The Correlation of Drug Ingestion and Brain Performance

Team 26, Brain Buds

New Mexico Supercomputing Challenge

Final Report

06 April 2022

Team Number: 26

School Name: Justice Code International

Team Members: Ifunanya Egbo, Praise Ejimkonye, Sayra Medrano, Chinyere Offor, Aileen Ukwuoma, Alexandrina Ukwuoma

Sponsors: Caia Brown, Becky Campbell, Ryan Palmer

Project Mentor: Daniel Fuka

Table of Contents

The Correlation of Drug Ingestion and Brain Performance

Executive Summary

The human brain is a remarkable organ comprised of complex systems that control human behavior and countless other biological processes. Thus, the ingestion of different substances affects the brain's physiology and its user's performance. Scientists have considered the influence of drug use on gray matter, which controls processing in the brain. Studies have found that various medicinal substances cause a reduction in the brain's gray matter and, subsequently, its size. The overarching consequence of this shrinkage is the disruption of communication between body systems. Therefore, we decided to research the influence of marijuana and nicotine on the brain's size and explore how the sequence of ingesting these substances influences overall brain size.

Introduction

Problem Statement

Drug use among teenagers in the United States is increasingly high and, although efforts have been made to curb alarming narcotics statistics, a comprehensive depiction of the brain's reaction to drugs is crucial. Specifically, we want to know how the sequence of drug ingestion influences the size of the brain. To address the issue of teenage drug use, we created a modeling architecture to show the influence of drugs on brain performance and dissuade teenagers from using the previously mentioned drugs. Our goal is to build a model that will allow the user to witness the movement of select drugs (in this case, nicotine and marijuana) throughout the brain and the influence of this movement on brain physiology.

Background Research

We discovered that nicotine affects the inside, or subcortical, parts of the brain. A consistent finding from imaging studies is that smokers have smaller total brain volume and notably smaller gray matter volume in comparison to non-smokers. Regarding marijuana, we found that it affects the outside, or cortical, part of the brain. Regions of the brain influenced by marijuana are the medial temporal cortex, temporal pole, parahippocampal gyrus, insula, and orbitofrontal cortex. These areas are rich with cannabinoid CB1 receptors. Furthermore, these regions are associated with motivation, emotional processing, and reasoning. Regular cannabis use causes gray matter reduction in these areas. [1]

Table 1. Local Maxima of Significant Clusters Showing Decreased Gray Matter Volume in Regular Cannabis Smokers [1]

Local Maxima of Significant Clusters Showing Decreased Gray Matter Volume in Regular Cannabis Smokers

Region	Left hemisphere MNI coordinates (mm)			*T*-value	Cluster extent	Right hemisphere MNI coordinates (mm)			*T*-value	Cluster extent
	x	y	z			x	y	z		
Superior orbital gyrus	−22	14	−14	5.15						
Temporal pole	−50	10	−14	5.14		50	14	−20	3.59	213[a]
Middle temporal gyrus	−56	2	−28	4.84	1215	64	−10	−20	4.36	271
Medial temporal pole	−48	10	−32	4.52		46	14	−34	3.94	213[a]
Insula lobe	−36	8	−10	4.22						
Parahippocampal gyrus	−26	10	−42	3.98	130	24	6	−36	3.62	64
Precuneus						12	−54	16	3.83	85

Open in a separate window

[a]Belong to the same cluster.

Our attendance of weekly Code Breaks and Justice Code Coding Sessions, combined with guidance from our mentor, allowed us to garner more knowledge regarding NetLogo's interface. We learned about patch colors (p-colors) and their corresponding numbers in NetLogo. This is crucial for our project as it entails identifying the influence of drugs on certain parts of the brain, and we are using a multicolored image of the brain that corresponds with various brain regions. With our existing architecture, we assigned different p-colors to each brain section. This helped us to determine where our turtles (representative of nicotine or marijuana) will concentrate and will allow us to depict shrinkage (in that brain shrinkage is associated with a color change).

Computational Model

Selection

Upon perusing NetLogo's model library, we saw a similarity between the pre-made Erosion model (precisely, the model entitled "Sample Models/Earth Science/Erosion") and the physiology of the brain. The movement of water in the Erosion model paralleled the brain's gyri and sulci (simply, its curves and grooves). We chose the Erosion model because it demonstrated interactions between multiple patches. However, the formatting and sliders of the aforementioned Erosion model were unsuitable for our project's objective. Therefore, we decided to modify certain aspects of the model. We examined two additional models during our project: the Dog Park model from the Beginner's Interactive NetLogo Dictionary and the Ants model entitled "Sample Models/Biology/Ants." The Dog Park model was vital to the development of our computational model. By analyzing its code, our group was able to add turtles to our model and alter them to have a leaf shape, representative of drugs in the brain. Furthermore, we utilized the "setxy random-xcor random-ycor" and "ask turtles" formats shown in the Dog Park code [6]. We used these conventions as foundations from which we coded our turtles to occupy random locations in the world and wiggle forward.

