.

#### Content:

- I found this study that focused on phantom models for human tissue ('tissue-equivalent')
- The material they tested was polyacrylamide-based, slightly different from our agar gel, but still quite relevant (given that it was another hydrogel)
- more prior examples were given for testing electrical conductivity, but thermal properties have been less explored
  - "The thermal properties of a phantom are important because they determine the temperature rise that results from the absorption of energy deposited by an applicator."
- The set-up illustrated below (as well as the included equation), could help us to build our own protocol:

The thermal conductivity of the samples, k [W m<sup>-1</sup>°C<sup>-1</sup>], was calc following expression:

$$k = \frac{Qx}{A\Delta T}$$

where Q is the heat flow through the sample [W], x is the thickness of the direction of heat flow [m], A is the cross-sectional area of the sample is the steady state temperature drop across the sample [°C].

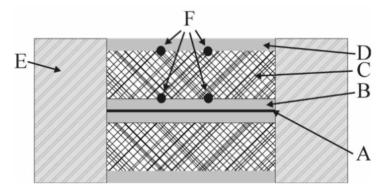


Figure 1. Schematic of the experimental set-up used to measure the thermal conductivity of polyacrylamide. A thin, flexible 5.1 × 5.1 cm heater (A) was placed between two steel plates (B), which in turn were sandwiched between two polyacrylamide samples (C) and another pair of steel plates (D). These components were surrounded on four sides by Styrofoam insulation (E). Two thermocouples (F) were placed on each side of one of the samples in the set-up.

I will present this method as an option to my team once we have completed fabrication of hydrogels with different agar/saline concentrations. Hopefully, this will provide us with a way to measure and tailor it to match brain literature values.



# 2025/11/13 - Hydrogels with Brain Tissue-like Properties

ORLA RYAN - Nov 13, 2025, 5:56 PM CST

Title: Hydrogels with Brain Tissue-like Properties

**Date:** 11/13/2025 **Content by:** Orla

Present: n/a

Goals: Delving into an article shared with the team by Dr. Dean on hydrogels specifically meant to model brain tissue.

#### Content:

- this article focused on surgical training/experimental research on brain tissues undergoing mechanical changes (such as traumatic brain injury)
- The team created a composite hydrogel out of a rigid "polysaccharides" network and a flexible "polyacrylamide" network
  - This hydrogel showed nonlinear mechanical behavior (like that of brain tissue) under various solution environments and strain rates
- Note: we are working on how to test the mechanical properties of our hydrogels to form the best possible prototype for our testing, so I
  hope to get some ideas from this study
- The brain shows complex mechanical behavior (depending on strain rate)
- It is possible that our agar-based gel may only achieve similar 'stress' levels, not imitating the nonlinear stress-strain curve; however, this is likely all that we would need (considering mechanical properties are not the most essential for us to emulate)
- · Their hydrogel was crosslinked
- Tests used: quasi-static uniaxial compression test (in different solution environments), with recordings of the change in cross-sectional area; high strain rate uniaxial dynamic compression test
  - o no mention of rheometer here

[1 J. Wang *et al.*, "Hydrogels with brain tissue-like mechanical properties in complex environments," *Materials & Design*, vol. 234, p. 112338, Oct. 2023, doi: 10.1016/j.matdes.2023.112338.

#### Conclusions/action items:

Considering the difficulties we have run into in exploring using a rheometer on campus, we may have to turn to alternate forms of mechanical testing. I can propose these ideas to the group.

# 2025/11/23 - Recap of Circuit Work

ORLA RYAN - Nov 23, 2025, 2:38 PM CST

Title: Recap of Circuit Work

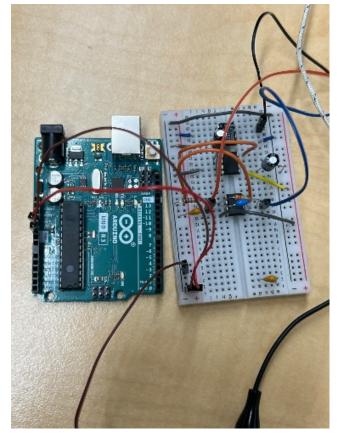
**Date:** 11/23/2025 **Content by:** Orla

Present: n/a

Goals: Providing a summary of the work I did yesterday on testing/refining our thermocouple circuit.

#### Content:

- we hope to use a thermocouple circuit (based upon one we built in BME 310)
- it has been giving us difficulty with achieving a proper read-out on the oscilloscope, so I came in yesterday to try and fiddle with it/get it working
- I changed out the resistors we were using (as in swapped them for newer/unused 1k and 330k ohm resistors, respectively)
  - tested using an independent thermocouple and showing the "rise time" output on an oscilloscope in room 1080 in ECB
- I achieved a consistent rising/falling with application of heat (holding the thermocouple)
- · Picture of the circuit:



#### Conclusions/action items:

The team will use this circuit (at least in part) to test the thermal conductivity of our hydrogels (both agar and gelatin).

ORLA RYAN - Dec 01, 2025, 9:07 AM CST

Title: Electrical Testing Research

Date: 12/1/2025
Content by: Orla

Present: n/a

**Goals:** Deciding a method through which to test hydrogel electrical conductivity next semester.

#### Content:

- there are several ways in which conductivity is usually measured, but we do not have access to the machinery required for all of them
  - four point probe method: requires a specific geometry (known distances between the four probes)/potentially a pre-made oscilloscope attachment which the teaching lab would not necessarily provide
    - there are also four-point probe resistance machines, but upon looking through available instrumentation throughout the College of Engineering, it does not appear that we would have access to one
  - conductivity meter: may require a specific conductivity cell (although this can be engineering, potentially)
  - Van der Pauw technique (similar to four-point probe)
- I think that the team's best option is to adapt these methods to be accessible for our purposes
  - use the power supply we have access to in the teaching lab, a digital multimeter, and probably construct our own case for hydrogels out of plastic or another simple material (drilling holes on either end to allow for electrode/wire insertion
- [1 "How is electrical conductivity measured? Electricity Magnetism." Accessed: Dec. 01, 2025. [Online]. Available: <a href="https://www.electricity-magnetism.org/how-is-electrical-conductivity-measured/">https://www.electricity-magnetism.org/how-is-electrical-conductivity-measured/</a>

#### Conclusions/action items:

I will write up a suitable protocol for use in the final deliverables that is accessible for the team.



# 2025/12/04 - Proposed Electrical Conductivity Testing Protocol

ORLA RYAN - Dec 04, 2025, 11:08 AM CST

Title: Proposed Electrical Conductivity Testing Protocol

**Date:** 12/4/25

Content by: Orla

Present: n/a

Goals: I am uploading my proposed protocol for next semester's electrical conductivity testing as well as the graphic I created for the final poster.

#### Content:

#### **Electrical Conductivity Testing Protocol**

#### Materials:

- · Keysight E3631A DC power supply
- · Two power cables
- · Jumper wires
- · Alligator clips
- Plastic box container (3 x 3 x 6 cm)
- Drill
- Digital multimeter with two test lead probes
- Fabricated gelatin gels of varying concentrations

#### Methods:

- 1. First, make the housing for the gels using the plastic container(s) and a drill. Drill a hole on each end of the length of the container to allow for later jumper wire and multimeter probe insertion.
- 2. After ensuring that all necessary power supply and measuring components are accessible, fabricate gels of desired concentrations and leave to set overnight at a temperature between 1°C to 4°C.
- 3. Collect the starting volumetric and mass measurements of gels to be tested.
- 4. Fit within the housing, ensuring there are no gaps.
- 5. Before turning on the DC power supply, connect the two power cables one to the positive power output and one to ground.
- 6. Connect the cable endpoints to alligator clips, then to two individual jumper wires.
- 7. Fit the jumper wires into either end of the gel casing, followed by the probes of the digital multimeter.
- 8. Begin by setting the DC power supply to output 1 V while keeping the current limit to 0. Then, slowly increase the current output to 1 A while monitoring on the digital multimeter.
- 9. Measure the voltage across the "resistor", or the gelatin housed within its casing.

#### Governing equations:

Resistivity ( $\rho$ ) = 1 / conductivity ( $\sigma$ )

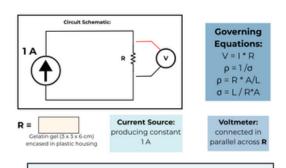
 $\rho = R * A/L$  (resistivity = resistance \* length / surface area)

 $\sigma = L / R*A$ 

#### Conclusions/action items:

Next semester, the team will complete more advanced testing including the protocol described above.

ORLA RYAN - Dec 04, 2025, 11:08 AM CST



#### Materials:

- Keysight E3631A DC power supply
- Two power cables
- · Jumper wires
- Alligator clips
- Plastic box container (3 x 3 x 6 cm)
- Drill
- · Digital multimeter with two test lead probes
- Fabricated gelatin gels of varying concentrations

**Planned Electrical Conductivity Testing** 

**Download** 

electrical\_conductivity\_1\_.png (135 kB)

# 2025/10/20 - Team Meeting Recap/Self Summary

ORLA RYAN - Oct 20, 2025, 3:03 PM CDT

Title: Team Meeting Recap/Self Summary

**Date:** 10/20/2025 **Content by:** Orla

Present: n/a

Goals: To go over the client meeting notes and familiarize myself with what I missed.

#### Content:

• This morning, the team had another meeting with the client, Dr. Ahmed, and alternate contact, Dr. Manattu. I was unable to attend this meeting due to lab, so am going over the meeting notes and rewriting them/noting any key takeaways for myself (to make sure I am up to date!)

#### Main topics discussed:

- · Age range/help modelling:
  - we will be focusing on the demographic of 5-7-year-old pediatric patients
    - "Younger kids", as this is the novel/newer aspect of the project
  - o Client will share at least 3 CT scans for a variety of ages within that range
    - Already segmented, can be used to model/print our final prototype
    - Will average the values of the scans shared with us (CONFIDENTIALITY is important)
- Funding/purchasing:
  - No specific answer from the client yet, unfortunately
  - o Dr. Ahmed will look back at our email (sent Friday) and "look into it"
- Preliminary report feedback:
  - Has not yet given it an in-depth read, but hopes to soon (specifically testing section)
  - · Clinical vs research usage -->
    - Research: patient sitting normally
    - Clinical: patient's head wrapped in a compressive dressing so that the TMS will not be DIRECTLY placed on the skull
  - Must also consider that TMS will physically be further from the brain due to the centimeters of dressing (intensity must be increased, but must be careful to avoid going too high and triggering seizures)
- · Contact method:
  - o Contact both Dr. Ahmed and Dr. Manattu (but did not offer any alternate contacts)
  - Double emailing is ok (although from past experience, it seems it will not be very effective)

#### Conclusions/action items:

We were able to get some more concrete guidelines around which to develop our prototype. However, we are still not sure how funding/purchasing will work going forward, especially given that we do not yet have a consistent, 'foolproof' communication method.



# 2025/09/11-Transcranial Magnetic Stimulation

CORISSA HUTMAKER - Sep 11, 2025, 8:37 PM CDT

**Title: Transcranial Magnetic Stimulation** 

Date: 9/11/25

Content by: Corissa Hutmaker

Present: NA

Goals: Learn about what TMS is in more basic terms

#### Content:

Link: https://www.mayoclinic.org/tests-procedures/transcranial-magnetic-stimulation/about/pac-20384625

- · magnetic fields sent through brain to stimulate nerve cells
- done noninvasively
- · can be used to treat depression, smoking addiction, and OCD when other things do not work
- · repetitive pulses sent through coil placed on the surface of the skull
- · activate areas of brain that have decreased activity during depression
- · deep TMS covers a wider area
- · how and why TMS works is not completely understood
- does not cause seizures or memory loss unlike electroshock therapy (the bell jar</3)
- · side effects are generally mild and lessen over time
  - · scalp discomfort
  - headache
  - o tingling, spasms, or twitching of facial muscles
  - lightheadedness
- possible side effects (rare)
  - o seizures (just said it didn't cause this?)
  - o mania in people with bipolar disorder
  - · hearing loss
- · 4-6 weeks of treatments 5 days a week
- may need repeat treatment

#### Conclusions/action items:

This treatment sounds kind of like an updated form of electroshock therapy. It will be interesting to learn more about how it works and how well it is understood from the perspective of other researchers.

