

I. Candidate Information

First Name: Rachael

Last Name: Serur

II. Capstone track selection and tentative title

Track: Wearables & IoT

Tentative Title: 3D-Printing the Human Brain for PubMed Interactivity

III. Design Questions, Technology, References, and Schedule

What are the context, need, significance, and estimated number of users of your proposed project?

My original conceptualization of this project in its first 2014 iteration (a 2D, interactive visualization of the brain in a single-page web application that navigated PubMed databases) came from my previous career as a clinical research coordinator for psychosis studies at Beth Israel Deaconess Medical Center.

Constellations of neurological biomarkers underlying any given disease, especially mental illnesses, are rapidly emerging patterns in neuroscientific literature based on findings in medical imaging. These are exciting advancements in the phenotypic categorization of psychological disorders previously only observed and defined by statistics of outward human behavior and cognition, without physical correlates, as catalogued in the Diagnostic Statistical Manual of Mental Disorders (DSM).

The details of the immediate deliverables of medical imaging, namely voxel-level data produced by Magnetic Resonance Imaging (MRI) scans, are at once scientifically rich and not easily navigable beyond interpretations of medical professionals and highly trained researchers. The conventional form of access for most is via publications in medical journals, many accessible

through the free online search engine, PubMed, provided by the United States Library of Medicine.

While text-based search strategies are innumerable for online academic publication databases, there is an opportunity to bring these findings to life via compelling, even artistic representations of subject matter. In this project's case, grey and white brain matter-- using a 3D-printed parts of the brain as touch-sensitive search navigation tools for PubMed.

This design exploration of the human brain as a form of visual and physical academic navigation has implications in both education and research. The project will be a proof of concept with physical representations of larger anatomical regions (lobes and/or clinically significant areas, the prefrontal cortex, for example). Such a project would have immediate applications in K-12 and undergraduate-level education, but the mechanics could feasibly be extended into applications for graduate, post-graduate, and medical education beyond the proof of concept by increasing the granularity of representation (linking physical points to their voxel correlates).

As a rough estimate for the number of potential users, according to [figures](#) from the National Center for Educational Statistics for 2015-16 alone, 117,400 students earned bachelor degrees in psychology, 113,749 in biological and biomedical sciences, and 288,896 in health professions and related programs. Such students, routinely tasked to search academic papers, might be the most interested to use this as a learning and research device. More likely than serving individual users, it could be mass-produced as a classroom tool for thousands of schools.

What is the proposed solution, novel product, or piece of art for your capstone project?

A 3D-printed interactive model of the human brain that controls the navigation of a single-page web application. The product will be an educational tool for psychology and neuroscience as well as an artistic exploration. The web application will react to user interactions with the brain model, mirroring interactions in easy-to-understand and eye-catching visualizations of the brain on-screen, and triggering searches of PubMed databases.

In addition, noteworthy attributes and quantities of search results could be stored within a backend database and used to train a prediction model around queries. The model could be used to empower the user with insights as they navigate within the application.

What are the expected measurable outcomes, audience size, or quantifiable behavior change?

Users will be able to more quickly and easily navigate academic publications on the topic of neuroscience in a demonstrably unique way: visually and spatially. Via a friendly graphic

interface and physical computing, studying and exploring the human brain will be an exciting interactive experience.

What are the different technologies that you will use and why are they needed for completing the project?

Technology #1: 3D Printing

Reason: To design a physical model that is 1) divided into meaningful anatomical regions of the brain, 2) compatible with physical computing components, and 3) visually appealing and engaging.

Technology #2: Physical Computing: Open-Source Single-Board Computer (SBC) & Touch Sensors

Reason: To connect touch sensor input from the physical model to the web application such that specific regions or points of the brain are recognizable to the app.

Technology #2: Node.js

Reason: To access input data from the physical computing sensors within the embedded linux system of the single-board computer.

Technology #3: Javascript Framework & Visualization Libraries

Reason: To create a cohesive and visually engaging frontend for the web application that guides the user through the search and exploration of articles and insights.

Technology #4: Backend Python Application & SQL Database

Reason: To save search query combinations over time, generate a predictive model for insights based on search results, and use the model to aid the user in academic inquiry and exploration.

Technology #5: PubMed API

Reason: To query the PubMed database for research articles relevant to user interactions of the web app and physical brain model.

References to four comparable pieces of work (e.g. publication, piece of art) in APA style if appropriate.