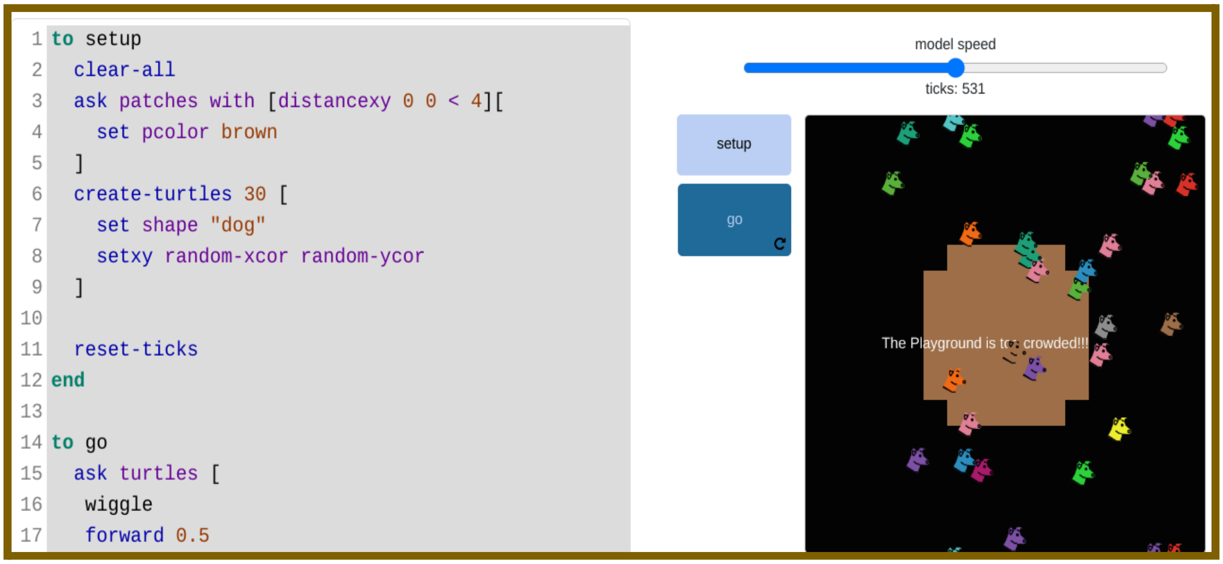

Figure 1. An Image Capture of the Code from the Dog Park Model [6]

The Ants model was also a vital learning tool. By examining the codes of models that depicted occurrences similar to those we hoped to replicate in our model (such as the random dispersion of turtles and the concentration of turtles in various areas of the world), we hoped to find a format we could use to model the movement of drug molecules in some regions of the brain. In the Ants model, we examined the dispersion of multiple ants from a single cluster to multi-colored patches in the world. Once the ants encountered these patches, color changes occurred, and numerous white beams emerged. We scrutinized the code and tried to correlate the events happening in the model's world with specific lines of code.

