A Computational Exploration of COPD Medication Adherence

The Rx Researchers

New Mexico Supercomputing Challenge

Final Report

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Executive Summary

Chronic Obstructive Pulmonary Disease (COPD) is an umbrella term for various diseases that cause breathing difficulties by blocking airflow to the lungs. Risk factors such as pollution, cigarette usage, social interactions, and concurrent diseases can influence the development of COPD. In our research project, we aimed to explore the effect of social factors on medication adherence among individuals with COPD or other respiratory ailments. We investigated different beliefs about COPD and medication adherence, assigned these perspectives to mobile agents within a simulated NetLogo population, and examined the influence of the ensuing interactions on COPD medication adherence. Our project combined sociology, epidemiology, and predictive modeling to observe how the interactions between different agents influenced medication adherence. Our findings emphasize the importance of social determinants of health to healthcare delivery, thus providing substantial evidence in favor of personalized, multifaceted approaches to healthcare.

Introduction

Problem Statement

Chronic Obstructive Pulmonary Disease is an increasingly prominent global health issue. COPD refers to respiratory illnesses, such as chronic bronchitis and emphysema, that cause airflow limitation. [1] Risk factors of COPD include childhood respiratory illness, smoke exposure, and aging. The Centers for Disease Control and Prevention found that, in 2018, COPD was the fourth leading cause of death in the United States. [2] This trend is only expected to continue. Medication adherence is the ability to follow a prescription based on timing, dosage,

and frequency of ingestion. [3] Adherence can depend on drug interactions, socioeconomic status, and medication types. Medication adherence is necessary for positive health outcomes, especially concerning COPD. Our research question is as follows: "How can social factors present in a population with COPD affect how long a sick individual adheres to COPD medications?" We hypothesize that individuals who encounter negative medical perspectives will exhibit diminished adherence to prescriptions aimed at alleviating the symptoms of COPD. This computational research project is significant on a local and global level; an in-depth exploration of the social aspect of medication adherence can drive policy and personal choices regarding compliance. This project aims to predict the effect of social interactions on medication adherence using programming and data visualization.

Project Description

The primary tool utilized in this project was version 6.4.0 of NetLogo, an agent-based programming language. The general steps we followed were conducting preliminary literature searches about COPD and medication adherence, locating a suitable base model using the NetLogo model library, altering the model components to fit our project, and running iterations to generate results concerning the effect of social interactions on medication adherence. Our study focuses on the influence of social factors on medication adherence; it does not necessarily incorporate other aspects of illness management like disease prognosis or treatment. Furthermore, our simulations might not capture the complexity of human interactions and individual thought.

Computational Model

Selection

We chose to program our model using NetLogo. NetLogo allowed us to visualize our project and explore the platform's BehaviorSpace addendum. BehaviorSpace allows NetLogo users to perform experiments with their models. It runs the model through multiple iterations, varies its settings, and tabulates the results of each run, thus allowing the user to realize a model's potential behaviors.

Modifications

The initial version of our model was a template that simulated the spread of HIV in a population. The initial code created individuals, relocated them, and tracked HIV infection.

