Designing an EEG Phantom to Represent Neurological Injury

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Abstract

Introduction: Early life sustained brain injury can lead to multiple motor disadvantages affecting everyday life. Patients who have suffered from a stroke or cerebral palsy display significant lesions affecting how electrical activity is dispersed throughout the brain. Brain-computer interface (BCI) headsets have significant potential to assist patients in completing motor tasks. Electrodes are placed on the skull to measure electrical signals, using electroencephalography (EEG), sent to a computer-based signal processing system, and translated to muscular movement with external devices. The goal is to develop a baseline truth representing EEG for pediatric patients with early-life brain injury by building a real-world phantom model based on participant-specific MRIs.

Methods: Participant MRI was reconstructed from 3T MRI T1-weighted images which were converted into STL files for effective 3D modeling within Blender software. MeshMixer, Autodesk Fusion 360, and SolidWorks 2019 software were also explored with the goal to produce highly accurate molds while considering printing feasibility. Slicing the STL file transversely and adding a spherical cutout, rather than slicing sagittally down the corpus callosum, allowing for easier extraction and less deformation of a JELL-O test material.

Results: Fusion 360 and Solidworks approaches were unable to produce the targeted transversal cut as they had difficulty keeping high anatomical precision. Further results are still ongoing; each layer (white matter, grey matter, cerebral spinal fluid (CSF), and skull) is to be represented by a gel with varying electrical conductivities to match an actual brain. Assembly of the model would consist of filling the innermost layer (white matter) with a gel-based material, placing it within the next innermost layer (grey matter), and so forth, to produce a layered 3D model. The signal source will be placed in the motor cortex and with EEG sensors we will record how the signal is dispersed with the presence of a lesion.

Conclusion: Future objectives will be focused on testing different gels and their conductivity, as well as measuring electrical activity on the phantom. This project will aid clinical outcomes of children with disabilities by accurately deciding where to place EEG electrodes to maximize the usage of electrical brain activity.