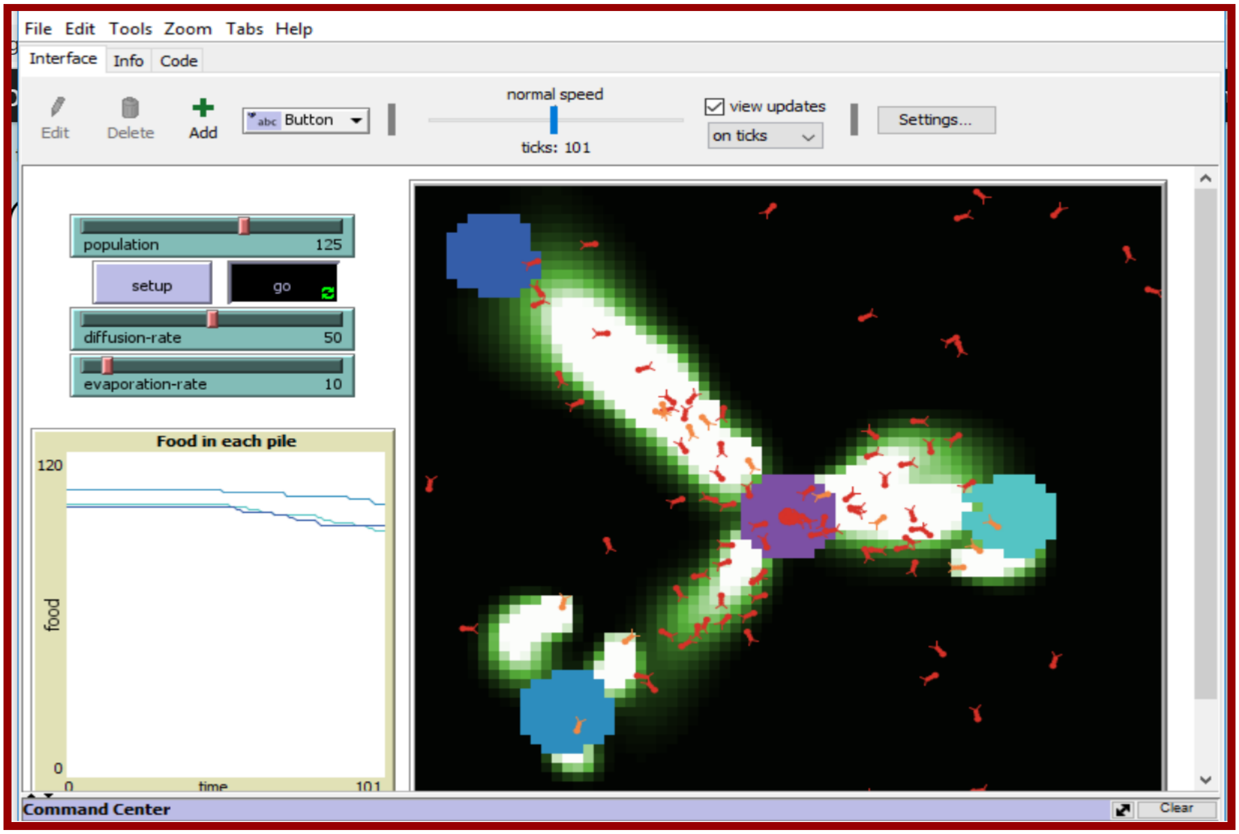

Figure 2. The Dispersion of Ants in the Ants Model [3]

Modifications

The first crucial modification we made to the rudimentary Erosion model was importing an image of the brain. Through the creation of a Github repository for our project, we added a multifaceted, two-dimensional image of the human brain on which we planned to add turtles. After extensive studies of NetLogo's index and dictionary, we modified the existing erosion sliders and inputted leaf-shaped turtles into the model, representing marijuana moving through the brain. Using the photo-editing platform Pixlr, our team assigned special p-colors to various sections of the brain, thus permitting the movement (and, later, concentration) of turtles in the model's world. Specifically, we used the scissors tool to crop our image of the brain and remove the conventional white background to highlight the actual brain. Using the "flood/fill" tool, we changed the colors of the insula, orbitofrontal cortex, hippocampal gyrus, temporal pole, and medial temporal cortex. Once we developed our Github repository, used Pixlr to modify our image of the brain, and imported the brain into our model, the next step was finding the p-color numbers of critical sections of our brain for future use in our code (see Figure 3). To make our brain model available to everybody, Github was helpful with the acquisition of the "fetch URL" and importation of p-colors (see Figure 4).