CORISSA HUTMAKER - Sep 11, 2025, 9:33 PM CDT

Title: DLPFC and Depression: Understanding the Brain's Role in Mood Regulation

Date: 9/11/25

Content by: Corissa Hutmaker

Present: NA

Goals: See how depression impacts DLPFC in brain to better understand TMS treatment

#### Content:

Link: https://neurolaunch.com/dlpfc-depression/

- · DLPFC=dorsolateral prefrontal cortex
- · located in prefrontal cortex of the frontal lobe
- deals with memory, decision-making, and emotions
- communicate with other areas of the brain about emotional processing (ex. amygdala)
- regulating emotions is main job
- DLPFC have abnormalities in depressed people (structure and function)
- less activity in DLPFC is correlated with many symptoms of depression
  - o memory issues, reduced emotional control, overall reduced cognitive function
- DLPFC correlated closely with GABA and dopamine neurotransmitters
- potential for biomarkers in this region to know if people are at risk for depression and to treat accordingly
- · still need to consider other regions of the brain that are impacted by depression

#### Conclusions/action items:

It is clear why TMS targets this area of the brain for treatment. I would like to see if there is any information about the long-term impacts to the DLPFC region of the brain after TMS treatment (human or non-human subjects).



# 2025/09/18-Shift in electrocorticography electrode locations after surgical implantation in children

CORISSA HUTMAKER - Sep 18, 2025, 7:12 PM CDT

Title: Shift in electrocorticography electrode locations after surgical implantation in children

Date: 9/18/25

Content by: Corissa Hutmaker

Present: NA

Goals: Learn about the natural shifting that occurs with implanted electrodes

#### Content:

Link: https://www.sciencedirect.com/science/article/pii/S0920121120301339

Citation: S. T. Foldes, B. T. Munter, B. L. Appavu, J. F. Kerrigan, and P. D. Adelson, "Shift in electrocorticography electrode locations after surgical implantation in children," Epilepsy Research, vol. 167, p. 106410, Nov. 2020, doi: 10.1016/j.eplepsyres.2020.106410.

- · brain shift: tissue deformation after surgery
- · post-surgical brain shifts average 3 to 24 mm
- · shifting of electrodes makes imaging unreliable
- · need to account for shifting when placing electrodes
- 18 patients studied were pediatric with drug resistant localization related epilepsy
  - o ages 3 to 19
- · mainly focusing on electrodes placed on the surface of the dura
  - platinum-iridium alloy electrode disks
- implanted a few depth electrodes as well, but did not expect to see shifting like the surface ones
- measured shift by looking at changes in distance between electrodes compared to original implant measurement of 10 mm apart
- · compression offset: movement out from the center of the brain
- · shear offset: component tangential to compression offset
- shifting range was 0.01 to 17.0 mm
  - o avg 5.64 mm, std 3.27 mm
- · eTIV (intracranial volume) and grid/strip had most impact on shift
- · age was not a significant factor
- · more shift in parietal than frontal and temporal
- · compressive offset happened most by far
- similar adult study found average shift of 5.6 mm, std 1.9 mm and another 5.4 mm, std 1.6 mm
- · strips moved significantly less

#### Conclusions/action items:

There was no information given about if the implanted depth electrodes moved or not. Because they expected no significant shifting from the beginning, it seems reasonable to assume that was the case post-operation. If there had been a significant shift, it would have been addressed. I hope to find a straight answer in an article about safe amount of shifting for depth electrodes.

CORISSA HUTMAKER - Sep 18, 2025, 7:16 PM CDT





#### **Download**

Shift\_in\_electrocorticography\_electrode\_locations\_after\_surgical\_implantation\_in\_children.pdf (638 kB)



# 2025/09/25-Human Brain Temperature

CORISSA HUTMAKER - Sep 25, 2025, 3:03 PM CDT

Title: Human brains run hot — sometimes more than 40 °C

Date: 9/25/25

Content by: Corissa Hutmaker

Present: NA

Goals: Have an accurate brain temperature to add to the design matrices

#### Content:

Link: https://www.nature.com/articles/d41586-022-01654-7

Citation: "Human brains run hot — sometimes more than 40 °C," Nature. Accessed: Sept. 25, 2025. [Online]. Available: https://www.nature.com/articles/d41586-022-01654-7

- brains are warmer than average body temperature
- average brain temp 38.5 °C
- · temp varied by location in the brain, time of day, and sex
- · people with regular heating and cooling cycles in the brain had better chances of surviving a traumatic brain injury

#### Conclusions/action items:

The temperature of the brain that will be listed in future documents will be 38.5 °C unless other preferred data is presented. The hydrogel materials chosen should be able to withstand heating to this point if accurate studies will be done.

# 2025/10/10-Intrinsic Thermal Conductivity of Gelatin Estimated Independently of Heat Conduction Models

CORISSA HUTMAKER - Oct 10, 2025, 11:21 AM CDT

Title: Intrinsic Thermal Conductivity of Gelatin Estimated Independently of Heat Conduction Models

Date: 10/10/25

Content by: Corissa Hutmaker

Present: NA

Goals: Document hydrogel properties

Content:

Link: https://www.jstage.jst.go.jp/article/bbb1961/55/2/55\_2\_487/\_pdf

Citation: T. Sakiyama, S. Han, A. Torii, O. Miyawaki, and T. Yano, "Intrinsic Thermal Conductivity of Gelatin Estimated Independently," Journal of Agricultural and Biological Chemistry, vol. 55, no. 2, pp. 487–492, 1991, doi: 10.1080/00021369.1991.10870602.

- · used 1:1 water to gelatin powder ratio
- · Shotherm RTM-G5 for measurements
- 300 K/m temperature gradient
- intrinsic thermal conductivity of 0.28-0.30 W/mK when testing done at 20 degrees C
- · stays pretty consistent for higher and lower temperatures

#### Conclusions/action items:

This article provided the thermal conductivity of gelatin, which was needed for the design matrices.

CORISSA HUTMAKER - Oct 10, 2025, 11:21 AM CDT



#### Download

Gelatin\_thermalconductivity.pdf (386 kB)



# 2025/11/09-Average Weight 0f Brain in Different Age Groups

CORISSA HUTMAKER - Nov 09, 2025, 2:13 PM CST

Title: Average Weight of Brain in Different Age Groups

Date: 11/09/2025

Content by: Corissa Hutmaker

Present: N/A

Goals: Determine average brain size to properly scale box ckull phantom

#### Content:

Link: https://www.ijcmaas.com/images/archieve/IJCMAAS APRIL 2016 VOL10 ISS2 05.pdf

Citation: M. B. Prasanna, J. Cessy, and P. A. Nandagopalan, "Average Weight of Brain in Different Age Groups," *International Journal of Current Medical And Applied Sciences*, vol. 10, no. 2, pp. 62–64, Apr. 2016, [Online]. Available: https://www.ijcmaas.com/images/archieve/IJCMAAS APRIL 2016 VOL10 ISS2 05.pdf

- analyzed 104 male, female, and fetal brains
- average weight of adult male brain is 1268g
- · average weight of adult female brain is 1208g
- · average weight overall is 1238g
- · brain weight decreased with older age
- · Average weight of brain in different age groups

Age groups	Males (gms)	Females (gms)
Fetus	450	396
0-5	1100	1000
6-10	1283	1125
11-15	1350	1200
16-20	1440	1200
21-25	1460	1320
26-30	1402	1320
31-35	1345	1260
36-40	1250	1250
41-45	1230	1250
46-50	1230	1250
51-55	1200	1270
56-60	1150	1175
61-65	1030	1100

- · a japanese study found the average to be a bit higher
  - 1397g for males
  - o 1229g for females

#### Conclusions/action items:

This article provided average weights of brains throughout various decades of life. Volume is slightly more valuable, but this is a good place to start.

CORISSA HUTMAKER - Nov 09, 2025, 1:50 PM CST







# Download

AverageWeightOfBrainInDifferentAgeGroups.pdf (189 kB)

#### 2025/11/09-Early Brain Growth and Development

CORISSA HUTMAKER - No

Title: Early Brain Growth and Development

Date: 11/9/2025

Content by: Corissa Hutmaker

Present: N/A

Goals: Get an idea of how the 5 year old brain compares to adult brain size to find volume for skull box phantom

#### Content:

Link: https://www.childrenslifetime.org/early-brain-growth-and-development #: -: text = By%205%20 years%20 of %20 age, with %20 the %20 brain%20 and %20 head.

Citation: "Early Brain Growth and Development," Children's Lifetime. Accessed: Nov. 07, 2025. [Online]. Available: https://www.childrenslifetime.org/early-brain-growth-and-development#:~:text=By%205%20years%20of%20age,with%20the%20brain%20and%20head.

- · brain at birth is about 25% of adult size
- lots of growth and learning happen in first 5 years of life
- brain at 5 years old is about 92% of adult size
- head is big because brain grows at much faster rate than the rest of the body



#### Conclusions/action items:

This will be a good guideline for determining how large to make the skull box phantom. It has proven to be difficult to find data on the volume of child brains. Using this information, the volume of other literature can be multiplied by 92% to get an approximate size for the 5 year old model we plan to make.

CORISSA HUTMAKER - Nov 09, 2025, 2:10 PM CST



Download

EarlyBrainGrowthAndDevelopment.pdf (2.83 MB)

# 2025/12/3-Measurement of Ex Vivo Liver, Brain and Pancreas Thermal Properties as Function of Temperature

CORISSA HUTMAKER - Dec 03, 2025, 12:37 PM CST

Title: Measurement of Ex Vivo Liver, Brain and Pancreas Thermal Properties as Function of Temperature

**Date:** 12/3/25

Content by: Corissa Hutmaker

Present: NA

Goals: Document thermal properties of brain tissue

#### Content:

Link: https://www.mdpi.com/1424-8220/21/12/4236#:~:text=3.3.,the%20model%20for%20brain%20tissue.

Citation: A. Mohammadi, L. Bianchi, S. Asadi, and P. Saccomandi, "Measurement of Ex Vivo Liver, Brain and Pancreas Thermal Properties as Function of Temperature," Sensors, vol. 21, no. 12, June 2021, doi: 10.3390/s21124236.

• finding values for cancer research with increase in thermal ablation techniques for treatment

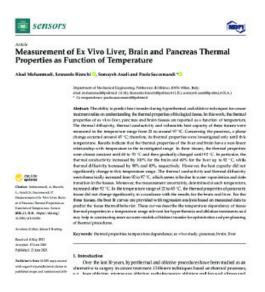
$$\rho C \frac{\partial T}{\partial t} = \nabla (k \nabla T) + Q_s + Q_b + Q_{met}$$

- · equation for heat transfer in tissues
- could solve for k (thermal conductivity)
- properties can be temp dependent
  - not as much in brain
- · using ex vivo calf brains
- · tested in temp range of 20 to 100 deg C
- · tissues have constant temp after a period of time
  - · approximately 1.5 hrs in this study
- at 33 deg C,  $k = 0.536 \pm 0.065 \text{ W/(m·K)}$ 
  - increased at 60 and 97 deg C tests
  - o other temps not really needed because body temp is not that high

#### Conclusions/action items:

The thermal conductivities are useful to compare to during testing. The values ex vivo will not be exactly the same but will serve a similar purpose.