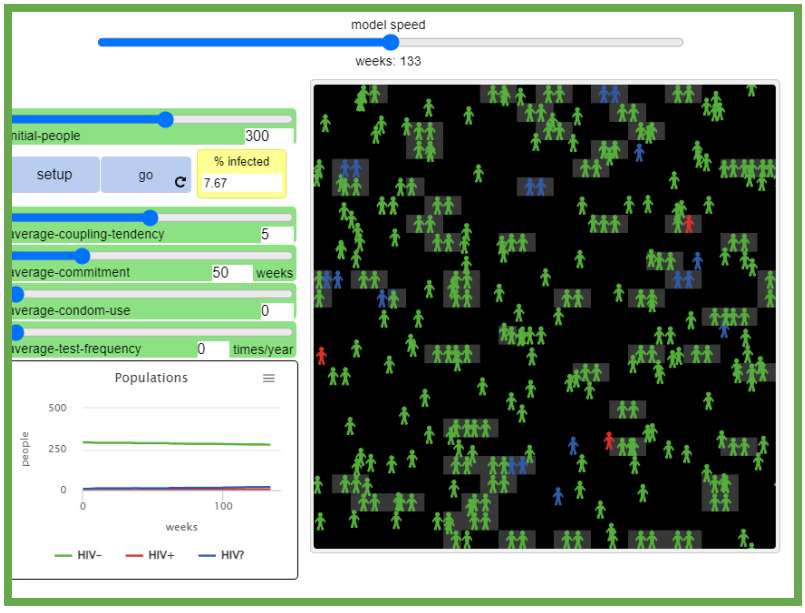

Figure 1. An Image Capture of the First Version of our Model (the HIV model)

We altered this model to include sliders entitled "initial-people," "chance-to-think-about-adherence-per-week," "average-outwardness," "average-conversation-interest," "average-medicinal-trust," and "average-doctor-visit-frequency." To the original code, we incorporated the ability to become

"uninfected" (which, as it pertains to our research question, depicts the regeneration of medicinal adherence). Also, we added a variety of computational procedures necessary for medication nonadherence (previously HIV) to spread.

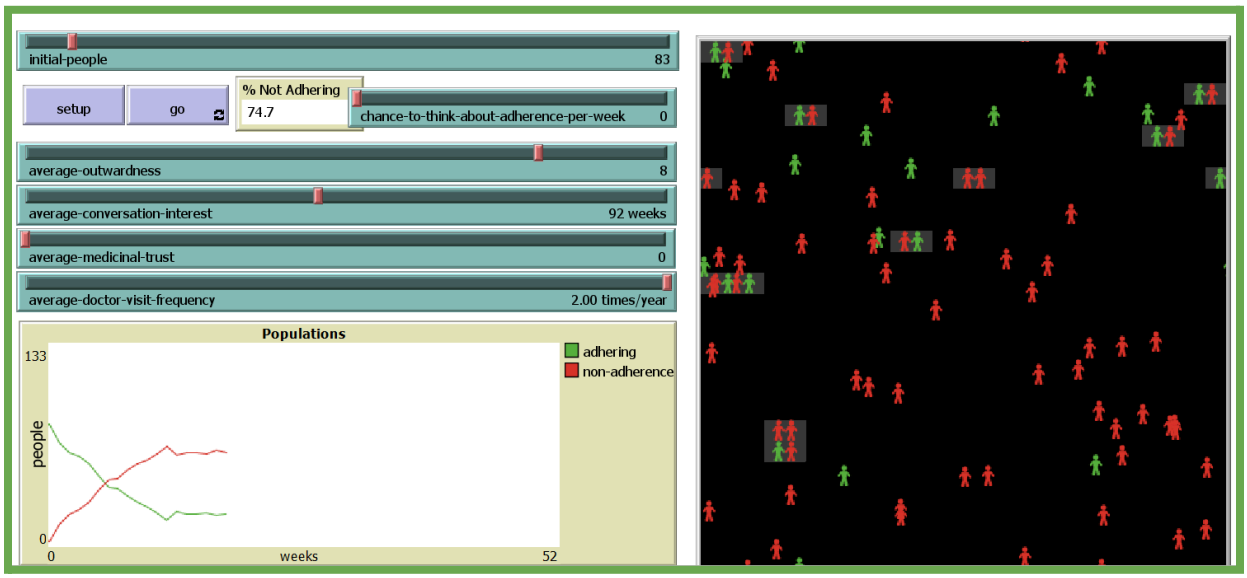

Figure 2. An Image Capture of the Sliders, Drop-Down Menus, and Sections of the Latest Version of our Model

Visualization

As NetLogo is an agent-based software, our model utilizes "turtles" that, as it pertains to our project, represent human beings with diverse views concerning medication adherence (see Figure 2). NetLogo allowed us to visualize the interactions between and movement of human beings and track how these encounters affected medication adherence. When the user presses "Setup," the model generates a population of people with COPD. A random yet small percentage of these individuals do not adhere to prescribed medications. Members of the population move and interact within themselves, deciding whether or not to adhere to their medications (based on personal beliefs or other individuals' recommendations). An accompanying graph displays changes in the population of adhering and non-adhering individuals as time progresses.