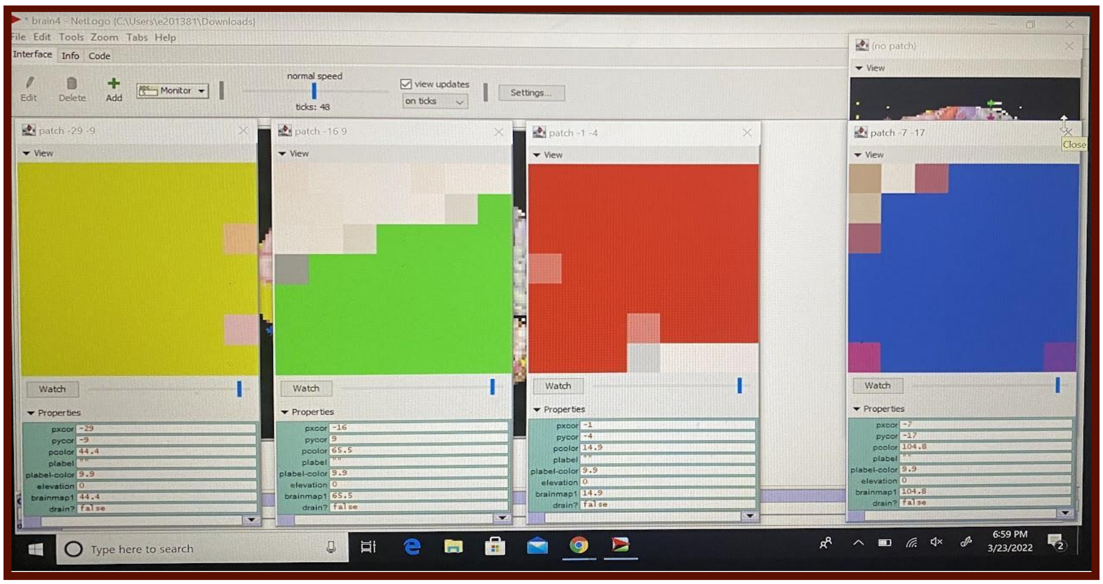

Figure 3. The Process of Assigning P-Color Numbers to Differently-Colored Brain Regions

README.md

NetLogo-BrainBuds.github.io

Team 26's public Brain Buds NetLogo site. https://www.netlogoweb.org/launch#https://NetLogo-BrainBuds.github.io/brain6.nlogo

Brain Region	Color	Pcolor Number
Insula	Green	65.5
Orbitofrontal Cortex	Yellow	44.4
Hippocampal Gyrus	Red	14.9
Temporal Pole	Purple	125.7
Medial Temporal Cortex	Blue	104.8

https://github.com/adam-p/markdown-here/wiki/Markdown-Cheatsheet#tables

Figure 4. An Image Capture of the README file of our Github Repository

Visualization

We removed the initial setup parameters and display controls of the Erosion model, which included the "hill?" and "bumpy?" widgets and the "show-water" and "hide-water" controls. Additionally, we removed the environmental parameter slider entitled "soil-hardness." After removing these original facets of the erosion model, we added sliders entitled "thc_amount" and "r," both of which relate to the amount of THC in the brain. We also included a "count turtles" monitor, which measured the number of turtles present in the model.

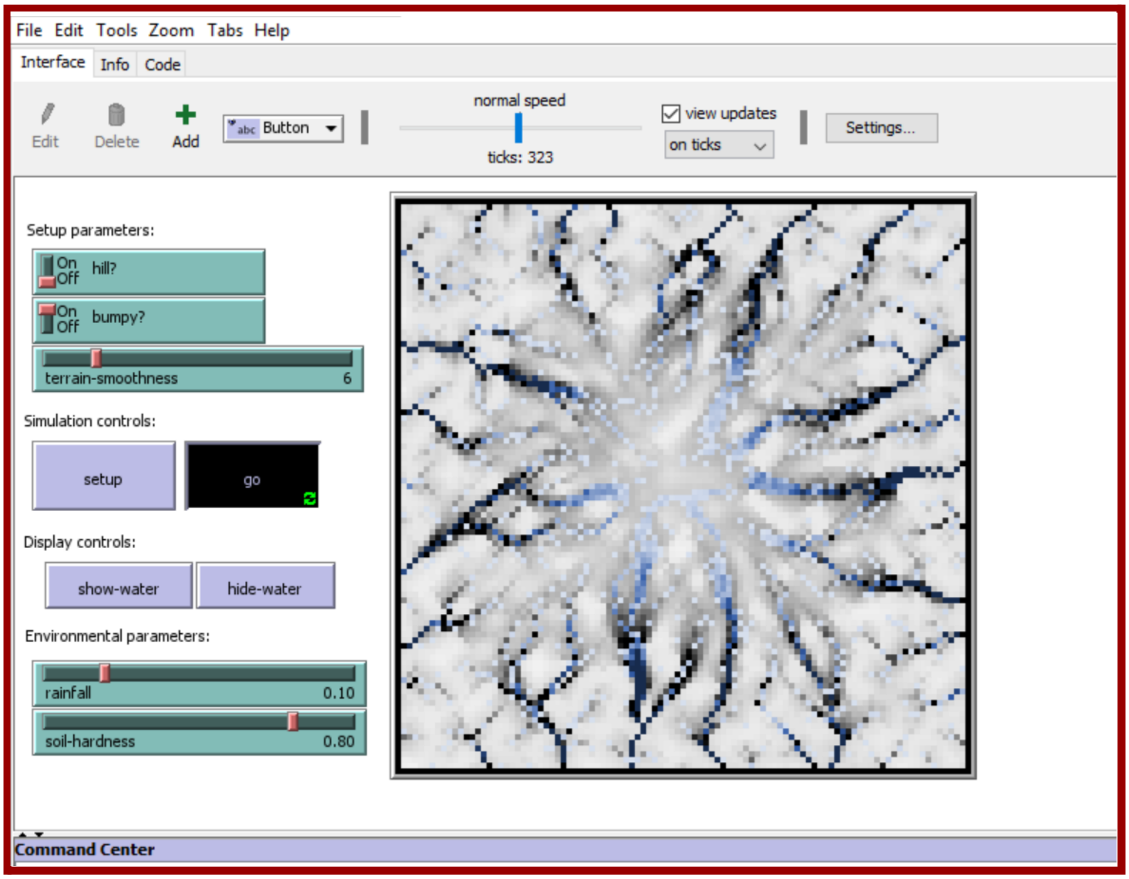

Figure 5. The Initial Erosion Model [2]