CORISSA HUTMAKER - Dec 03, 2025, 12:37 PM CST





## **Download**

MeasurementExVivoBrainThermalProperties.pdf (2.15 MB)



## 2025/09/11-Effects of TMS on Human Brain Recorded with iEEG

CORISSA HUTMAKER - Sep 11, 2025, 8:08 PM CDT

Title: Effects of transcranial magnetic stimulation on the human brain recorded with intracranial electrocorticography

**Date:** 9/11/25

Content by: Corissa Hutmaker

Present: NA

Goals: Learn more about the scope of this project

Content:

#### Intro

- · TMS=transcranial magnetic stimulation
  - "noninvasive technique for modulating the regional excitability of the human brain"
  - · used for treatment of depression, smoking addiction, migraines, and OCD
  - cannot fully understand impact of TMS by using surface electrodes
- · need to use iEEG to understand how TMS impacts brain locally and in other connected brain regions

#### Testing

- · Gel-based brain phantom
  - o studying electrode heating, displacement, and induction of secondary currents
  - phantom made from polyacrylic acid saline gel in 8 inch container with 3/16 inch polymethyl methacrylate wall
- · 22 neurosurgical patients with epilepsy
  - had implantation surgery
  - monitored for 14 days after surgery
  - 0.5 Hz pulses sent via TMS to dIPFC
    - sent same pulse to different brain areas in a couple patients as well to study effects on different areas of the hrain
- · processed with matlab
- · 10 uV threshold for TMS response

#### Results and discussion

- phantom
  - o no significant electrode heating or displacement
  - o voltage drops in electrodes happen exponentially for electrode distance from coil
  - o charge density still much lower than safety threshold even at max power
  - · no extra stimulation with iEEG
- humans
  - o no adverse events that do not already typically occur from TMS
  - $\circ~$  2-4 stimulation sites per patient, 0.5 Hz
- not sure if TMS is effective for depression and treating necessary regions
- · sample size too small

### Conclusions/action items:

The phantom in this article seemed to address the areas given in the project statement. The team will have to consult the client to see what changes will be made to the phantom we make and what the desired results are.

CORISSA HUTMAKER - Sep 11, 2025, 8:09 PM CDT

www.netue.con/ep	Molecular Psychiatry
ARTICLE	R.Onthomas



## **Download**

Effects\_of\_transcranial\_magnetic\_stimulation\_on\_the\_human\_brain\_recorded\_with\_intracranial\_electrocorticography.pdf (2.36 MB)

## 2025/09/18-Head phantoms for bioelectromagnetic applications: a material study

CORISSA HUTMAKER - Sep 18, 2025, 8:08 PM CDT

Title: Head phantoms for bioelectromagnetic applications: a material study

Date: 9/18/25

Content by: Corissa Hutmaker

Present: NA

Goals: Learn about which material type to choose for the phantom

#### Content:

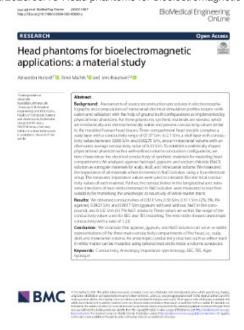
Link: https://pmc.ncbi.nlm.nih.gov/articles/PMC7685571/

Citation: A. Hunold, R. Machts, and J. Haueisen, "Head phantoms for bioelectromagnetic applications: a material study.," Biomed Eng Online, vol. 19, no. 1, p. 87, Nov. 2020, doi: 10.1186/s12938-020-00830-y.

- · conductivity for intracranial volume is 0.33 S/m
- · material in this study is supposed to be structurally sound enough to implant electrodes
- 0.17% NaCl solution
  - o conductivity of 0.301 S/m
  - o 21.04 degrees C
  - using calculations that better accommodate for temp changes, conductivity is 0.332 S/m
  - worked for frequencies of 0.1 Hz-100 kHz
- · 2 wt% agar hydrogel in 17% NaCl solution
  - o conductivity of 0.284 S/m
  - o adjusted conductivity is 0.314 S/m
- · 3 wt% agar hydrogel
  - o conductivity is 0.272 S/m
  - o adjusted conductivity 0.302 S/m
- · 4 wt% agar hydrogel
  - o conductivity is 0.281 S/m
  - o adjusted conductivity 0.311 S/m
- all agar materials consistent for 0.1 Hz-100 kHz frequency range
- gypsum
  - o conductivity increased for frequencies above 1 kHz (only considered up to this point)
  - o conductivity of 0.0017 S/m
  - · all rounds very low compared to desired brain tissue conductivity
  - · should not consider
- · conductivity anisotropy
  - · consistent for frequencies
  - · conductivity in longitudinal direction was 0.32 S/m
  - conductivity in transverse direction was 0.12 S/m
  - 1:2.7 ratio
- 2 wt% agarose in NaCl 17% solution probably best for this application
- conclusion suggests coating gypsum with agar to get a hollow compartment that will not impact the conductivity of the agar and to mimic the scalp layer

#### Conclusions/action items:

These materials will be good to keep in mind as they are generally pretty available. More research about other materials that could potentially be easier is still necessary.



## Download

Head\_phantoms\_for\_bioelectromagnetic\_applications\_a\_material\_study.pdf (1.37 MB)

## 2025/12/1-Safety of intracranial electrodes in an MRI environment: a technical report

CORISSA HUTMAKER - Dec 02, 2025, 11:49 PM CST

Title: Safety of intracranial electrodes in an MRI environment: a technical report

Date: 12/1/25

Content by: Corissa Hutmaker

Present: NA

Goals: Document typical behavior of intracranial electrodes when in electric field environment such as MRI

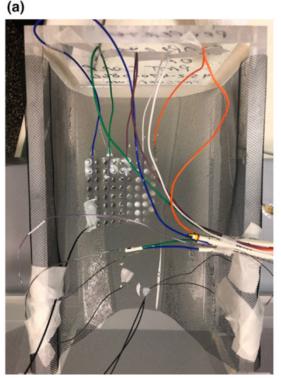
#### Content:

Link: https://pmc.ncbi.nlm.nih.gov/articles/PMC11569409/

Citation: Y. B. Bezchlibnyk, R. Quiles, J. Barber, B. Osa, K. Clifford, and R. Murtaugh, "Safety of intracranial electrodes in an MRI environment: a technical report.," Journal of Medical Radiation Sciences, vol. 71, no. 3, pp. 461–473, Sept. 2024, doi: 10.1002/jmrs.775.

- · iEEG for localizing seizure onset zone
- · testing safety of iEEG with 3.0 Tesla MRI for better visualization of electrodes
- · used surface and depth electrodes
- · phantom of human adult head and torso
- · did testing for displacement, torque, and heating
  - displacement
    - looking for ferromagnetic activity
    - ASTM F2052-15 'Standard Test Method for Measurement of Magnetically Induced Displacement Force on Medical Devices in the Magnetic Resonance Environment'
  - torque
    - ASTM F2213-17 'Standard Test Method for Measurement of Magnetically Induced Torque on Medical Devices in the Magnetic Resonance Environment'
  - heating
    - radiofrequency-induced heating
    - ASTM F2182-11 'Standard Test Method for Measurement of Radio Frequency Induced Heating On or Near Passive Implants During Magnetic Resonance Imaging'
    - used gel composition of distilled water (99.499%), Carbomer 980 (0.498%), and magnesium nitrate (0.003%) which had conductivity of 0.47 S/m and a specific heat capacity of 4160 J/(kg°C) at 21°C
    - took continuous temp measurements with fluoroptic thermometer
    - measured individually and all at once

(b)





- artifacts
  - ASTM F2119-07 'Standard Test Method for Evaluation of MR Image Artifacts from Passive Implants'
- · results
  - minimal displacement. deflection angle was in acceptable range
  - o no rotation occurred
  - o all temp changes were less than 2 deg C
- all results were in safe ranges declared before testing began
- · study did not include human or animal subjects
- 15 minute scan times
- · different manufacturers for MRI machines could produce different results
- secure all electrode components before testing

### Conclusions/action items:

Some of the testing procedures used in this article could be useful for next semester. We can look further into some of the standard test methods used, especially for heating and displacement.

CORISSA HUTMAKER - Dec 02, 2025, 11:50 PM CST



**Download** 

SafetyofIntracranialElectrodesinanMRIEnvironment.pdf (4.02 MB)

CORISSA HUTMAKER - Dec 03, 2025, 12:45 PM CST

Title: SDS Pages for Gelatin

Date: 12/3/25

Content by: Corissa Hutmaker

Present: NA

Goals: Save the SDS page used for initial research as well as the SDS for the gelatin ordered

Content:

See attached.

Note: ATP document is the one used for initial design matrices and preliminary report. Sigma-Aldrich is the gelatin the team ordered and plans to use.

#### Conclusions/action items:

Gelatin will be used for testing against agar and may be used for the final prototype.

CORISSA HUTMAKER - Dec 03, 2025, 12:46 PM CST



## **Download**

#### Gelatin-Rousselot-SDS.pdf (474 kB)

CORISSA HUTMAKER - Dec 03, 2025, 12:46 PM CST



The life science business of Merck KGaA, barmstadt, Germany operates as PHI i poreSigna in the US and Canada

SIGMA

## **Download**

## g1890.pdf (158 kB)

CORISSA HUTMAKER - Dec 03, 2025, 12:51 PM CST

Title: Agar SDS Pages

Date: 12/3/25

Content by: Corissa Hutmaker

Present: NA

Goals: Document agar SDS pages used in initial research and for prototyping

Content:

See attached.

Note: TM Media page was for design matrices and Thermo Fisher was used for prototyping.

#### Conclusions/action items:

The information in the SDS pages will be considered when making the final prototype.

CORISSA HUTMAKER - Dec 03, 2025, 12:51 PM CST



## **Download**

## Agar\_powder\_MTR\_AGHS\_EN.pdf (38.1 kB)

CORISSA HUTMAKER - Dec 03, 2025, 12:51 PM CST



SECTION 4- PRIST AID MEASURES

By Cladiact, Clark for and remote any constitutions in trimediately flut begin with investigation and in for at least 100 minutes, seeping eye that upon Cold work may be used. On our time any appropriate Contract that it is sufficiently and in fact that are contracted to the contract that the contract th

#### SECTIONS: FIRE FIGHTING MEASURES

### **Download**

MSDS-1201.pdf (435 kB)

CORISSA HUTMAKER - Sep 26, 2025, 12:27 PM CDT

**Title: BPAG Meeting** 

Date: 9/26/25

Content by: Corissa Hutmaker

Present: all bpags

Goals: learn about purchasing information

#### Content:

- have the client buy it for you/go through their funding people
  - have approval for the purchases from them still
- put all original receipts in notebook
- · keep track of expenses on spreadsheet
- if funding is through UW, supposed to use shopUW
- · try to avoid personal payment and getting refunded
  - o if personal payment needs to happen, it should be BPAG paying
- BMEDesign account \$50 from Makerspace
- · client can setup account through UW funding chain at makerspace
- stuff at team lab is now free (screws and bolts and stuff)
- · if getting reimbursed, need to start it before the poster session
  - need the invoice with name, date, amount, etc.
  - o can take multiple weeks
- · very against reimbursement
- use accounting template
  - o put in notebook, progress reports, and final report
- · contact dr p with questions before purchasing
- if funding is lost, there is a thing on the website to ask for funding from the department

### Conclusions/action items:

Do not purchase stuff yourself to avoid reimbursements because the funding people do not like it and make sure to organize all spending.

CORISSA HUTMAKER - Dec 01, 2025, 2:05 PM CST

**Title: Proof of Trainings** 

Date: 12/1/25

Content by: Corissa Hutmaker

Present: NA

Goals: Document completed trainings

Content:

See attached.

## Conclusions/action items:

The required trainings have been completed up to this point and are attached.

CORISSA HUTMAKER - Dec 01, 2025, 2:05 PM CST



## **Download**

## GraingerTrainings\_CorissaHutmaker.pdf (109 kB)

CORISSA HUTMAKER - Dec 01, 2025, 2:05 PM CST



## **Download**

BMECertifications\_CorissaHutmaker.pdf (250 kB)



## 2025/9/16: Basic principles of TMS and rTMS

HELENE SCHROEDER - Sep 16, 2025, 12:44 PM CDT

Title: Basic principles of transcranial magnetic stimulation (TMS) and repetitive TMS (rTMS)

Date: 9/16/2025

Content by: Helene Schroeder

Present: N/A

Goals: To learn more about how TMS works to better understand what we need our phantom to mimic.