Limitations

Some limitations we encountered regarding our model were a peculiarly minuscule amount of public data, an unforeseen programming issue (that resulted in the removal of a minor code feature), and the fact that no data gathered from a small group can genuinely represent the state of a larger, general population.

Problem-Solving Method

Procedure

The first step in our process was conducting literature searches regarding Chronic Obstructive Pulmonary Disease and medication adherence. We perused works from the National Institute of Health and other renowned medical journals. One significant piece of literature concerning medication adherence is a paper entitled "Treatment Adherence in Patients with Obstructive Pulmonary Diseases" by Henryka Homętowska et al., 2022. [4] This paper provided a table describing the sociodemographic and clinical characteristics of patients in a study about treatment adherence. This table, alongside other graphs from diverse articles, provided the percentage distributions with which we designated different medical viewpoints to the agents in our environment.

If applicable, why did you stop taking your prescribed medication? (**n=325)**	Improvement	243 (74.77%)
	Lack of improvement	52 (16.00%)
	I felt unwell when taking it	59 (18.15%)
	Side effects	42 (12.92%)
	Fear of side effects	11 (3.38%)
	I did not buy the next dose	43 (13.23%)
	I did not have a prescription to continue the therapy	36 (11.08%)

	Lack of money	33 (10.15%)
	None of the above	70 (21.54%)
	I did not stop taking my medication	23 (7.08%)

Table 1. Sociodemographic and Clinical Characteristics of Patients Studied

After conducting literary searches and obtaining the necessary statistics, we updated our model accordingly. Our model assigns the aforementioned beliefs or perspectives concerning COPD prescriptions to different agents in the NetLogo environment, thereby simulating human interaction and the spread of ideas. The model then tracks populational changes in adherence over time.

Conclusions

Results

Our model shows that medicinal adherence reaches a point of equilibrium with the percent adherence remaining within a 20% range from wherever it sits based on the given variables.

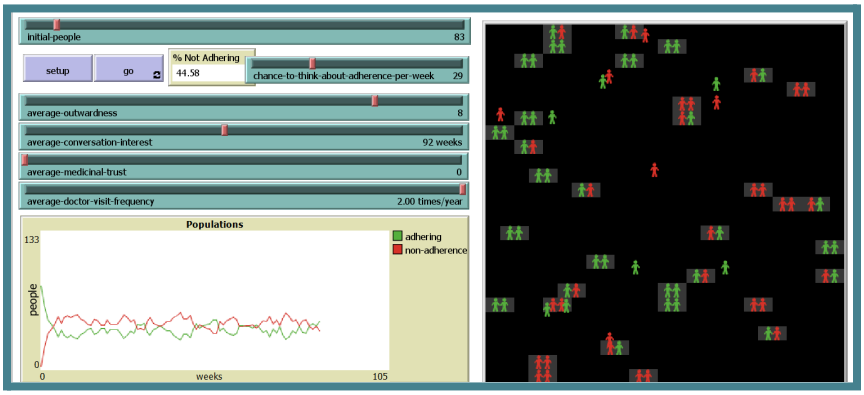

Figure 3. An Image Capture of Our Model Displaying Equilibrium

Our results suggest that, regardless of efforts to increase medicinal adherence, there will always be a population that does not adhere to prescribed regimens. Surprisingly, the

non-adhering population is always moderately large, even when the model's variables suggest that the percentage of non-adhering individuals will be negligible.