In our personalization of the Erosion model, we tentatively included a "starting-age" slider to model the correlation between the age at which individuals begin using drugs and the influence of this decision on the brain's physiology (as shown in Figure 6). However, since we want to focus on one variable at a time, we plan to erase this slider in the future.

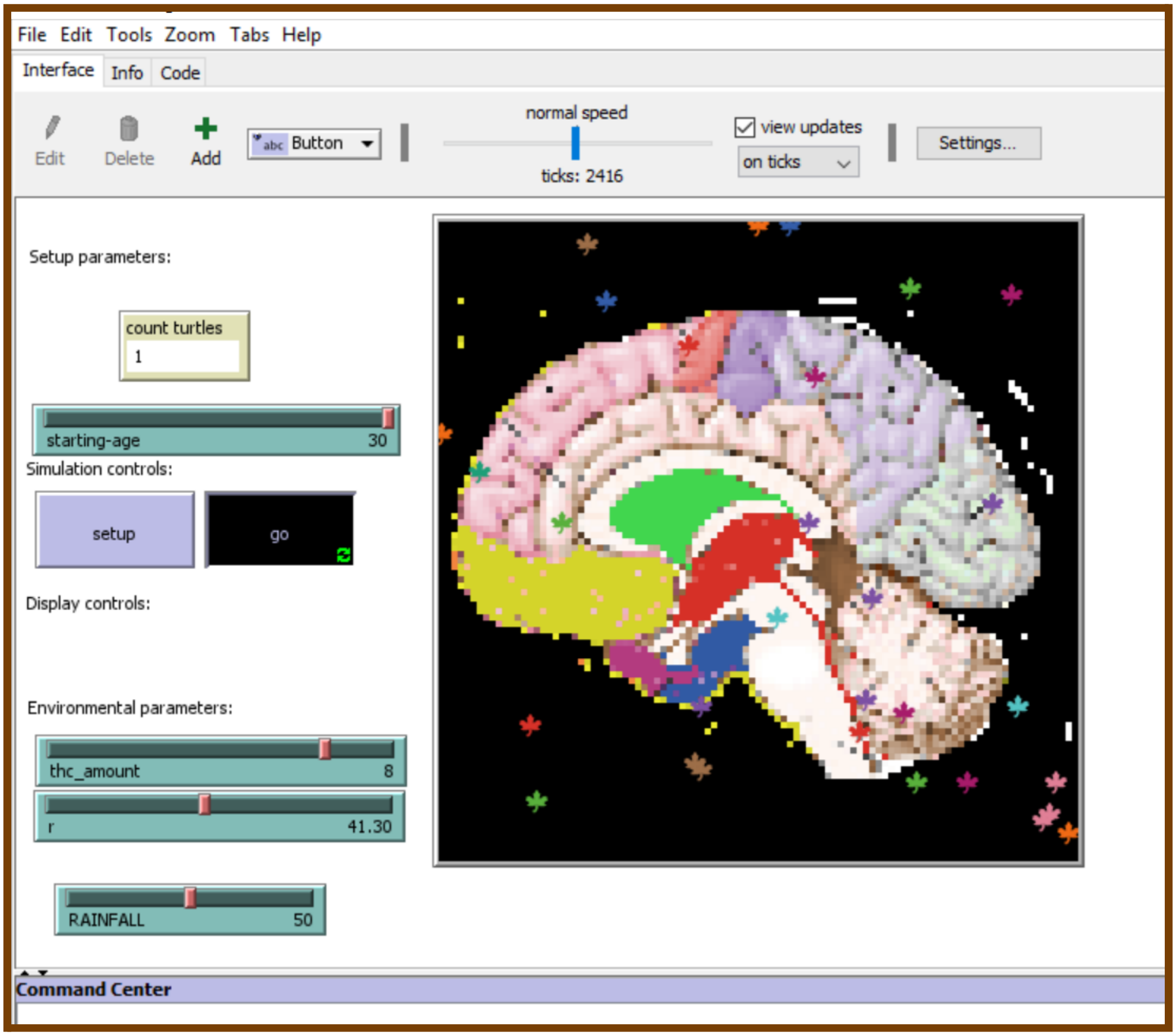

Figure 6. Our Brain Map after Modifications to the Erosion Model [9]

Limitations

The limitations we encountered in this project regarded our knowledge of NetLogo's systems and an unavailability of computers. The latter, although later resolved, encouraged us to make our model easily accessible on NetLogo Web with a Github repository. We had to go to extreme lengths to ensure our model was available and usable by anybody because traditional NetLogo imports are unavailable for NetLogo Web. As stated in NetLogo's user manual, users often encounter messages such as "Import-pcolors file name" and "note, this primitive is not compatible with NetLogo Web." Evidently, it is difficult for users to import images to NetLogo Web, so an important early stage of our project was overcoming this obstacle.