Link: https://doi.org/10.1016/j.rehab.2015.05.005

#### Citation:

W. Klomjai, R. Katz, and A. Lackmy-Vallée, "Basic principles of transcranial magnetic stimulation (TMS) and repetitive TMS (rTMS)," Annals of Physical and Rehabilitation Medicine, vol. 58, no. 4, pp. 208–213, Sep. 2015, doi: https://doi.org/10.1016/j.rehab.2015.05.005.

#### Content:

#### Abstract

- · TMS and rTMS
  - · indirect and noninvasive
  - · induce excitability changes in the motor cortex
  - · via wire coil generating a magnetic field passing through the scalp
- · rTMS thought to induce plasticity
- · potential therapy for neurological and psychiatric diseases
- physiological mechanisms causing the effects of TMS and rTMS are not well understood
- · goal of review is to summarize known facts about TMS and rTMS

#### Introduction

- · single-pulse TMS is mostly used
- · rTMS is used to induce changes in brain activity
- · TMS of motor cortex causes a twitch in the target muscle, causing motor-evoked potential (MEP) on electromyography
- · main knowledge is from animal studies and in vitro experiments on hippocampal slices

#### Animal experiments

- · skull removed to expose the brain
- · implanted electrodes to record discharges from subcortical fibers and fibers of pyramidal decussation
- response was found to be spaced from 1-2 ms

#### First experiments in humans

- 1980, transcranial electrical stimulation
- · concious humans
- · through scalp
- · 2 electrodes
  - arm motor area
  - · 4 cm above first electrode
- electrodes connected to high-capacity condenser charged up to 2000 V
- · twitch in arm muscles
- · TES was uncomfortale and painful
- · main current contracted scalp muscles and induced pain
- proposed to change TES to TMS
- 1990

## Variability of TMS-induced responses

- · depends on physical and biological parameters
  - o magnetic pulse waveform
  - · shape and orientation of coil
  - intensity
  - · frequency and pattern of stimulation
  - o orientation of current lines
  - o excitable neural elements
- TMS can be monophasic or biphasic
- · lots of different types of coils
  - circcular
  - o figure eight
  - double-cone
  - o air-cooled
  - o etc.

#### Conclusion

- · effects of TMS and rTMS differ and have different protocols
- calibrated paradigms need to be defined to be reproducible
- · variability lies within clinical trials

#### Conclusions/action items:

This article was decently helpful at helping me understand how TMS works. I don't really need to focus on rTMS since that doesn't apply to the project, but the information about TMS was helpful. It seems like there is a lot of uncertainty surrounding TMS and its long term effects, which aligns with what I know about TMS.

Next I will do research into iEEG to understand that more. After that, I will try to see if there are any other articles about combining iEEG and TMS that isn't the article our client provided us with.



## 2025/9/17: TMS in the Treatment of Neurological Diseases

HELENE SCHROEDER - Sep 17, 2025, 1:32 PM CDT

Title: TMS in the Treatment of Neurological Diseases

Date: 9/17/2025

Content by: Helene Schroeder

Present: N/A

Goals: To learn more about TMS and its use for treating epilepsy (and other neurological diseases)

Link: https://pmc.ncbi.nlm.nih.gov/articles/PMC9163300/

#### Citation:

F. A. Somaa, T. A. de Graaf, and A. T. Sack, "Transcranial Magnetic Stimulation in the Treatment of Neurological Diseases," Frontiers in Neurology, vol. 13, May 2022, doi: https://doi.org/10.3389/fneur.2022.793253.

#### Content:

#### Abstract

- · TMs has widespread use in research and clinical applications
- psychiatric applications
  - depression
  - OCD
  - more
- · rTMS for neurorehabilitation after motor stroke
- this article reviews clinical evidence for rTMS in pioneering neurological applications including alzheimer's, epilepsy, multiple sclerosis, and conciousness disorders

#### Introduction

- · TMS is non-invasive, safe, and painless
- · activates/modulates cortical targets in CNS
- based on Faraday's law of electromagnetic induction using coils and perpendicular magnetic fields to reach the brain to generate an electric field and currents
- induces TMS-induced action potentials that can be measured with EEG and/or MEP (motor evoked potentials) and/or fMRI (functional MRI)
- · effects of rTMS depend on parameters and coil geometry
- · low frequency rTMS decreases excitability
- · many types of coils and pulses
- there are few rTMS protocols

#### TMS in Epilepsy

- main treatment for epilepsy is antiepileptic drugs (AEDs)
- 1/3 of patients on AEDs develop a resistance though
- · many of these patients are not suitable for surgical ablation
- these patients may respond to LF-TMS though
- · rTMS could reduce risk of seizures due to its ability to cause prolonged inhibitory effect on synaptic potential and focal cortical excitability
- · TMS also used to study effects of AEDs on the brain
- in patients who ARE candidates for surgical ablation, TMS helps to identify the brain areas that are more seizure prone
- · TMS can also help identify areas of cortical excitability
- a review of 7 pilot studies showed that TMS was used in patients who were AED resistant
  - o defnition of resistance varied between studies
- meta-analysis of 11 studies evaluated effectiveness of LF-rTMS in medically intractable epilepsy
  - found that there is significant effect size in seizure frequency

- seizure reduction was higher in patients with neocortical epilepsy or cortical dysplasia than those with epileptic disorders
- patients with temporal seize focus had favorable response than those with extratemporal epilepsy
- stimulation with figure-8 coil had more favorable response
- seizure reduction rates were higher in patients under 21 years
- also higher reduction rates in patients treated with targeted stimulation vs. without
- · gaps and challenges
  - no recommentation for therapeutic use of TMS in epilepy yet
  - some reviews have found rTMS to be safe and effective in reducing epileptiform discharges BUT had no clear evidence of the efficacy of rTMS in reducing seizure frequency
  - currently too much variability in TMS techniques used in studies, outcomes reported, and definition of drug-resistant enilensy
- · TMS may induce seizures in patients with a known neurological disorder

#### Conclusions/action items:

I only read the sections of this article that specifically mentioned epilepsy. This article talked about a lot of different neurological conditions that do not apply to our project, which is why I did not focus on those. This article has told me a lot about TMS treatment for epilepsy. Specifically, there is a lot of uncertainty for its use to treat epilepsy, and the results can be very varied depending on what type of epilepsy someone has and their treatment protocol. In the future I think I may try to find more information regarding iEEG or TMS treatment in children, which is what our phantom aims to mimic.

# 2025/10/6: Natural and Synthetic Polymers for Biomedical and Environmental Applications

HELENE SCHROEDER - Oct 06, 2025, 6:43 PM CDT

Title: Natural and Synthetic Polymers for Biomedical and Environmental Applications

Date: 10/6/2025

Content by: Helene Schroeder

Present: N/A

Goals: To learn mroe about hydrogels that are used in biomedical applications to help determine which material we should use for our project.

Link: https://pmc.ncbi.nlm.nih.gov/articles/PMC11055061/

#### Citation:

[1]G. Satchanska, S. Davidova, and P. D. Petrov, "Natural and Synthetic Polymers for Biomedical and Environmental Applications," Polymers, vol. 16, no. 8, pp. 1159–1159, Apr. 2024, doi: https://doi.org/10.3390/polym16081159.

#### Content:

#### Abstract:

- · natural and synthetic polymers are very versatile for making biomaterials
- natural polymers
  - o organic
  - · found in nature
  - most common: polysaccharides (alginate, hylauronic acid, starch) and proteins (collagen, silk, fibrin) and bacterial polyesters
  - used for drug delivery, tissue engineering, stem cell morphogenesis, wound healing, regenerative medicine, food packaging, etc.
- synthetic polymers
  - PLA, PAA, PVA, PEG, etc. are biocompatible and biodegradable
  - drug release systems, nano-carriers, tissue engineering, dispersion of bacterial biofilms, gene delivery systems, bio-ink, textiles in medicine, agriculture, heavy metals removal, food packaging

#### Introduction

- · natural polymers are similar to ECM components and can be used to avoid chronic immune response and toxicity
- · cellulose and chitin play role in maintaining structural integrity of cells in plants and animals
- lysozymes protect against the surrounding environment
- using natural materials is favorable since they are in natural abundance, renewable, and have a lower carbon footprint
- · natural polymers are also used to support life and allow organisms to adjust to their surroundings
- · natural polymers from marine resources are becoming more popular due to abundance and biologically active
  - o crustaceans, seaweeds, algae
  - o agar, chitin/chitosan, alginate
  - o biocompatible, biodegradable, biologically active
  - · issues with solubility in water
- · synthetic polymers are polymers produced in labs (aka manufactured polymers)
- synthetic are thermoplatic and thermoset ploymers and elastomers
  - PE, PS, PA, PVA, PTFE, PI, phenol formaldehyde resins, etc.
- · backbone is made of carbon-carbon bonds and have monomers
- · initiators and catalysts are used to inititate the chemical rxns between monomers

### Natural polymers

 hydrogels: 3D networks formed by hydrophylic polymers through chemical crosslinking (covalent or ionic bonds) or physical crosslinking (hydrogen bonds, van der waals forces, physical entanglement)

- alginate, starch, cellulose derivatives, chitosan, gelatin, collagen, HA, pectin, etc.
- good degradability, biocompatibility, nontoxic degradation products, good flexibility similar to tissue, natural abundance
- natural hydrogel polymers are promising alternatives for the ECM in biomedical applications
  - biodegradability
  - biocompatibility
  - · mechanical property tunability
  - biomimicry
  - responsiveness
- advantages:
  - bioactive
  - biocompatible
  - 3D geometry
  - antigenicity
  - non-toxic byproducts of biodegradation
  - o intrinsic structural resemblance
- · disadvantages:
  - · microbial contamination (endotoxins)
  - · decreased tunability
  - immogenic response
  - · uncontrollable rate of degradation
  - poor mechanical strength

### Synthetic polymers

- · highly engineerable
- chemical composition, functional group type, extent of functionalization, molecular weight, charge density, distribution, degradation, and stability can be tailored
- good for antiviral, antibacterial, antifungal, antitumor uses
- · wide range of mechanical properties
- · good biocompatibility
- · degradation rate is easily manipulated
- durable
- · porous
- · can lead to reduced cell adhesion and scaffold integration
  - · mitigated by adding stimuli and growth factors
- block copolymer micelles (BCMs) are nanocarriers of various low-molar-mass therapeutic substances and biomacromolecules intended to treat numerous diseases
- "ynthetic polymers offer several advantages over natural ECMs, including more tunable stiffness, cell ligand density, and other
  biochemical properties. However, these synthetic materials are biologically inactive and thus must be functionalized with cell adhesion
  peptide domains to encourage cell adhesion and crosslinked to form biodegradable bonds for cell remodeling of the ECM."
- strength, flexibility, degradation rate, resistivity, and chemical inertness can be tuned
- advantages;
  - tunable properties
  - · endless forms
  - established structures over natural polymers
  - polymerization, interlinkage, functionality of molecular weight, structure, and physical and chemical features make them easily synthesized
- · disadvantages:
  - · lack cell adhesion sites
  - o require chemical modification to enhance cell adhesion

#### Conclusions/action items:

This article was very helpful in helping me understand the differences between natural and synthetic polymers that are used in biomedical applications like scaffolds. Each have their own advantages and disadvantages, which should be considered when we choose a material for our phantom. Synthetic materials are highly tunable, but natural materials are widely available and closely resemble the natural ECM which can be useful when creating scaffolds.





## 2025/9/10: Effects of transcranial magnetic stimulation on the human brain recorded with intracranial electrocorticography

HELENE SCHROEDER - Sep 10, 2025, 8:30 PM CDT

Title: Effects of transcranial magnetic stimulation on the human brain recorded with intracranial electrocorticography

Date: 9/10/2025

Content by: Helene Schroeder

Present: N/A

Goals: To read the relevant materials recommended to us by our client to gain knowledge and create questions for our first client meeting.

Link: https://www.nature.com/articles/s41380-024-02405-y

#### Citation:

J. B. Wang et al., "Effects of transcranial magnetic stimulation on the human brain recorded with intracranial electrocorticography," Molecular psychiatry, Feb. 2024, doi: https://doi.org/10.1038/s41380-024-02405-y.