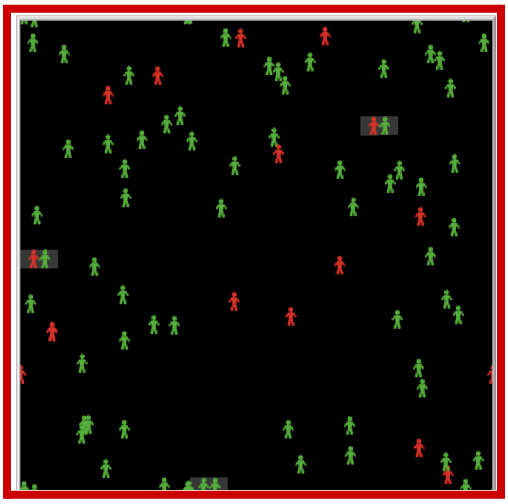

Figure 4. An Image Capture of a Small, Non-Adhering population (in red)

Verification

Naturally, social interactions are complex and involve more nuance than simple statements. Our model reflects real-world statistics about medical adherence and social interactions. To verify the results of our model in the future, we intend to use NetLogo's BehaviorSpace addendum. However, our current scarcity of research could render the use of this platform ineffective.

Corroboration

Our results are corroborated by the information we compiled from various medical studies during our research. The resources we accessed were verified and reliable, and the data we inputted into our model reflects accurate data from these sources. Ultimately, the outcome of our model is corroborated by real-world trends concerning medication adherence and COPD.

Discussion

Our results suggest the difficulty of removing nonadherence in a human population. Individuals are more likely than not to exercise poor medication adherence. This discovery was our most significant achievement, as it elucidates an underlying societal issue that, in reality, must be addressed to ensure positive health outcomes.

Future Work

To refine our model and increase its predictability, we will continue searching for novel studies related to COPD and medical adherence. In the future, we might also incorporate other factors influencing medication adherence (besides social interactions), such as economic status and pre-existing medical knowledge.

Acknowledgments

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

We thank the nonprofit Justice Code for establishing meeting times with our sponsors and mentors and providing collaboration spaces.

We acknowledge the guidance of Ms. Caia Brown and Ms. Rebecca Campbell from Justice Code. [5] Ms. Patty Meyer, Ms. Celia Einhorn, and Ms. Mary Sagartz from the Supercomputing Challenge have proved indispensable to our team's understanding of NetLogo by providing coding lessons.

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

We thank Uri Wilensky, Northwestern University, and NetLogo for the coding language and models we utilized to build our model. [6]

Finally, we thank the judges, scientists, and individuals associated with the Supercomputing Challenge for their input throughout this project.

References

1. Association AL. Learn about COPD. American Lung Association. January 24, 2024. Accessed April 9, 2024. https://www.lung.org/lung-health-diseases/lung-disease-lookup/copd/learn-about-copd.

2. Basics about COPD. Centers for Disease Control and Prevention. June 30, 2023. Accessed April 9, 2024. http://www.cdc.gov/copd/basics-about.html.

3. Aremu TO, Oluwole OE, Adeyinka KO, Schommer JC. Medication adherence and compliance: Recipe for improving patient outcomes. *Pharmacy*. 2022;10(5):106. doi:10.3390/pharmacy10050106

4. Homętowska H, Świątoniowska-Lonc N, Klekowski J, Chabowski M, Jankowska-Polańska B. Treatment adherence in patients with obstructive pulmonary diseases. *International Journal of Environmental Research and Public Health*. 2022;19(18):11573. doi:10.3390/ijerph191811573