Regarding the model itself, a significant limitation we experienced was figuring out how to make the leaf-shaped turtles concentrate on various regions in the brain. This is crucial to our model's visualization of marijuana particles accumulating in areas of the brain that contain cannabinoid CB1 receptors. Additionally, we are continuing to develop the model to change the color of a certain patch once a leaf-shaped turtle passes over it. The purpose of this is to depict the shrinkage of the brain in the aforementioned regions (the medial temporal cortex, temporal pole, parahippocampal gyrus, insula, and orbitofrontal cortex) once marijuana enters an individual's system.

Problem Solving Method

Verification

We set up our model to be as realistic and accurate to the real world as possible. In combination with other lifestyle habits (whether salubrious or detrimental), the ingestion of drugs could likely exacerbate or offset a decrease in brain size. We are working to include some of these variables, which will be represented by "tics," the initial number of THC particles/turtles and the ability to increase or decrease the number of turtles over time.

Corroboration

Throughout our project, we learned that you cannot validate anything in science or fully prove that it is true. That said, corroboration, or even conditional validation, is a better way of explaining our results in this case. [8] Our results are corroborated by the information we compiled from various studies during our research. We examined MRI (magnetic resonance imaging) scans from the study we used as the basis of our project. A recurrent finding was that gray matter volume (associated with brain size) is lower in regular smokers, and the reduction in volume correlates with the regions we highlighted in the brain that we included in our model. [1]

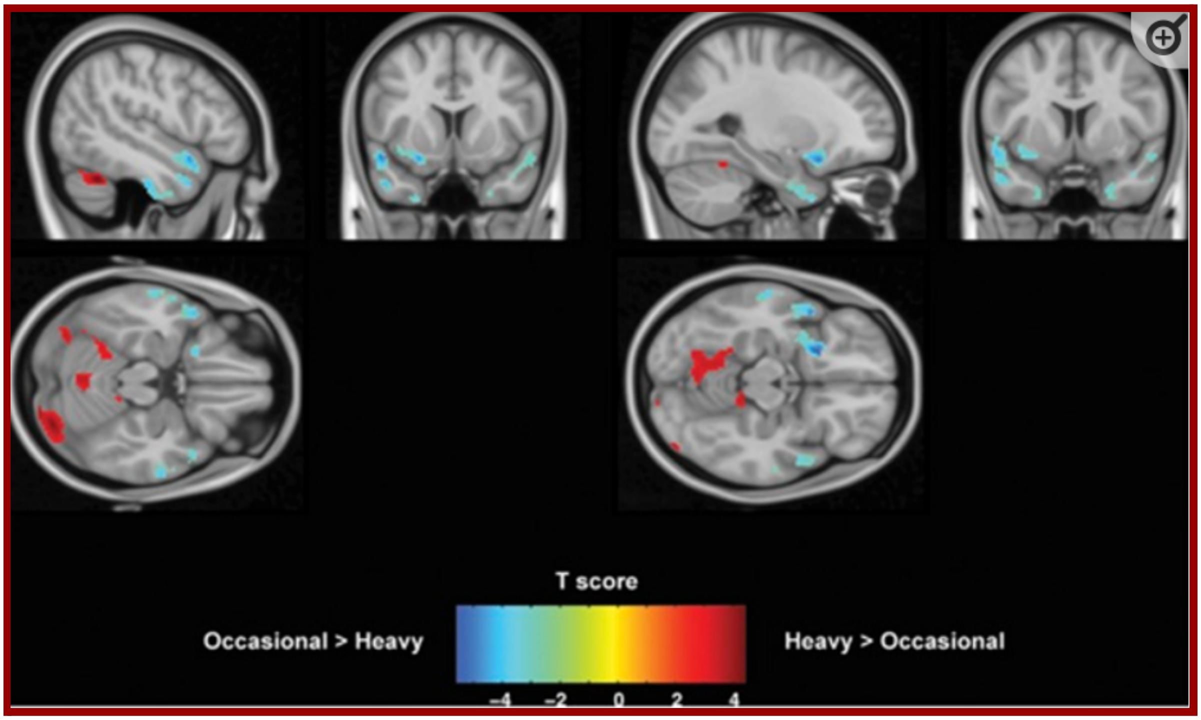

Figure 7. Voxel-Based Morphometry Results on Gray Matter[1]