#### Content:

#### Abstract

- · transcranial magnetic stimulation (TMS): noninvasive technique for neuromodulation
  - o not well understood (the problem)
- intracranial electrocorticography (iEEG)
- using a gel-based phantom
- performed TMS-iEEG in 22 neurosurgical patients
- evaluated intracranial responses to single pulses of TMS to dorsolateral prefrontal cortex (dIPFC)
- TMS is capable of inducing evoked potentials in dIPFC and downstream regions (anterior cingulate and insular cortex)
- · findings show that TMS-iEEG is safe and can be used to examine effects of TMS

### Introduction

- TMS is noninvasive technique for modulating regional excitability of human brain
- FDA cleared for depression, smoking cessation, migraines, OCD (and trials for more)
- also used experimentally to probe neural circuitry in brain
- . TMS in animals has been studied and understood, but in humans it has not be studied extensively
  - · limiation is lack of high spatial/temporal resolution
- neural activity measured with high spatiotemporal resolution with iEEG
- iEEG studies have not been used with TMS before
  - studies with it could help to understand how TMS affects the brain
- study uses gel-based phantom to investigate safety of applying TMS while recording iEEG
- study then had experiment with 10 patients to look at the local and downstream electrophysiological effects of single pulses of TMS applied to dIPFC
- findings
- 1. TMS-iEEG is a viable tool for studying the electrophysiological effects of TMS on the human brain
- 2. TMS is capable of inducing responses both locally and in functionally connected downstream neuronal populations in humans

### Methods

- · gel-based phantom
- evaluating
  - electrodes heating
  - · electrode displacement
  - · induction of secondary electric currents
- delivered TMS to phantom with electrodes placed within the gel and on the surface to mimic human conditions
- distance from TMS coil to electrode contacts: 10 mm (smallest distance/largest amplitude possible between coil and iEEG electrodes)

- TMS has to cross skin, skull, and cerebrospinal fluid space before it reaches the electrodes
- 100% machine output at 10-40 Hz
- TMS equipment
  - MagVenture MagPro X100 230V
  - · 8 liquid cooled Cool-B65 A/P coil
  - stimulation pulse: biphasic sinusoidal with pulse width of 290 microseconds (except for experiment for measuring displacement: monophasic)
- phantom
  - · filled with polyacrylic acid saline gel
  - o placed in 8-inch cubic container with 3/16th inch polymethyl methacylate (PMMA) wall
  - american society for testing and materials standards section F2182
  - o more details on measurement of parameters in Fig 1 and supplementary materials
- · subjects
  - 22 neurosurgical patients with medically intractable epilepsy in safety analysis
  - 10 patients received 50 pulses of 0.5 Hz TMS applied to dIPFC
  - admitted to U of Iowa hosp. for monitoring (14 days)
- paper also details recording and processing of TMS (see section for more details)

#### Results

- · TMS is safe with iEEG in vitro
  - o no significant heating of electrodes
  - · no electrode displacement
  - · induced voltage drops
- TMS-iEEG is safe in humans
- · TMS-evoked potentials observed with TMS-iEEG were specific to active TMS
- · local response of TMS applied to dIPFC
- · TMS induces network level brain responses that include the ACC and insular cortex

#### Conclusions/action items:

This article was recommended to us by our client to read for background information, as the phantom these researchers made is similar to what our project will entail. I have learned more about TMS and iEEG and how the effects of TMS are not understood in humans, which is why a phantom is needed in order to evaluate its safety. This study explored if electrodes increased in temperature or moved around, which would be dangerous to the patient. The results concluded that TMS-iEEG were in fact safe for human use.

## 2025/9/17: Brain-mimicking phantom for biomechanical validation of motion sensitive MRI

HELENE SCHROEDER - Sep 20, 2025, 5:03 PM CDT

Title: Brain-mimicking phantom for biomechanical validation of motion sensitive MR imaging techniques

Date: 9/20/2025

Content by: Helene Schroeder

Present: N/A

Goals: To learn about other brain phantoms that have been created.

Link: https://www.sciencedirect.com/science/article/abs/pii/S1751616121003556?via%3Dihub

#### Citation:

Efe Ozakaya *et al.*, "Brain-mimicking phantom for biomechanical validation of motion sensitive MR imaging techniques," vol. 122, pp. 104680-104680, Oct. 2021, doi: https://doi.org/10.1016/j.jmbbm.2021.104680.

#### Content:

#### Abstract

- · MRI allow for noninvasive evaluation of tissues by using different excitation schemes
- · cardiac pulsation or respiration
- · diagnostic value
- magnetic resonance elastography (MRE)
- this study designed a novel phantom test setup that enables both low and high frequency responses of a brain-mimicking phantom to be capture
  - allows for aMRI and MRE imaging to be used on the same phantom
- · 2 different vibration sources
  - pneumatic actuator for low frequency/intrinsic motion (1 Hz)
  - peizoelectric actuator for high frequency (30-60 Hz)
- results show that in MRE experiments performed from 30-60 Hz, propagating shear waves attenuate faster at higher driving frequencies

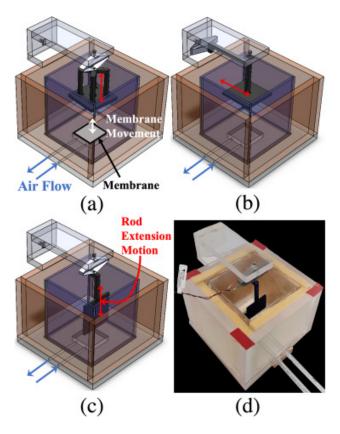
#### Intro

- · mechanical characterization of soft tissues non invasively has become widespread thanks to MRE
- MRE
  - · external mechanical vibration source is driven in sync with MRI by utilizing motion encoding gradients (MEGs)
  - · used as a diagnostic tool to measure stiffness of the brain to relate stiffness variation to diseases like MS and alzheimer's
  - o also to detect tumors or study post-mortem changes in brain tissue
- · cushioning caused by skull, meninges, and cerebrospinal fluid (CSF) cause wave scattering and attenuation
- new way to probe the mechanics of the brain has emerged
- · cardiac-induced physiological vibrations
- cerebral peduncle is main vibration source
- · possibility of elastrography at low frequency actuation to be investigated
- recent increase of interest in studying low vs high frequency performance of MRE through phantom experiments
- · soft tissues are viscoelastic, exhibit frequency dependent mechanical behavior
- · study mimics cardiac induced motion through inflating and deflating a flexible membrane and visualize it using aMRE
- . on the same phantom, mimic effect of external vibration source positioning and its coupling with the tissue mimicking phantom via MRE

#### Methods/materials

- phantom
  - o setup dimensions chosen based on MR head coil size
  - 15.2x15.2 cm<sup>2</sup> square base piece with 3.8x3.8 cm<sup>2</sup> square cavity in the center (depth of 0.76 cm) and four outer side pieces (13.97 cm x 10.166 cm) cut from thick clear acrylic sheet

- · square cavity covered with a flexible membrane to be used as low frequency actuation when air is pumped into it
- allow air flow with an inlet and outlet hole (diameter =0.3cm)
- o plastic tubing to serve as air passages



^phantom test set up

#### Conclusions/action items:

In this study, researchers made a tissue mimicking phantom test set up that can be used with aMRI and MRE. The results of this study was that the phantom worked to mimic brain biomechanics.

This article was helpful in giving me a sense as to what other brain phantoms can look like, but was limited as it didn't really talk about the actual brain phantoms itself much. This phantom is a square shape, which is good for initial testing purposes, but ours will aim to mimic the shape of the brain as well (not just the volume).



# 9/30/2025: Utilisation of 3D Printing in the Manufacturing of an Anthropomorphic Paediatric Head Phantom for the Optimisation of Scanning Parameters in CT

HELENE SCHROEDER - Sep 30, 2025, 10:52 PM CDT

Title: Utilisation of 3D Printing in the Manufacturing of an Anthropomorphic Paediatric Head Phantom for the Optimisation of Scanning Parameters in

Date: 9/30/2025

Content by: Helene

Present: N/A

Goals: To learn more about a pediatric phantom that was created using 3D printing.

Link: https://www.mdpi.com/2075-4418/13/2/328

#### Citation:

[1] Merim Jusufbegović et al., "Utilisation of 3D Printing in the Manufacturing of an Anthropomorphic Paediatric Head Phantom for the Optimisation of Scanning Parameters in CT," Diagnostics, vol. 13, no. 2, pp. 328–328, Jan. 2023, doi: https://doi.org/10.3390/diagnostics13020328.

#### Content:

#### Abstract

- computed tomography (CT) is diagnostic process using ionizing radiation to obtain info about the interior anatomic structure of the human body
- · exposes patients to radiation leading to stochastic effects
- because of this, optimizing imaging protocols is important (to reduce radiation exposure)
- this paper assembled a 3d printed infant head phantom and matched its image quality parameters with those obtained for a
  commercially available adult head phantom using the imaging protocol dedicated for adults
- an optimized scanning protocol was designed which resulted in dose reductions for pediatric patients while keeping image quality at adequate levels

#### Introduction

- · CT is very commonly used
- · typically has very good image quality and are fast!
- · increasing demand for CT leads to increase in patients exposure to radiation and is therefore a public health issue
- particular concern for pediatric patients who have an increased risk of stochastic effects due to higher radiation sensitivity of developing organs and tissues, as well as having a longer life expectancy
- imaging parameters must be tailored/maintained to keep radiation doses as low as possible without comprimising the image guality
- optimization process as a radiation protection principle in medical uses of ionizing radiation
- one approach of optimization process is to create a phantom
- phantom should mimic the size, anatomy, and tissue density of the body part of consideration
- "anthropomorphic"
  - replicate anatomical structures of the body and emulate different tissues' attenuation of x-rays
- · there are many phantoms in use but many researchers like to use their own anthropomorphic phantoms using CAD and 3D printing
- · 3D printers are accessible and versatile
- generally expected that materials are tissue equivalent (or as close as possible)
- soft tissues can be mimicked using PMMA and resins (and some 3D printed materials)
- · cortical bone mimicked using gypsum and other dense materials
- this study describes the process of making an anthropomorphic phantom of an infant patient's head that simulates various tissue densities
- phantom was used to optimize CT scanning parameters in the protocol for scanning infant's heads
- aim of the study is to analyze and determine whether a novel age-based CT head imaging protocol, calibrated using a 3D-printed anthropomorphic phantom can be used in clinical practice without comprimising image quality

- testing carried out at Emergency Medicine Clinic of the Sarajevo University Clinical Center (KCUS)
- phantom printed at the Faculty of Mechanical Engineering of Sarajevo University
- this is in hosnia
- adult head phantoms and an adult head protocol were used as reference image quality parameters
- evaluated the subjective image quality for an unoptimized and optimized scanning protocol
- · adult phantom
  - ATOM Max
  - composed of materials that have similar attentuation properties of normal tissue
  - "Brain tissue (average) consists of carbon (53.60%), oxygen (26.49%), hydrogen (8.16%), nitrogen (1.53%), magnesium (9.98%), and chlorine (0.19%). Cortical bone includes calcium (22.91%), as well as carbon (25.37%), oxygen (35.28%), hydrogen (3.30%), nitrogen (0.91%), magnesium (3.36%), chlorine (0.03%), and phosphorus (8.82%). The density of the two materials are 1.07 g/cm3 and 1.91 g/cm3 for brain and cortical bone tissue, respectively."
  - o dimensions: 18x22.3x27 cm
  - mass: 6.4 kg
  - limited use for pediatrics
- · pediatric phantom
  - · CT imaging data sets (DICOM) were used for generating patient-specific 3D models of anatomical structures of the head
  - o phantom was printed as a casting mold and filled with gypsum plaster and epoxy resin
  - 3D slicer software used to create 3D model from the 2D DICOM image
  - · model exported as STL file
  - 3D printed with Grey V4 material for high-resoluation rapid prototyping
  - Grey V4:
    - "Standard" group of Formlabs resins
    - intended for the SLA (stereolithography) printing of strong and precise concept models and prototypes with precise details
    - matte finish
    - opaque appearance
  - o resin and hardener (including epoxy resin) used to fill in the brain and other soft tissue
  - plaster turns into gypsum and becomes bone-like and is good for mimicking bone tissue in imaging phantoms

#### Discussion/Conclusion

- · pediatrics are more at risk for getting cancer after radiation exposure comapred to adults
- · phantom they made was used to create an optimized protocol for imaging pedatric heads using CT
- optimized meaning reduction in patient doses of ionising radiation without comprimising diagnostic information
- · their phantom lacked structural complexity, so contrast analysis studies couldn't be performed
- the epoxy resin used in the manufacturin gprocess and human brain matter do not have the same HU values (attenuation), so the phantom couldn't be used in radiotherapy
- phantom will provide data for calculations of ionizing radiation dose and its biological effects in investigations of radiation protection for patients

#### Conclusions/action items:

This article was super informative and helpful at telling me about another pediatric brain phantom that was created. This will help me with creating my slide in the presentation regarding competing designs. This phantom was created to test if the protocol for doing CT scans of kid's brains could be optimized, meaning less dangerous due to radiation exposure. The phantom was 3D printed by taking DICOM images and turning them into 3D part files to be printed. The skull was 3D printed with Grey V4 resin made by Formlabs. The brain/soft tissue was made with epoxy resin. Plaster was also used for the skull to mimic bone tissue. In the end, they found that the phantom was useful in creating an optimized protocol for pediatric CT scanning to limit radiation exposure.