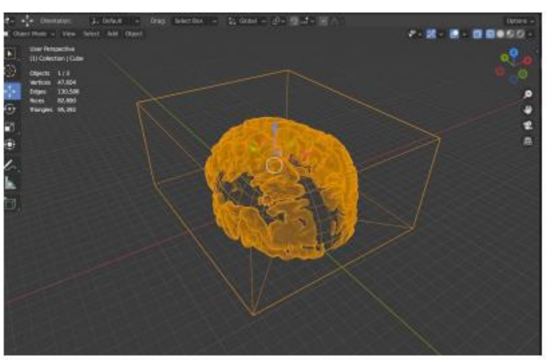
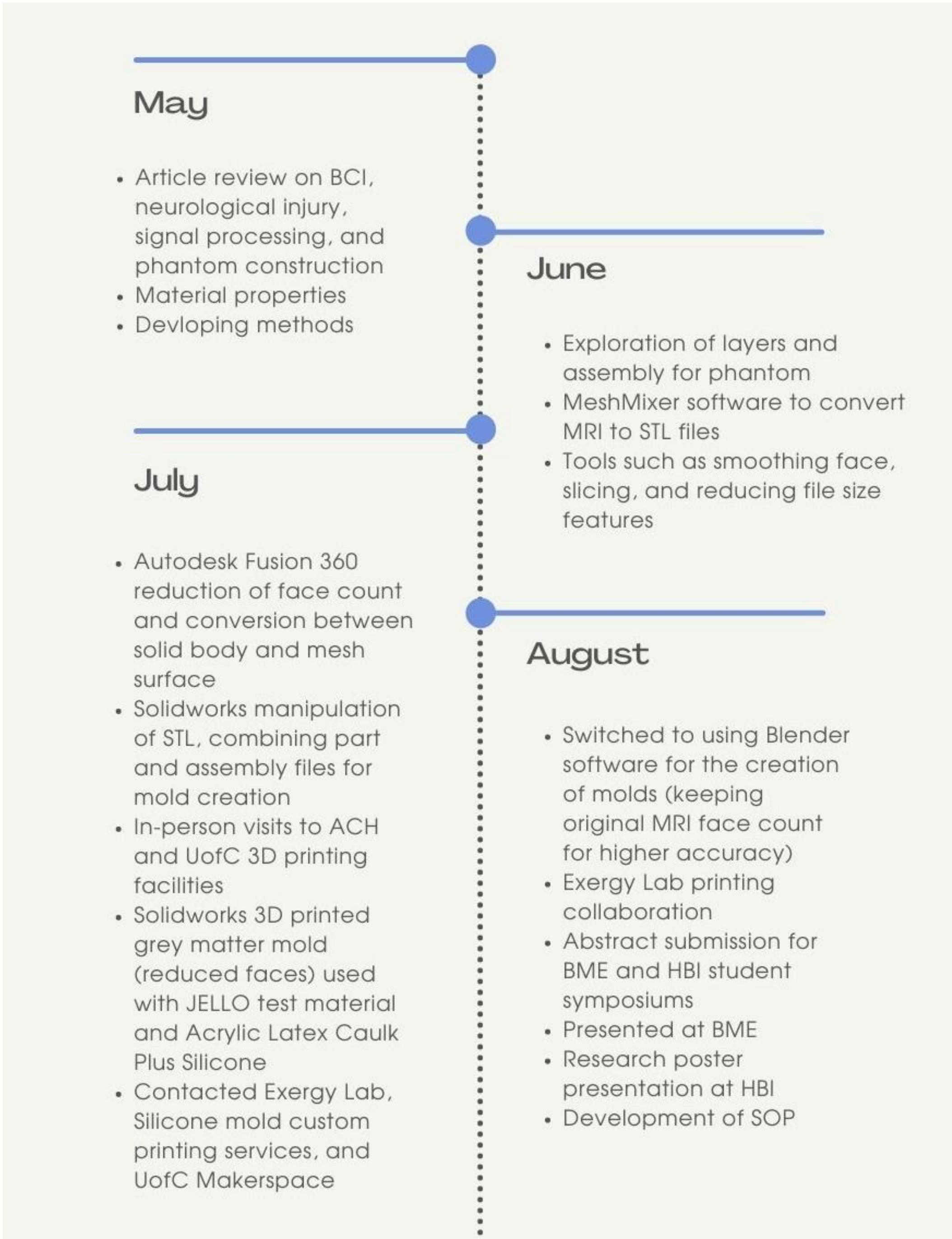


Figure 1. Transverse cut of white matter MRI mold creation done in Blender

Timeline of Project



Methods Version 01

SolidWorks Phantom File Handling- Converting MRI files into 3D-printable STL files

1. Obtain MRI images as STL files and download on to personal device
2. Begin with gm_10-1003 (grey matter) file. Import into MeshMixer and select 'Edit', 'Align', and keep default settings (Source: Base Point. Destination: World Origin / Y-up. Transformation: Translation and Rotation). Click 'Accept' to move the position of the brain.
3. Select 'Edit' and 'Plane cut' to slice the brain sagittally down the corpus callosum into two hemispheres
4. Save file as obj. type and open in SOLIDWORKS 2019. During opening, select 'Options' and ensure 'Solid Body' is checked under 'Import as'.
5. Roll back the parts of the object that are surfaces or additional 'Imported' parts to eliminate them from use. Only save the object with the main 'Imported 1' in the current unrolled back state.
    a. Add a center of mass (COM) to this part by using 'Insert', 'Reference Geometry', then 'COM'.
    b. Ensure the COM is at the center of the object and not located at the origin. If it automatically places it incorrectly, try closing and opening the file again and repeating the above steps.
    c. Save the brain as a 'Part' file type (*.prt *.sldprt)
6. Open a new part file and create a box large enough to encase the obj. brain file fully. Save the file as a part file.
    d. Add a center of mass (COM) to this part by using 'Insert', 'Reference Geometry', then 'COM'.
    e. Save the box as a 'Part' file type (*.prt *.sldprt)
7. Open a new assembly file and import both the created box and brain files.
8. Under the FeatureManager Design Tree, right click each file and select 'Float'.
9. Select 'Mates', 'Coincident Mate', and select both of the COMs for the box and brain to place the brain inside. Rotate the assembly to ensure the brain is fully enclosed and there is sufficient space left around the edges for best printing results.
    f. Note: The orientation of the brain must be aligned with the box. The box should enclose the brain accurately, without leaving an excessive amount of space on all sides. The orientation of the brain may need to be adjusted under 'Assembly', 'Move Component', then 'Rotate Component'.
10. Under the FeatureManager Design Tree, select the box part. Select 'Edit Part'.
11. Under 'Insert', 'Features', select 'Cavity'. Under the 'Design Components', use the FeatureManager Design Tree to select the brain obj. and leave the Scale Parameters as the default settings (Scale about: Component Origins. Check box for Uniform Scaling at 0.00%)
12. Do not exit the 'Edit Component' feature for the box. Create a reference plane along the line of where the mold will split in half to open up; under 'Features', 'Reference Geometry', select 'Plane'. Choose either the Top, Front, or Right plane as the reference.