Conclusion

Results

When our model is run, the leaf-shaped turtles are randomly strewn across the brain (Figure 6). Although the movement of these particles is apparent in our model, we are continuing development to add how exactly they affect the brain in our map. The attachment of leaf particles to cannabinoid receptors is one aspect of our model we will ameliorate in the weeks between our submission of this report and our final presentation. We are continuing to compile results that prove that, with varying degrees of marijuana (and, if time permits, nicotine) in an individual's brain, the sections rich in cannabinoid receptors will reduce in size.

Discussion

We hypothesized that an individual's intake of nicotine followed by the ingestion of marijuana is more subtractive to the brain's size than the opposite sequence of ingestion, in which the person takes marijuana before using nicotine. Our model shows the physiology of the brain and highlights its potential to fluctuate depending on the consumption of certain substances. This is intended to accompany other scientific findings that show that drugs and similar illicit substances are harmful to human minds, an especially relevant fact in today's society. In our mission, we created a community-shared architecture that imports data from shared open sources directly into NetLogo Web. During our presentation, we will show how this platform helps to depict locations of the brain that are impacted by drug intake. This intake of drugs (specifically marijuana and nicotine) might have varying impacts on the brain depending on the sequence of ingestion.

Future Work

While we managed to create a model that showed the presence of marijuana in the brain and its random dispersion, we did not show the concentration of marijuana particles in specific regions and the consequent shrinkage (which we planned to indicate by a color change). Thus, it is valuable that we continue to develop a model with adequate code that visualizes this phenomenon. Furthermore, while we compiled ample research about the influence of nicotine on the brain, we seldom explored the nicotine aspect of our hypothesis. Fortunately, the foundational architecture we have developed will allow us to replicate the visuals from the current (marijuana) brain model. Therefore, an essential task for our group in the future is creating another brain that can be imported into our architecture (that explicitly shows the brain under the influence of nicotine) and finding a way to amalgamate the two brains (of marijuana and nicotine) to acquire information about brain shrinkage.

Acknowledgments

Our progress in this year's Supercomputing Challenge would not have been possible without help from various individuals and organizations.

We thank the nonprofit organization Justice Code for arranging meeting times with our sponsors and mentor and providing us with digital and physical meeting spaces to collaborate bi-weekly (on Wednesdays and Saturdays). [10] We are also grateful for the opportunity to interact with other students from Nigeria and Palestine.

We acknowledge the guidance of Ms. Caia Brown, Ms. Rebecca Campbell, and Ms. Ryan Palmer from Justice Code. Ms. Patty Meyer and Ms. Mary Sagartz have also been crucial to our team's understanding of NetLogo through weekly coding lessons. Their diligence and eagerness to assist us during this challenge were extremely helpful, enabling us to learn about coding while simultaneously completing a computational science project.

We appreciate our mentor, Daniel Fuka, whose expertise in biological systems and engineering has contributed significantly to our project.

We thank Uri Wilensky, Northwestern University, and NetLogo for the coding language we used to create our model. We also thank them for the various models from which we drew inspiration to develop ours.

Finally, we thank the judges, scientists, and individuals associated with the Supercomputing Challenge for their input throughout this project (through Code Breaks and regular e-mail correspondence) and their creation of a space in which scientific curiosity thrives.

References

1. Battistella, Giovanni, et al. “Long-Term Effects of Cannabis on Brain Structure.” *Nature News*, Nature Publishing Group, 17 Mar. 2014, https://www.nature.com/articles/npp201467.
2. Dunham, G., Tisue, S. and Wilensky, U. (2004). NetLogo Erosion model. http://ccl.northwestern.edu/netlogo/models/Erosion. Center for Connected Learning and Computer-Based Modeling, Northwestern University, Evanston, IL.
3. Wilensky, U. (1997). NetLogo Ants model. http://ccl.northwestern.edu/netlogo/models/Ants. Center for Connected Learning and Computer-Based Modeling, Northwestern University, Evanston, IL.
4. Wilensky, U. (1999). NetLogo. http://ccl.northwestern.edu/netlogo/. Center for Connected Learning and Computer-Based Modeling, Northwestern University, Evanston, IL.
5. Wilensky, U. (Author). (2003). NetLogo 2.0. Software http://ccl.northwestern.edu/netlogo
6. *The Count Primitive*. (2021). Beginner’s Interactive NetLogo Dictionary. https://ccl.northwestern.edu/netlogo/bind/primitive/count.html (accessed: 30 March 2022).
7. Elbejjani, Martine, et al. “Cigarette Smoking and Gray Matter Brain Volumes in Middle Age Adults: The Cardia Brain MRI Sub-Study.” *Translational Psychiatry*, Nature Publishing Group UK, 11 Feb. 2019, https://www.ncbi.nlm.nih.gov/pmc/articles/PMC6370765/.