## 2025/9/21 - Properties of Polymers for Design Matrix

LILLY MACKENZIE - Sep 21, 2025, 2:21 PM CDT

Title: Properties of Formlabs Resins for Design Matrix

Date: 9/21/2025
Content by: Lilly

Present: All

Goals: Determine properties (mechanical, electrical, reactivity) of relevant polymers for ranking in design matrix

#### Content:

- I found the following datasheets for some of our potential skull materials that would be available to 3D print on the UW Makerspace Formlabs printers.
- In order to characterize their electrical conductivity I looked at their bulk constituents (poly(acrylate) for BioMed and poly(urethane methacrylate) for standard clear) and then we found electrical conductivity for those -- those values will be linked in Orla's section of the notebook.
- The rest of the values were taken straight from the datasheets. The metric used for mechanical properties was flexural modulus, as this was most easily found when characterizing the mechanical properties of cranial bone

#### Conclusions/action items:

Use values and specs found in these datasheets to inform our material choices

LILLY MACKENZIE - Sep 21, 2025, 2:22 PM CDT

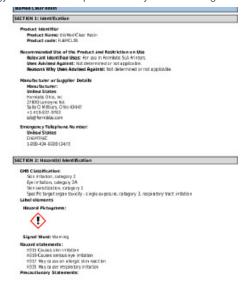


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Formlabs\_Biomed\_Datasheet.pdf (595 kB)

LILLY MACKENZIE - Sep 21, 2025, 2:22 PM CDT





**Download** 

## Formlabs\_Biomed\_Safety\_Sheet.pdf (148 kB)

LILLY MACKENZIE - Sep 21, 2025, 2:22 PM CDT

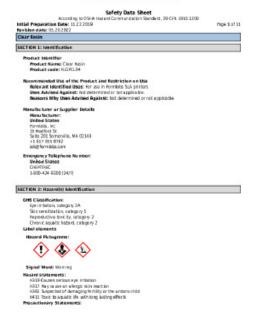


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## Formlabs\_Clear\_Datasheet.pdf (996 kB)

LILLY MACKENZIE - Sep 21, 2025, 2:22 PM CDT





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Formlabs\_Clear\_Safety\_Sheet.pdf (158 kB)

## 2025/9/21 - PAA Hydrogel Research

Goals: Get a better idea about which type of PAA hydrogel we would likely use

LILLY MACKENZIE - Sep 21, 2025, 3:08 PM CDT

Title:	
Date:	
Content by:	
Present:	

#### Content:

- The team had some difficulty rating our hydrogel options because of the vast number of possibilities within each category. We aimed to
  approach the brain tissue material as a result of literature review, and determine our options based off of the compositions of each
  hydrogel that former papers used.
- I will look at papers creating brain phantoms with each of the four hydrogel options, and narrow down the compositions (% crosslinker, potential addition of other constituents) to rank in the design matrix

#### Paper:

- This paper was meant as a testing framework to TBI data -- using PLA skulls and PAA hydrogel brains to determine the risk/impact of certain brain traumas and their connection to TBIs
- The paper categorizes several formulas of PAA based on acrylamide weight % (wt%) and crosslinker ratio, as well as samples that were heated or that used linear acrylamide

#### Data:

- Storage modulus (slope of the loading curve) trends:
  - For 15:1 PAA to crosslinker ratio, the storage modulus decreases with decreasing acrylamide wt%
  - o for 60:1 PAA to crosslinker ratio, the storage modulus also decreases with decreasing acrylamide wt%
  - the 5 wt% acrylamide gel had the lowest storage modulus, and both 60:1 gels were between the 5 wt% and 7 wt% 15:1 gels
- Loss modulus (slope of the unloading curve) trends:
  - o mostly similar trends, except now the 60:1 7 wt% has the lowest modulus, and the 15:1 5 wt% is between both 60:1 gels
- · Hydrogel swelling trends
  - the hydrogel swelled increasing amounts within decreasing crosslinker density; the 60:1 gel swelled the most while the 15:1 gel swelled the least.
- · Light absorbance trends
  - the hydrogels with the most crosslinking absorbed the most light
  - this test was done on six hydrogels: 2 heated at 15:1 ratio and 5 and 10 wt%, and four unheated: 7 wt% and 10 wt% at 15:1 and 60:1 ratios
  - the 15:1 hydrogels both absorbed the most light, with the 10 wt% absorbing the most of the two, followed by the heated 10 wt% and the heated 5 wt%, and finally the 60:1 in both wt % conditions were around the same

#### Conclusions/action items:

Additional research into the NaCl/conductivity management of these hydrogels should be done to determine the exact mixture. We can meet with our advisor to figure out the feasibility of doing multiple copolymers in the hydrogel -- cost, properties, other complications etc.

Source:

## 2025/9/21 - Pediatric Brain Stiffness

LILLY MACKENZIE - Sep 21, 2025, 3:50 PM CDT

Title: Pediatric Brain Stiffness Research

Date: 9/21/2025
Content by: Lilly

Present:

Goals: Find a reference value for pediatric brain tissue stiffness, potentially for patients w epilepsy (f there is variance)

#### Content:

- This study looked at patients with epilepsy (median age 12 years old), median onset of seizures at 2 years old
- broad range of physiological origins (not sure if that phrasing is correct) for the epilepsy --> paper uses the phrase "epileptogenic substrate"
  - tumors
  - o cortical disorganization
  - infarction
  - · tuberous sclerosis complex
  - · Rasmussen's Encephalitis
- there was also a broad range of brain locations that were tested based on the patient's epilepy's origin
- provides a PRESSURE, not elastic modulus, value --> nonlinear relationship that generally correlates higher pressure to higher Young's modulus

#### Data:

- looking at all brain regions and separating solely based on dysplastic/non dysplastic brain tissue, the range of pressure varied greatly across and within patients, from around 5 mmHg to 100 mmHg
- when separated based on hystiopathic diagnosis (values in mmHq):
  - o normal/gliosis ranged from 4-60 mmHg, mean around 4
  - FCD type 1 ranged from 25-60, mean of 48
  - FCD type 2/Tuber ranged from 60-85, mean of 67
  - other ranged from 30 to 80m mean of 63
- The table below categorizes the pressures based on a variety of variables. Considering we are working with a broad range of patients (theoretically), we can discuss with clients about the parameters/variables we should consider, but perhaps severity of histopathology could be a good one

 Table 2.

 Brain elasticity measures by covariates. T-test performed for dichotomized variables. ANOVA test performed when variables had more than 2 categories.

Independent variable	Mean (SD) mm Hg		Mean (SD) mm Hg		p value
Age of seizure onset (dichotomized)	< 2y 36.0 (35.0)		≥ 2y 49.8 (30.0)		< 0.001**
Duration of seizures (dichotomized)	<7y 42.3 (32.3)		≥7y 44.6 (34.5)		0.110**
No. of AEDs (dichotomized)	< 2 50.0 ( 31.9)		≥242.3(33.3)		0.230
Age at surgery (dichotomized)	< 12y 40.7 ( 33.7)		≥ 12y 46.3 (32.3)		0.211
Gender	Female 41.8 (32.2)		Male 44.5 (34.0)		0.517
Prior Craniotomy	No 41.0 (32.6)		Yes 56.0 (33.7)		0.011**
Side of Brain	Left 43.2 (33.7)		Right 43.3 (32.8)		0.976
Lobe	Frontal 47.6 (35.1)	Temporal 39.7 (30.6)	Parietal 40.6 (31.4)	Occipital 25.3 (40.6)	0.238
Post invasive EEG implant (grid, strip or depth)	No 40.7 (33.1)		Yes 56.0 (30.5)		0.007**
MRI	No Lesion 30.6 (33.0)		Lesion 54.5 (31.9)		0.058**
FDG-PET	Isometabolic 41.8 (33.2)		Hypometabolic 48.1 (3)	2.9)	0.615
Diagnosis	Non-dysplastic 40.3 (32.2)		Dysplastic 44.5 (33.6)		0.610
Pathology	Normal/Gliosis 26.4 (32.4)	CD 142.3 (34.8)	CD II/Tuber 69.7 (16.0)	) Other 50.6 (34.9)	0.009**
Pathology (dichotomized)	Less affected 23.6 (31.4)		More affected 63.9 (23.	1)	0.034**
Histopathological Severity	Mild 23.8 (31.3)	Moderate 67.7 (17.5)	Severe 73.0 (13.8)		< 0.001**

<sup>\*</sup>For continuous variables, the cut-point was set at the median value.

#### Conclusions/action items:

share these values with the group, make comparisons in metric units for the brain stiffness, discuss with client what regions would be most relevant Citation: A. Fallah *et al.*, "Novel tonometer device distinguishes brain stiffness in epilepsy surgery," *Sci Rep*, vol. 10, p. 20978, Dec. 2020, doi: 10.1038/s41598-020-77888-0.

<sup>\*\*</sup>Statistically significant association with brain clasticity on univariate analysis. These variables were used for the multi-variate analysis.

## 2025/9/21 - Brain stiffness using MRE

LILLY MACKENZIE - Sep 21, 2025, 4:04 PM CDT

Title: Measurements of brain tissue stiffness using magnetic resonance elastrography (MRE)

Date: 9/21/2025
Content by: Lilly

Present:

Goals: Find a number of values (review paper) for brain tissue stiffness using

### Content:

- MRE is a technique of tissue stiffness characterization....
- The paper gathered the following information:

Table 3. MRE results for GBT in healthy participants.

Author	N	Inversion	f in Hz	Shear stiffness (kPa)	Loss tangent (rad)
Dittmann et al (2015)	8	MDEV	10, 15, 20	0.62 ± 0.08	0.09 ± 0.17
			10, 20, 30, 40, 50	1.38 ± 0.20	0.24 ± 0.10
Fehlner et al (2016)	33	MDEV	30, 35, 40, 45,		
			50, 55, 60	1.62 ± 0.18	0.61 ± 0.04
Hatt et al (2015)	9	DI	30	1.03 ± 0.09	0.70 ± 0.21
Sack et al (2009)	55	MF-SP	50	1.69 ± 0.26	0.38 ± 0.06
Wuerfel et al (2010)*	34	MF-SP	50	1.82 ± 0.22	0.38 ± 0.08
Streitberger ct al (2010)*	25	MF-SP	50	2.30 ± 0.30	0.47 ± 0.12
Sack et al (2011)	66	MF-SP	50	2.52 ± 0.32	0.47 ± 0.07
Lipp et al (2013) <sup>a</sup>	18	DI	50	2.05 ± 0.19	0.26 ± 0.04
Murphy et al (2013b)	10	DI	60	2.99 ± 0.02	n/a
Arani et al (2015)	45	DI	60	2.59 ± 0.10	n/a
Huston <i>et al</i> ( <u>2015</u> )*	9	DI	60	2.76 ± 0.08	n/a
Fattahi et al (2015)"	21	DI	60	2.55 ± 0.11	n/a
Murphy et al (2016)*	32	DI	60	2.51 ± 0.09	n/a

Note. Values show mean  $\pm$  standard deviation (SD). <sup>8</sup>Control data from clinical studies. n/a - not available. Published values can be found in table 1 of appendix 2 in the supplementary material.