5. Home. Justice Code. Accessed April 9, 2024. http://www.justicecode.org/.

6. Wilensky U. Netlogo Home Page. 1999. Accessed April 9, 2024. http://ccl.northwestern.edu/netlogo/.

Appendix: Code

```
globals [
  dropping-adherence-chance  ;; The chance out of 100 that an infected person will
pass on
                     ;;   infection during one week of couplehood.
  chance-of-effects     ;; How long a person will be infected before symptoms occur
                     ;;   which may cause the person to get tested.
  slider-check-1    ;; Temporary variables for slider values, so that if sliders
  slider-check-2    ;;   are changed on the fly, the model will notice and
  slider-check-3    ;;   change people's tendencies appropriately.
  slider-check-4
  slider-check-5
  slider-check-6 ;; fear from symptoms IG
]

turtles-own [
  not-adhering?          ;; If true, the person is infected.  It may be known or
unknown.
  doctor-thing
  known?             ;; If true, the infection is known (and infected? must also be
true).
  length-of-nonadherence   ;; How long the person has been infected.
  speaking?           ;; If true, the person is in a sexually active couple.
  duration-of-conversation      ;; How long the person has been in a couple.
  ;; the next four values are controlled by sliders
  conversation-interest         ;; How long the person will stay in a
couple-relationship.
  outwardness  ;; How likely the person is to join a couple.
  medicinal-trust         ;; The percent chance a person uses protection.
  doctor-visit-frequency     ;; Number of times a person will get tested per year.
  speaking-to            ;; The person that is our current partner in a couple.
  symptoms?
  fear-after-flare-up
  symptom-chance
]

;;;
;;; SETUP PROCEDURES
;;;

to setup
  clear-all
  setup-globals
  setup-people
  reset-ticks
end

to setup-globals
  set dropping-adherence-chance 25    ;; data states that 10-40% of people take their
medicine in prescribed doses.
  set chance-of-effects 200.0
  set slider-check-1 average-conversation-interest
  set slider-check-2 average-outwardness
  set slider-check-3 average-medicinal-trust
  set slider-check-4 average-doctor-visit-frequency
end

to setup-people
```

```
  create-turtles initial-people
    [ setxy random-xcor random-ycor
      set known? false
      set symptoms? true
      set speaking? false
      set speaking-to nobody
      ifelse random 2 = 0
        [ set shape "person righty" ]
        [ set shape "person lefty" ]
      ;; 2.5% of the people start out infected, but they don't know it
      set not-adhering? (who < initial-people * 0.025)
      set symptoms? (who < initial-people * 0.025)
      if not-adhering?
        [ set length-of-nonadherence random-float chance-of-effects ]
      assign-conversation-interest
      assign-outwardness
      assign-medicinal-trust
      assign-doctor-visit-frequency
      assign-color ]
end

to assign-color  ;; turtle procedure
  if not not-adhering?
    [ set color green ]
  if not-adhering? and symptoms?
      [ set color red ]
  if not-adhering? and not symptoms?
      [ set color blue ]
end



to assign-conversation-interest  ;; turtle procedure
  set conversation-interest random-near average-conversation-interest
end

to assign-outwardness  ;; turtle procedure
  set outwardness random-near average-outwardness
end

to assign-medicinal-trust  ;; turtle procedure
  set medicinal-trust random-near average-medicinal-trust
end

to assign-doctor-visit-frequency
  set doctor-visit-frequency random-near average-doctor-visit-frequency
end


to-report random-near [center]
  let result 0
  repeat 40
    [ set result (result + random-float center) ]
  report result / 20
end


to go
  if all? turtles [known?]
    [ stop ]
```

```
  check-sliders
  ask turtles
    [ if not-adhering?
        [ set length-of-nonadherence length-of-nonadherence + 1 ]
      if speaking?
        [ set duration-of-conversation duration-of-conversation + 1 ] ]
  ask turtles
    [ if not speaking?
        [ move ] ]
  ;; Righties are always the ones to initiate talking.  This is purely
  ;; arbitrary choice which makes the coding easier.
  ask turtles
    [ if not speaking? and shape = "person righty" and (random-float 10.0 <
outwardness)
        [ talk ] ]
  ask turtles [ untalk ]
  ask turtles [ infect ]
  ask turtles [ uninfect ]
  ask turtles [ doctor-visit ]