8. Beven, K., Young, P. (2013) "A Guide to Good Practice in ... - Wiley Online Library." A Guide to Good Practice in Modeling Semantics for Authors and Referees, 2013, https://agupubs.onlinelibrary.wiley.com/doi/full/10.1002/wrcr.20393.
9. Ukwuoma, A.A., Offor, C., Ukwuoma, A.I., Medrano, S., Egbo, I., Ejimkonye, P., Palmer, R., Fuka, D.R. (2022). NetLogo-BrainBuds/NetLogo-BrainBuds.github.io: The Correlation of Drug Ingestion and Brain Performance (v1.0.0). Zenodo. https://doi.org/10.5281/zenodo.6416182
10. Justice Code. (2022). Justice Code Creating Global Citizens https://www.justicecode.org/ (Accessed 5 April 2022).

Appendix: Code

```
extensions [import-a fetch]

globals [
  show-brainmap1?     ;; whether the brainmap1 is visible
  drains          ;; agentset of all edge patches where the brainmap1 is
  land            ;; agentset of all non-edge patches
]

patches-own [
  elevation       ;; elevation here (may be negative)
  brainmap1           ;; depth of brainmap1 here
  drain?          ;; is this an edge patch?
]

to test-fetch-url-async
end

to getbrainmap
  clear-all
  fetch:url-async "https://professoraileen.github.io/brain.png"
import-a:pcolors
  ask patches [
    set elevation pcolor
  ]
  set-default-shape turtles "leaf"
  ;; turtles should be evenly spaced around the circle
  crt marijuana_amt [
    set size 5  ;; easier to see

    rt 90
  ]
end

to setup
  clear-all
```

```
  fetch:url-async "https://NetLogo-BrainBuds.github.io/pixlrbrain.png"
import-a:pcolors
  set show-brainmap1? true
  ask patches [
    set brainmap1 pcolor
  ]


  create-turtles marijuana_amt [
    set shape "leaf"
    set color yellow
    setxy random-xcor random-ycor
    set size 4
  ]
  create-turtles marijuana_amt [
    set shape "leaf"
    set color red
    setxy random-xcor random-ycor
    set size 4
  ]
  create-turtles marijuana_amt [
    set shape "leaf"
    set color pink
    setxy random-xcor random-ycor
    set size 4
  ]
  create-turtles marijuana_amt [
    set shape "leaf"
    set color blue
    setxy random-xcor random-ycor
    set size 4
  ]
  create-turtles marijuana_amt [
    set shape "leaf"
    set color green
    setxy random-xcor random-ycor
    set size 4
  ]
```

```
;;  ask land [ recolor ]
  reset-ticks
end

to recolor  ;; patch procedure
  ifelse brainmap1 = 0 or not show-brainmap1?
    [ set pcolor scale-color white elevation -250 100 ]
    [ set pcolor scale-color blue (min list brainmap1 75) 100 -10 ]
end

to go
  ask turtles [

    if color = yellow
    [
      set heading towardsxy -33 -8
      if [pcolor] of patch-here = 44.4
      [
        ;ask patches
        ;[
            set pcolor black
        ;]
      ]
    ]
    if color = red
    [
      set heading towardsxy 0 0
      if [pcolor] of patch-here = 14.9
      [
        ;ask patches
        ;[
            set pcolor black
        ;]
      ]
    ]

     if color = pink
```

```
[
  set heading towardsxy -19 -20
  if [pcolor] of patch-here = 125.7
  [
    ;ask patches
    ;[
        set pcolor black
    ;]
  ]
]


 if color = green
[
  set heading towardsxy -13 6
  if [pcolor] of patch-here = 65.5
  [
    ;ask patches
    ;[
        set pcolor black
    ;]
  ]
]

 if color = blue
[
  set heading towardsxy -7 -17
  if [pcolor] of patch-here = 104.8
  [
    ;ask patches
    ;[
        set pcolor black
    ;]
  ]
]
forward 0.5
wiggle
if [pcolor] of patch-here = black
```

```
    [
      forward random 10
    ]
    ;move-to one-of patches
  ]
  tick
end

to wiggle
  left random 90
  right random 90
end




; Copyright 2022 BrainBuds.
; See Info tab for full copyright and license.
```