- · where GBT stands for global brain tissue
- the ranges displayed show 0.62-2.99 kPa stifness depending on the frequency of the MRE measurements stiffness increases with frequency , about 0.4kPa per 10 Hz increase
- the paper also evaluated based on grey matter vs white matter -- in our case, since grey matter is the most external portion of the brain, it may make sense to use this value as our goal

Table 4. MRE studies investigating grey matter (GM) and white matter (WM) in healthy participants.

Author 1		Approach	ich fin Hz	GM		WM	
				Shear stiffness (kPa)	Loss tangent (rad)	Shear stiffness (kPa)	Loss tangent (rad)
Braun et al ( <u>2014</u> )	5	MDEV	30, 40, 50, 60	0.98 ± 0.25	0.95 ± 0.03	1.16 ± 0.29	1.03 ± 0.04
Johnson <i>et al</i> (2013a)	3	NLI	50	2.01 ± 0.08	0.37 ± 0.18	2.86 ± 0.13	0.46 ± 0.15
Johnson et al (2013b)	7	NLI	50	2.41 ± 0.19	0.48 ± 0.17	3.30 ± 0.35	0.52 ± 0.20
Clayton et al (2012)	5	LFE	60	3.77 ± 0.50	0.50 ± 0.27	4.16 ± 0.17	0.54 ± 0.08
McCracken et al (2005)	6	DI	80	5.30 ± 1.30	n/a	10.70 ± 1.40	n/a
Zhang et al (2011)	8	DI	80	2.72 ± 0.22	0.44 ± 0.14	2.85 ± 0.36	0.47 ± 0.28
Green <i>et al</i> (2008)	5	DI	90	4.48 ± 0.31	0.68 ± 0.10	4.24 ± 0.31	0.75 ± 0.10
Kruse et al (2008)	25	LFE	100	5.22 ± 1.15	n/a	13.60 ± 3.19	n/a

Note. Values show mean  $\pm$  standard deviation (SD). n/a = not available. Published values for each study can be found in table  $\ge$  of appendix 2 in the supplementary material.

- only one study found grey matter to be stiffer than white matter. The range of stiffness goes from 0.98 to 5.3 kPa here, and again depends on frequency
  - I'm not sure what frequency we should be looking at as a reference
- Finally, the reveiw paper looked at brain stiffness by region -- again, I'm not sure what region we should be focusing on

Table 5. MRE studies investigating brain regions in healthy participants.

Study author	Murphy et al (2013b)	Huston et al (2015)	Arani et al (2015)	Murphy et al (2016)
N	10	9	45	32
Mean age	23-55	61	74	n/a
Frontal lobe	3.15 ± 0.04	2.95 ± 0.10	2.70 ± 0.02	2.65 ± 0.15
Temporal lobe	3.17 ± 0.04	3.00 ± 0.13	2.80 ± 0.02	2.69 ± 0.11
Occipital lobe	3.21 ± 0.04	2.92 ± 0.09	2.80 ± 0.03	2.65 ± 0.13
Parietal lobe	2.87 ± 0.03	2.70 ± 0.08	2.60 ± 0.02	2.42 ± 0.10
Deep GM/WM	3.41 ± 0.07	3.12 ± 0.33	3.00 ± 0.02	2.79 ± 0.25
Cerebellum	2.38 ± 0.03	2.36 ± 0.16	2.20 ± 0.02	2.15 ± 0.11
Sensory-motor	n/a	2.99 ± 0.18	2.80 ± 0.03	2.82 ± 0.29

Note. Values show mean shear stiffness (kPa)  $\pm$  standard deviation (SD). n/a = not available.

### Conclusions/action items:

Importantly, the stiffness was all on the range of kPa, and below 10 kPa. This scale is enough to rate our chosen hydrogels on I would say, and specifics can be figured out later.

# Citation:

L. V. Hiscox *et al.*, "Magnetic resonance elastography (MRE) of the human brain: technique, findings and clinical applications," *Phys. Med. Biol.*, vol. 61, no. 24, pp. R401–R437, Dec. 2016, doi: 10.1088/0031-9155/61/24/R401.

# 2025/10/5 - Agar Polymerization techniques

LILLY MACKENZIE - Oct 05, 2025, 12:56 PM CDT

**Title: Agar Polymerization Techniques** 

Date: 10/5/2025

Content by: Lilly

Present:

Goals: Learn about some polymerization techniques for Agar and protocols

### Content:

This protocol below is an option to look at composition of agar. We will also be tuning with NaCl

- Step1
  weigh agar powder using an electric scale and add it into the bottle filled with distilled water (in this protocol 1.5% agar solution was used)
- Step2
  gently shake the bottle to mix agar powder and water. And put the bottle inside a microwave and microwave for 1–2 min to boil the solution. The bottle cap should be loosely closed, or the entrance of the bottle is covered by using a wrap to avoid damaging the bottle due to vapor during boiling the solution. The microwave heating process is repeated two to three times to dissolve all agar powder. Once agar powder is completely dissolved in water, then the solution becomes clear.
- Step3 place the bottle with the boiling solution on a heat plate setting the temperature at 50 °C to cool down the solution to approximately 50 °C. The high temperature might cause denaturation of the intraplid and Nigrosine, resulting in detrimental effects on obtaining optimal optical properties of a phantom. During cooling down, the bottle should be closed to prevent evaporation.
- Step4
   Add the appropriate concentration of intralipid and Nigrosin solutions into the bottle to adjust the optical properties of the solution.
- Step5
   Mix the solution several times using a vortex to homogenize the distributions of intralipid and Nigrosin within the agar solution. And pour the mixed solution into the mold. Petri dishes or 3D-printed structures are the most commonly used molds.
- Step6
   Cool down the solution in the mold at room temperature or inside a refrigerator to allow the phantom to set. During the hardening process, the mold can be wrapped to prevent the dehydration of the phantom. The created phantom can be detached from the mold after two 3 h of the cool down process.

This is a very basic procedure but it's good to know some of the steps to creating an agar-based gel. We will look at specific compositions of agar and NaCl to get the properties we want with other papers

# Conclusions/action items:

Fabrication of agar-based tissue-mimicking phantom for the technical evaluation of biomedical optical imaging systems - ScienceDirect

M. Kim et al., "Fabrication of agar-based tissue-mimicking phantom for the technical evaluation of biomedical optical imaging systems," Current Applied Physics, vol. 61, pp. 80–85, May 2024, doi: 10.1016/j.cap.2024.02.013.

# 2025/10/11 - NaCI/PA/Agar Hydrogel Methods

LILLY MACKENZIE - Oct 12, 2025, 4:22 PM CDT

Title: Injectible NaCL/PA/Agar hydrogel

Date: 10/12/2025 Content by: Lilly

Present: Lilly

Goals: learn about methods for a specific Agar (+other reagents) photopolymerized hydrogel

Content:

- This paper used an agar hydrogel with NaCl and acrylamide for wearable sensors
- Notably, they use a photopolymerization technique, which we are looking to use, to achieve the shape we want

## Materials/Methods:

- Used high gel strength (100-1200g/cm^2) agar from Aladdin Industrial Corporation
- didn't purify reagents further than how they came purchased
- · steps:
  - 20 wt% acrylamide, 1.6 wt% agar, 3wt% NaCl (based on weight of acrylamide), 0.065 wt% MBAA and DI water
  - dissolved all reagents in a beaker
  - · heated to 90 C for 15 minutes to dissolve the agar
  - o transferred into different molds and cooled to 4C
  - photopolymerized for 2h by UV (365 nm, 8W intensity)

## Testing:

- · Rheological
  - o rotational rheometer
  - 50mm parallel plates
  - o 0.5 mm gap distance
  - o linear viscoelastic region found via: 0.1-100%, 1 Hz frequency strain sweep
  - temperature sweeps from 70-20C, 1% straing and 1Hz
  - time strain sweep 1% strain, 1Hz at 25C
  - · silicone oil was used during rheological measurements
- · They also did mechanical tests
  - 250 N load tension
  - o 2000N compression
  - 100mm/min on 5 mm diameter, 20 mm gauge length samples (tensile)
  - o 5mm/min, 15mm diameter, 10mm height samples (compression)
- · important Findings:
  - viscosity of the hydrogel increased alongside increasing NaCl concentration

## Conclusions/action items:

Some of the properties of this hydrogel aren't necessarily important for us, but its good to know some of the common values for wt% of different reagents, as well as which reagents can be mixed in hydrogels with agar. I think the biggest takeaway from this though is the testing protocols

# Citation:

W. Hou et al., "Design of injectable agar/NaCl/polyacrylamide ionic hydrogels for high performance strain sensors," Carbohydrate Polymers, vol. 211, pp. 322–328, May 2019, doi: 10.1016/j.carbpol.2019.01.094.

LILLY MACKENZIE - Oct 12, 2025, 5:48 PM CDT

Title: Agar Background

Date: 10/12/2025
Content by: Lilly

Present:

Goals: Establish a background on agar composition for preliminary report

### Content:

note: this source is from a chapter on seaweed-based food packaging

- · derived from red seaweeds
- · made up of agarose and agarose pectin, both polysaccharides
- · the gelling ability is due to agarose
- thermo-reversible, water soluble, transparent
- · concentration, type of agar, preparation method, and additives can all affect physicochemical mechanical properties
  - · increasing agar concentration changes thickness, tensile strength, percent elongation, decreases water solubility
  - polyols and sugars can improve functional properties:
    - glycerol can improve properties (percent elongation, thermal stability) of pure agar, can worsen properties (tensile strength, tear resistance)
    - can also add biopolymers: starch, chitosan, locust bean gum, etc.

## Conclusions/action items:

Overall this source wasn't super helpful, but it was an interesting way to see some of the other uses of agar and potentially things it could be mixed with. They are considering edible/food grade materials though, which is not a concern for us and could be needlessly complicated

B. Ayyakkalai, J. Nath, H. G. Rao, V. Venkata, S. S. Nori, and S. Suryanarayan, "Chapter 17 - Seaweed derived sustainable packaging," in Applications of Seaweeds in Food and Nutrition, D. I. Hefft and C. O. Adetunji, Eds., Elsevier, 2024, pp. 263–287. doi: 10.1016/B978-0-323-91803-9.00006-8.

LILLY MACKENZIE - Nov 09, 2025, 1:33 PM CST

Title: Irgacure Research for Crosslinking

Date: 11/7/2025

Content by: Lilly

Present: All

Goals: Learn about irgacure as a potential crosslinker

Content:

The teaching lab has 2 types of irgacure: 184 and 651. I will research both as potential options

The paper I looked at uses dissolved in 70% ethanol (184) and 100% methanol (651) at the following w/v ratios: 0.01, 0.05, 0.1 and 0.2 g ml-1.

UV curing: used a bandpass filter, allowing 320–500 nm. Two different UV light intensities, 5 and 20 mW cm–2 for 5 minutes **while testing with the rheometers** --> we would have to come up with alternate testing since the teaching lab rheometer does not have a UV attachment.

more info on the testing we did is under fabrication in team activities

# Conclusions/action items:

Citation: I. Mironi-Harpaz, D. Y. Wang, S. Venkatraman, and D. Seliktar, "Photopolymerization of cell-encapsulating hydrogels: Crosslinking efficiency versus cytotoxicity," Acta Biomaterialia, vol. 8, no. 5, pp. 1838–1848, May 2012, doi: 10.1016/j.actbio.2011.12.034.