  ask turtles [ assign-color ]
  tick
end

to check-sliders
  if (slider-check-1 != average-conversation-interest)
    [ ask turtles [ assign-conversation-interest ]
      set slider-check-1 average-conversation-interest ]
  if (slider-check-2 != average-outwardness)
    [ ask turtles [ assign-outwardness ]
      set slider-check-2 average-outwardness ]
  if (slider-check-3 != average-medicinal-trust)
    [ ask turtles [ assign-medicinal-trust ]
      set slider-check-3 average-medicinal-trust ]
  if (slider-check-4 != average-doctor-visit-frequency )
    [ ask turtles [ assign-doctor-visit-frequency ]
      set slider-check-4 average-doctor-visit-frequency ]
end

to move
  rt random-float 360
  fd 1
end



to talk
  let potential-speaking-to one-of (turtles-at -1 0)
                           with [not speaking? and shape = "person lefty"]
  if potential-speaking-to != nobody
    [ if random-float 10.0 < [outwardness] of potential-speaking-to
      [ set speaking-to potential-speaking-to
        set speaking? true
        ask speaking-to [ set speaking? true ]
        ask speaking-to [ set speaking-to myself ]
        move-to patch-here
        ask potential-speaking-to [move-to patch-here]
        set pcolor gray - 3
        ask (patch-at -1 0) [ set pcolor gray - 3 ] ] ]
end
```

```
to untalk  ;; turtle procedure
  if speaking? and (shape = "person righty")
    [ if (duration-of-conversation > conversation-interest) or
         ([duration-of-conversation] of speaking-to) > ([conversation-interest] of
speaking-to)
        [ set speaking? false
          set duration-of-conversation 0
          ask speaking-to [ set duration-of-conversation 0 ]
          set pcolor black
          ask (patch-at -1 0) [ set pcolor black ]
          ask speaking-to [ set speaking-to nobody ]
          ask speaking-to [ set speaking? false ]
          set speaking-to nobody ] ]
end


to infect  ;; turtle procedure
  if((random-float 100) < chance-to-think-about-adherence-per-week)
  [
    if(random-float 100 < 25)
    [
     set not-adhering? true
    ]
  ]
  if speaking? and not-adhering? and not known?
    [ if random-float 10 > medicinal-trust or
         random-float 10 > ([medicinal-trust] of speaking-to)
        [ if random-float 100 < dropping-adherence-chance
            [ ask speaking-to [ set not-adhering? true ] ] ] ]
  ;; uninfect due to unnintentional reasons such as a lack of funds
  if ((random-float 100) < 13.23)
 [
  set not-adhering? true;
 ]
end
to uninfect  ;; turtle procedure
  if speaking? and not-adhering? and not known?
    [ if random-float 10 > medicinal-trust or
         random-float 10 > ([medicinal-trust] of speaking-to)
        [ if random-float 100 < dropping-adherence-chance
            [ ask speaking-to [ set not-adhering? false ] ] ] ]
  if((random-float 100) < chance-to-think-about-adherence-per-week)
  [
    if(random-float 100 < 25)
    [
     set not-adhering? false
    ]
  ]
end

;;to test  ;; turtle procedure
;;  if random-float 52 < doctor-visit-frequency
;;    [ if not-adhering?
;;        [ set known? true ] ]
;;  if length-of-nonadherence > chance-of-effects
;;    [ if random-float 100 < 5
;;        [ set known? true ] ]
;;end
```

```
to doctor-visit
  if random-float 52 < doctor-visit-frequency
  [
    set doctor-thing random-float 100
    if (not-adhering?)
    [
      if (doctor-thing < 27.1)
      [
        if (random-float 100 < 25)
        [
          set not-adhering? false
        ]
      ]
      if (doctor-thing > 27.1) and (doctor-thing < 63.8)
      [
        if (random-float 100 < 50)
        [
          set not-adhering? false
        ]
      ]
      if (doctor-thing > 63.8)
      [
        if (random-float 100 < 75)
        [
          set not-adhering? false
        ]
      ]
    ]
  ]
end

to symptom-change
;;~30-50% a year
  set symptom-chance ((random-float 20) + 30)
  if((random-float 100) < 52.1)
  [
  if((random-float 100) < symptom-chance)
    [
      set symptoms? true
    ]
  ]

end

;;https://www.ncbi.nlm.nih.gov/pmc/articles/PMC8901192/#:~:text=Between%2030%25%20and%
2050%25%20of,least%20one%20exacerbation%20per%20year.&text=Even%20a%20single%20moderat
e%20exacerbation,an%20increased%20risk%20of%20death.


to-report %not-adhering
  ifelse any? turtles
    [ report (count turtles with [not-adhering?] / count turtles) * 100 ]
    [ report 0 ]
end
```