Adjust the placement of the new plane to align lengthwise down the center of the enclosed brain object.

13. Do not exit the ‘Edit Component’ feature for the box. Under ‘Insert’, ‘Features’, select ‘Split’. For the ‘Trim Tools’ option, select the reference plane just created. Select the option for ‘Selected bodies’ and ensure only the box part is being split. Select ‘Cut Bodies’. Save each slice as new part files.
14. Exit the ‘Edit Component’ feature. Ensure all files are saved.

Solidworks Software Note: This method description was used for the creation of the initial 3D printed, reduced face count mold for the grey matter done at Makerspace UofC facilities. Revisions had to be made and ultimately, Blender was chosen to create the molds. This was due to the fact that the original MRI file for the white matter did not import as a fully enclosed surface, and thus a center of mass (COM) could not exist on the part file. Solidworks could be a useful tool in the future for creating technical drawings with specific measurements of lesion depth/width.

Methods Version 02

Blender Phantom File Handling- Converting MRI files into 3D-printable STL files

1. Obtain MRI images as STL files and download on to personal device
2. In ‘Object Mode’ select, ‘Add’, ‘Mesh’, ‘Cube’ to insert a cube body
    a. Note that Blender often automatically provides a default cube once the application is opened, and in this case, creating one is not necessary
3. Select ‘File’, ‘Import’, ‘STL’ and select either the grey matter, white matter, or skull downloaded file
4. On the Task Manager (located on the top right side of the screen) select the Cube part
5. Resize the Cube using the Tool Bar (located on the left side of the screen) so that it covers the entire motor cortex and lesioned area of the appropriate file
    a. Ensure sufficient space surrounding cutout so that printability is maintained
6. Having the Cube still selected, select ‘Modifier Properties’ and ‘Add Modifier’
    a. Choose ‘Boolean’ type
    b. Under preferences, select ‘Difference’
    c. The operand type needs to be set to ‘Object’ so that the STL file can be selected
    d. Select ‘Apply’
7. Delete the STL file
8. Save the mold and download on to personal device

Future Directions

Exergy Solutions Printing and Assembly

- Continue contact with Exergy Solutions at UofC LifeSciences Hub (printing 3 mold designs for white matter, grey matter, and skull layers)
- Ensure each fit within each other for pouring gel material (easily fit within one another)
    - Including liquid CSF layer
    - Deciding thickness of each layer
- Disposable mold material possibility

Material Properties

- Altering conductivity of each layer
    - Microbeads
    - Soaking in electrolytic solution
    - Manufactured conductivity when purchasing material
- Printing material for mold (PLA, Silicone, something more flexible?)

Signal Measurement

- Square wave signal received through phantom
- Measuring relative amplitudes and tracking location/dispersion of signal
- Comparing to the non-lesioned hemisphere of brain possibility