LILLY MACKENZIE - Sep 13, 2025, 10:43 PM CDT

Title: Effects of Transcranial Magnetic Stimulation ... provided paper

Date: 9/13/2025
Content by: Lilly

Present:

Goals: Take detailed notes on the paper provided by the client to better understand and interpret the proposed problem

### Content:

• the goal of this paper was to use a gel based phantom to test the safety (defined as evoked electrical potentials, heat, and movement of electrodes) of the simultaneous use of transcranial magnetic stimulation (TMS) and intracranial electroencephalogram(iEEG) - note this is called intractranial electrocorticography in the paper

### **TMS**

- TMS can affect excitability of various parts of the human brain and is used to tread a variety of neuropsychiatric disorders, as well as as an experimental tool
- TMS is well understood in animal models but less so in humans, although it has FDA approval as treatment for a number of disorders

### **iEEG**

- · iEEG is used to measure neural activity via electrodes placed inside or on the surface of the brain
- · typically used in epilepsy patients awaiting surgery to understand brain activity both spatially and temporally following stimulation
- iEEG is also used to understand other modulatory techniques, such as transcranial direct/alternative current stimulations
- the goal is to use iEEG to better understand the effect of TMS on the brain

## bulk of the paper:

- typically you can't have TMS done when you have any "intracranial hardware" due to safety concerns, but those guidelines are under review
- · this paper aimed to test the safety of TMS with iEEG in humans
  - "safety and electrophysiological effects of TMS at clinically used intensities while recording from multi-site intracranial electrodes"
- The paper started with a gel based phantom before continuing to test safety on surgery patients,
- Finally looked at the local and downstream effects of TMS applied to the dorsolateral prefrontal cortex (depression and neurospsychiatric disorders)

## Gel phantom

- focus was electrode heating, displacement, and induction of currents while measuring with the phantom.
- · delivered TMS while elctrodes were placed inside the gel and on the surface
- set the distance between TMS coil and electrodes as small as would feasibly occur in vivo (10 mm) to achieve the highest possible magnetic field
- gel was polyacrilic acid (PAA) saline gel in a cubic container with a polymethyl methacrylate (PMMA)wall (mimicking the skull.
  - · 8 inch cubic container
  - o 3/6 inch thick PMMA wall

## Conclusions/action items:

Citation: J. B. Wang et al., "Effects of transcranial magnetic stimulation on the human brain recorded with intracranial electrocorticography," Mol Psychiatry, vol. 29, no. 5, pp. 1228–1240, May 2024, doi: 10.1038/s41380-024-02405-y.

# 2025/9/14 - Safety Considerations for TMS

LILLY MACKENZIE - Sep 14, 2025, 2:16 PM CDT

Title: Overview of Safety considerations for TMS

Date: 9/14/2025
Content by: Lilly

Present:

Goals: Find codes and standards discussing the safety of TMS use

### Content:

- on CFR, I navigated through the food and drug section to find medical devices specifically for neurology, and further as treatments for neurological disorders
- From there, I found a standard, CFR 882.5802, which details the necessary testing required for TMS for neurological and psychiatric disorders, as would be used in the current project
- This standard requires the following tests to be done on the TMS device:
  - · Performance testing must demonstrate electromagnetic compatibility, electrical safety, and thermal safety.
    - (2) Software verification, validation, and hazard analysis must be performed.
    - (3) The patient-contacting components of the device must be demonstrated to be biocompatible.
    - (4) Non-clinical performance testing must demonstrate that the device performs as intended under anticipated conditions of use. The following performance characteristics must be tested:
    - (i) Magnetic pulse output testing;
    - (ii) Magnetic and electrical field testing;
    - (iii) Testing of the safety features built into the device; and
    - (iv) Testing of the sound levels patients are exposed to during device use.
    - (5) The physician and patient labeling must include the following:
    - (i) The risks and benefits associated with use of the device;
    - (ii) Detailed instructions to prevent seizures, to monitor the patient for seizure activity during treatment, and to provide seizure management care if one were to occur during treatment; and
    - (iii) A description of the ear protection to be worn by the patient during use of the device, including the type of protection and its noise reduction rating. (copy and pasted from the CFR website)
- Section 4 was the most relevant to us, as we are not the actual operators of the device but in order to properly comply with this standard, the phantom must undergo the underlined tests with the TMS coil

### Conclusions/action items:

"21 CFR 882.5802 -- Transcranial magnetic stimulation system for neurological and psychiatric disorders and conditions." Accessed: Sep. 14, 2025. [Online]. Available: https://www.ecfr.gov/current/title-21/part-882/section-882.5802



# 2025/9/14 - Standard for Measuring heating and induced current

LILLY MACKENZIE - Sep 14, 2025, 2:42 PM CDT

Title: Standard for measuring heating and induced current

Date: 9/14/2025
Content by: Lilly

Present:

Goals: Collect standards to test our phantom for temperature changes under simultaneous TMS/iEEG

### Content:

- · The standard discusses a test method for evaluating temperature changes of implanted devices due to magnetic resonance imaging
- the standard specifies the following relevant parameters for our project
  - the phantom and its housing should be constructed in such a way that the measurement device is not more than 2 cm from the phantom surface
  - Electrical conductivity of the phantom material at the test temperature shall be 0.47 6 10 % S/m.
    - this is in order for the test phantom to work but I will have to look further to determine if this is feasible while trying to maintain physiological values
  - the standard also specifies a procedure for creating a gel saline phantom that complies with their testing protocol further investigation will have to be done to determine if this fits our outlined criteria, but I will include the procedure here regardless:
    - 8.3.1.2 Preparation of PAA gelled-saline:
      - (1) Add NaCl to distilled or deionized water and stir to dissolve completely.
      - (2) Add PAA slowly to avoid lumps, stir to suspend completely.
      - (3) After one hour, blend the suspension into a slurry. A slow blender has been found to be satisfactory to minimize bubbles.
      - (4) The slurry is ready to use after 24 h. Stir occasionally. The appearance of the slurry should be semi-transparent, with a minimal amount of bubbles, and free of lumps.
      - (5) Verify that the conductivity is 0.47 610 % S/m, measured at frequencies lower than 15 kHz (see Note 7). The temperature at which the measurement is done should be reported.
  - o for each test, the temperature probes should be places within 1 mm of the previous trial
  - there should be no air bubbles in the gelled saline, as they could affect temperature readings
  - any fans should be turned off, as they can affect temperature readings
  - Record the temperature change for 15 min with a temporal resolution of at least 2 s
  - record before applying magnetic resonance for at least 2 minutes to achieve an equilibrium base value
  - repeat measurements in the same procedure without the implants

# Conclusions/action items:

citation: Standard Test Method for Measurement of Radio Frequency Induced Heating On or Near Passive Implants During Magnetic Resonance Imaging, F2182 – 19, ASTM International, April 2020



# 2025/11/18 - Thermal conductivity testing protocol research

LILLY MACKENZIE - Nov 18, 2025, 2:15 PM CST

Title: Thermal conductivity testing protocol research

Date: 11/18/2025
Content by: Lilly

Present: Lilly

**Goals:** figure out a protocol that is reasonable to complete to test our gels for thermal conductivity. Hoping to test this weekend and have a better idea of which Agar percent is good for our purposes.

### Content:

Based on a brief search, I think the Lee's method of determining thermal conductivity of poor conductors could be a good idea - water is unclear because it has a high specific heat capacity, but it does transfer heat better than other substances. Considering the 0.5 W/mK ish value for agar is about 3 orders of magnitude less than metals, I think its fair to consider it a poor conductor of heat

Lee's disc method:

Heat Flow Rate (Q) =  $k \cdot A \cdot (T_1-T_2) / d$ 

k - thermal conductivity

 $A = area (m^2)$ 

T1, T2 are temperatures in K

d= distance heat is traveling (m)

Q = heat flow in watts - Q can also be written as m\*c\*(dT/dt) where m =mass of sample, c is the specific heat of the sample (J/kg-K), and Dt/dT is rate of cooling (K/sec)

the experimental setup outlined here is a bit more complicated than I think we need, but this equation seems useful. Basically, they are using two highly conductive cylinders surrounding the sample and then measuring how the temperature changes through the first. My thought is we could put two brass disks on the hot plate and measure their temperature change that way, but I would have to figure out a good way to eliminate residual heat traveling through the air.

## Conclusions/action items:

I will have to come back to this and work out some of the details before this weekend, but this seems like a reasonable test



# 2025/9/19 - Training Documentation

LILLY MACKENZIE - Sep 19, 2025, 1:45 PM CDT

Title: Lilly Mackenzie Training Documentation

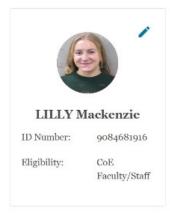
Date: 9.19.2025

Content by: LIlly

Present:

Goals:

Content:



Profile

Program Registrations

Bookings

Memberships

Orders

Invoices

My Memberships				
Membership Type	Start Date	Expiry Date	Renew	Card Info
Wood Lathe	Tue, Feb 13 2024	Permanent	Not Renewable	N/A
Access Fee	Mon, May 22 2023	Sun, Dec 31 2023	Not Renewable	N/A
Machining	Sun, Jan 1 2023	Tue, Dec 30 3000	Not Renewable	N/A
Lab Orientation	Sun, Jan 1 2023	Tue, Dec 30 3000	Not Renewable	N/A
Laser Cutter	Sun, Jan 1 2023	Tue, Dec 30 3000	Not Renewable	N/A
Shop Tools	Sun, Jan 1 2023	Tue, Dec 30 3000	Not Renewable	N/A
Woodshop Orientation	Sun, Jan 1 2023	Tue, Dec 30 3000	Not Renewable	N/A
Squaring, Shaping, & Joining	Sun, Jan 1 2023	Tue, Dec 30 3000	Not Renewable	N/A
Wood Lathe	Sun, Jan 1 2023	Tue, Dec 30 3000	Not Renewable	N/A
CNC Mill I	Sun, Jan 1 2023	Tue, Dec 30 3000	Not Renewable	N/A



This certifies that Lilly Mackenzie has completed training for the following course(s):

**Expand All** 

Collapse All

Course	Assignment	Completion	Expiration
Biosafety 102: Bloodborne Pathogens for Laboratory and Research	Biosafety 102: Bloodborne Pathogens Safety in Research Quiz 2025	8/20/2025	8/20/2026
Biosafety 106: Autoclave Use	Biosafety 106: Autoclave Use: Safety and Efficacy - Verification Quiz	9/8/2024	No Expiration
Biosafety Required Training	Biosafety Required Training Quiz 2024	3/7/2024	3/7/2029
Chemical Safety: Cryogen Safety Training	Part 1 Final Quiz	9/8/2024	9/8/2029
Chemical Safety: Cryogen Safety Training	Part 2 Final Quiz	9/8/2024	9/8/2029
Chemical Safety: The OSHA Lab Standard	Final Quiz	4/11/2025	
Disposing of Hazardous Chemicals	Final Quiz	9/12/2024	9/12/2029

Conclusions/action items:

2014/11/03-Entry guidelines 192 of 193



John Puccinelli - Sep 05, 2016, 1:18 PM CDT

Use this as a guide for every entry

- Every text entry of your notebook should have the **bold titles** below.
- Every page/entry should be **named starting with the date** of the entry's first creation/activity, subsequent material from future dates can be added later.

You can create a copy of the blank template by first opening the desired folder, clicking on "New", selecting "Copy Existing Page...", and then select "2014/11/03-Template")

Title: Descriptive title (i.e. Client Meeting)

Date: 9/5/2016

Content by: The one person who wrote the content

Present: Names of those present if more than just you (not necessary for individual work)

Goals: Establish clear goals for all text entries (meetings, individual work, etc.).

Content:

Contains clear and organized notes (also includes any references used)

### Conclusions/action items:

Recap only the most significant findings and/or action items resulting from the entry.

2014/11/03-Template 193 of 193



John Puccinelli - Nov 03, 2014, 3:20 PM CST

Title:	
Date:	
Content by:	
Present:	
Goals:	
Content:	
Conclusions/action items:	