Reference #1:

Serur, R. A. (2014, July 19). PubBrain. Retrieved from <https://github.com/rserur/PubBrain>

Reference #2:

Giraud, S., Brock, A. M., Macé, M. J., & Jouffrais, C. (2017). Map Learning with a 3D Printed Interactive Small-Scale Model: Improvement of Space and Text Memorization in Visually Impaired Students. *Frontiers in Psychology*, 8. doi:10.3389/fpsyg.2017.00930

Reference #3:

Notter, M. (2019, March 15). Miykael/3dprintyourbrain. Retrieved from <https://github.com/miykael/3dprintyourbrain>

Reference #4:

DiCola, T. (2014, December 23). MPR121 Capacitive Touch Sensor on Raspberry Pi & BeagleBone Black. Retrieved from <https://learn.adafruit.com/mpr121-capacitive-touch-sensor-on-raspberry-pi-and-beaglebone-black/overview>

Tentative Milestones

Milestone #1: 3D-Printed model of the human brain

Date: September 15th, 2019

Description: Several interlocking 3D printouts of human brain regions, each of anatomical and/or neurological significance, that are built to allow the affixation of corresponding touch sensors.

Milestone #2: Physical brain model equipped with sensor inputs that register in Node.js on SBC

Date: October 1st, 2019

Description: The 3D-printed model of the brain will be connected to touch sensors, the data of which will register meaningfully on an SBC (e.g., if a user touched the amygdala on the model, a small Node.js program recognize that it was the amygdala).

Milestone #3: Inputs from physical model manipulate PubMed API-connected frontend web application

Date: October 15th, 2019

Description: All possible input from the physical model will register in a rudimentary version of the frontend web application, fully connected to the PubMed API (that is, able to execute search queries and return results).

Milestone #4: 3D visualizations and interactivity

Date: November 20th, 2019

Description: Physical model interactions will be mirrored by an on-screen and interactive visualization of the brain using [Three.js](#), a 3D library for Javascript. The exact 3D models used for printing should be loadable with this library. (Alternatively, SVGs from the original 2D version of this project could also be used.)

Milestone #5: Backend database and prediction model

Date: December 20th, 2019

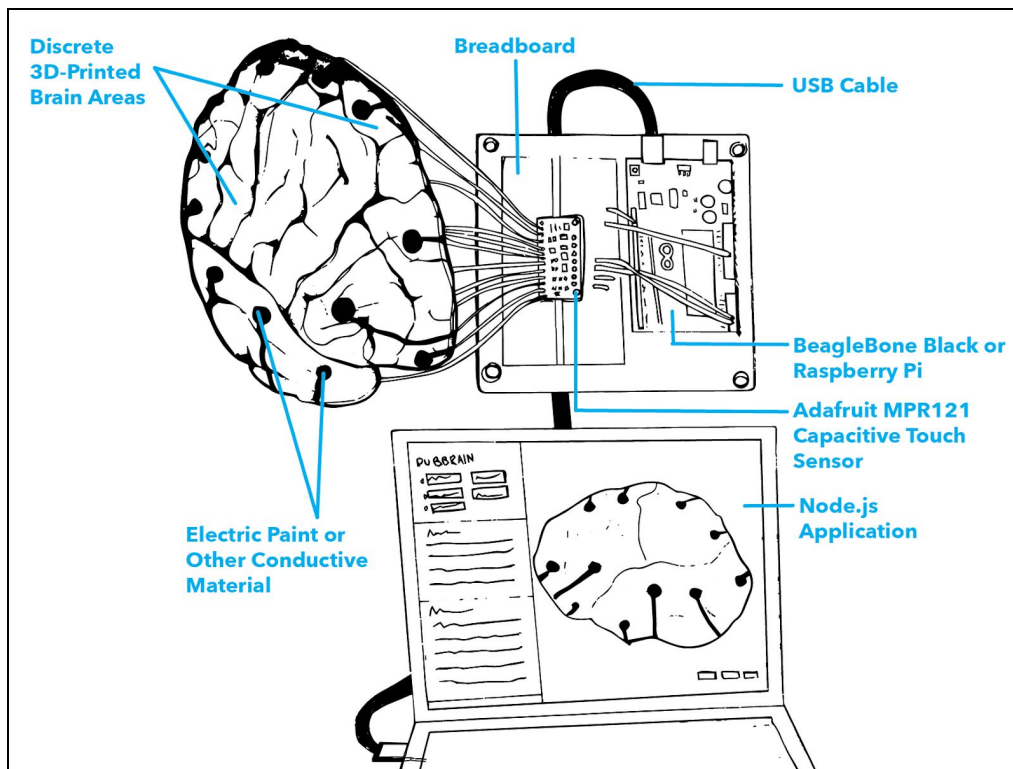
Description: All search queries that yield results will be saved into a backend SQL database.

IV. Project Description

To create a physical model of the human brain using 3D printing, an initial surface model would need to be created with [FreeSurfer](#), an open source software suite developed by the Martinos Center at Massachusetts General Hospital for the analysis of magnetic resource imaging (MRI) scan data. Then, an open source script simply titled [3Dprinting_brain.sh](#) could be used to create a 3D model of cortical areas via the open source system for processing and editing 3D meshes for 3D printing preparation, [MeshLab](#).

Alternatively, according to a tutorial by Teresa K. Pegors, PhD, a software platform specific to the interactive segmentation and visualization of medical images, [3D Slicer](#), could be used. The platform can generate files editable in 3D rendering software like [FreeCAD](#), [SketchUp](#), or [Blender](#). Using the resulting 3D model, a low-cost 3D printer or 3D printing service (e.g., [ShapeWays](#)) would be used to print out discrete, noteworthy areas of the brain.

Some experimentation would be necessary before a conductive material for touch sensors can be chosen, but a flexible option is Electric Paint by [Bare Conductive](#). Their company also offers a candidate for the touch sensor hardware, the [Pi Cap](#), or the similar Adafruit 12-Key Capacitive Touch Sensor Breakout ([MPR121](#)) can be used.



Pictured: A sketch of the project's core components.

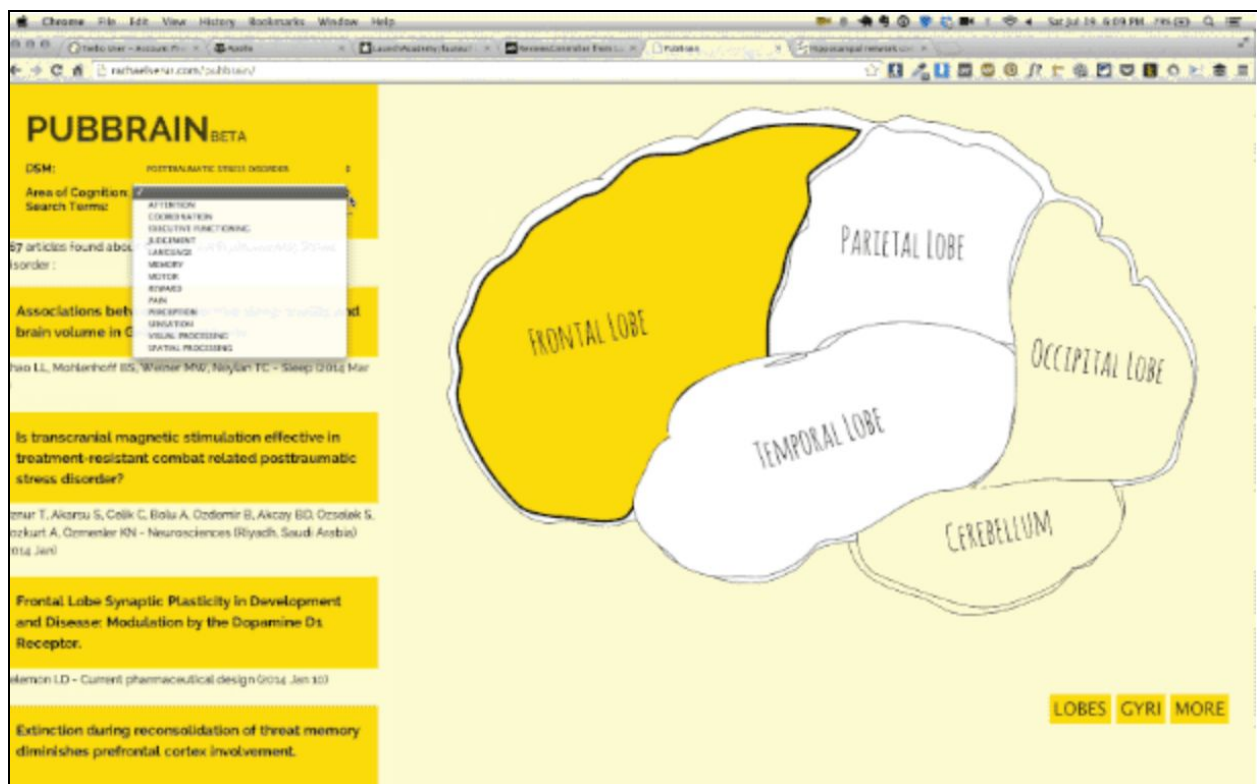
The breakout, connected to the physical brain model, can then be wired as sensory input to a microcontroller. Options include the [Arduino](#), [Raspberry Pi](#), or [BeagleBone Black](#). BeagleBone offers a Node.js library for event interpretation from the microcontroller.

A Node.js physical computing library, coupled with an Express.js API that updates a frontend interface, would allow for a rough visual mapping of the sensory input to an identical 3D model rendered in-browser using Three.js.

The user interface will otherwise resemble that of the original 2D, digital “PubBrain” project, my spring 2014 final for DGMD-E15, "Creative Explorations in Screen-Based and Physical Computing."

The interface will feature a sidebar form with a dropdown for the DSM, other noteworthy areas of research, and keyword search. Those form fields will combine with input from the physical 3D model to trigger PubMed searches for relevant articles.

Since the primary goal of this capstone is to explore the educational possibilities of physical computing, the 3D model rendered in-browser will not also act as input to PubMed searches. Rather, it will light up and react to physical sensory input as the user interacts with the physical brain model.



Pictured: A screenshot from the original PubBrain project.