Marijuana Abuse Dynamics for High School Students

Tom Knight – Dr. Yun Kang (Advisor)

MAT 350 – Fall 2023

CISA, Polytechnic Applied Mathematics

College of Integrative Sciences and Arts

ARIZONA STATE UNIVERSITY

CISA Student Showcase

Introduction and Objectives

The use of marijuana has become less restricted in the U.S., with adult-use recreational marijuana now legal in 24 states [Figure (A)].[1] We are concerned that these legal changes make it easier for minors to access marijuana. In fact, one study performed in Washington state found that legal, nonmedical marijuana predicted a higher likelihood of self-reported past year marijuana use among 10-20-year-olds.[2] Whether or not it's related to progressive legalization of marijuana, another study found that adolescent use of marijuana increased by 245% during 2000-2020.[3]

How should we feel about this? Studies have shown that marijuana can be difficult to quit[4] and can be a gateway drug[5]. One study found that habitual marijuana use may cause a loss of IQ[6]. Others have found that adolescent marijuana use may increase the chance of adverse psychosocial events[7], as well as increased marijuana use in adulthood[8].

While these are only studies, we are convinced, in part due to personal experience, that it is better to err on the side of caution. In keeping with our concerns, we have developed a mathematical model describing the dynamics of substance abuse in a high school context. Our goal is to examine patterns of marijuana abuse and to propose mitigating strategies.

Research Questions:

- How can we apply our model to understand the dynamics of marijuana abuse in a high school setting?
- How can we use our model to provide strategies to reduce substance abuse in high schools? For example, should we try to convince current marijuana users to stop, or is more effective to deter young people from using marijuana before they have the chance to start?

Figure (A)[1]

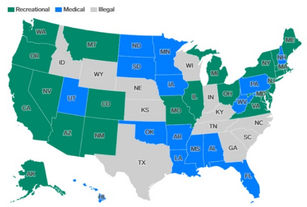
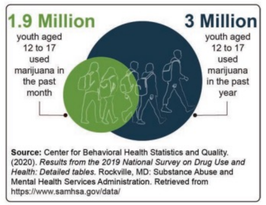
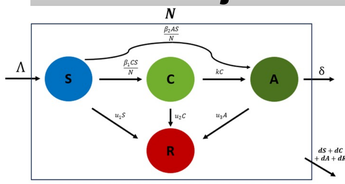


Figure (B)[8]

Graphic made in 2020. Last year = 2019.



Pre-existing Research: Marijuana Use Model For Adults[9]



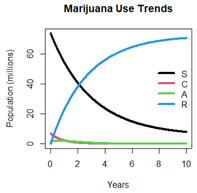
$$N(t) = S(t) + C(t) + A(t) + R(t)$$

$$\frac{dS}{dt} = \Lambda - \frac{\beta_1 CS}{N} - \frac{\beta_2 AS}{N} - dS - u_1 S$$

$$\frac{dC}{dt} = \frac{\beta_1 CS}{N} + \frac{\beta_2 AS}{N} - kC - u_2 C - dC$$

$$\frac{dA}{dt} = kC - u_3 A - \delta A$$

$$\frac{dR}{dt} = u_1 S + u_2 C + u_3 A - dR$$



Groups and Assumptions:

- **Susceptible (*S*)** persons do not use marijuana and never have used it.
- **Casual (*C*)** users smoke occasionally; next are the **Addicted (*A*)** users.
- **Removed (*R*)** persons have developed a "no-smoking" attitude.
- We assume that as time passes, every new adult is in the S group.
- Individuals in the R group stay in this group for the rest of their lives.
- Only A-members are at risk of marijuana induced-death.
- The u_i are seen as control measures, that is, mitigation strategies.

Graph at upper-right:

$S(0) = 73.94, C(0) = 6.85, A(0) = 1.37, R(0) = 0, u_1 = 0.3, u_2 = 0.7, u_3 = 0.7$
$\Lambda = 1.701, d = 0.025, \beta_1 = 0.5, \beta_2 = 0.1, k = 0.5, \delta = 0.085$

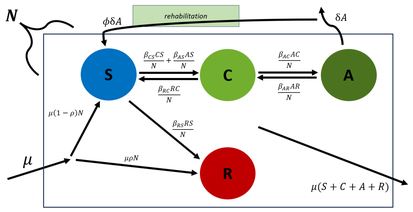
Parameter Definitions

- Λ = recruitment rate into S class, *i.e.*, new adults becoming of age
- β_1 = spread of smoking habit from contact with C class
- β_2 = spread of smoking habit from contact with A class ($\beta_1 < \beta_2$)
- k = progression rate from C to A
- u_1 = removal rate from S to R
- u_2 = removal rate from C to R
- u_3 = removal rate from A to R
- d = natural death rate of population
- δ = marijuana-induced death rate

Acknowledgements

A huge thank you to Dr. Yun Kang; thank you to MAT 350 classmates for your participation.

Modified Model for High School Context



$$N(t) = S(t) + C(t) + A(t) + R(t)$$

$$\frac{dS}{dt} = \mu(1-\rho)N - \frac{\beta_{CS} CS}{N} - \frac{\beta_{AS} AS}{N} - \mu S - \frac{\beta_{RS} RS}{N} + \frac{\beta_{RC} RC}{N} + \phi\delta A$$

$$\frac{dC}{dt} = \frac{\beta_{CS} CS}{N} + \frac{\beta_{AS} AS}{N} - \mu C - \frac{\beta_{CA} AC}{N} - \frac{\beta_{RC} RC}{N} + \frac{\beta_{RA} RA}{N}$$

$$\frac{dA}{dt} = \frac{\beta_{AC} AC}{N} - \mu A - \delta A - \frac{\beta_{RA} RA}{N}$$

$$\frac{dR}{dt} = \mu\rho N + \frac{\beta_{RS} RS}{N} - \mu R$$

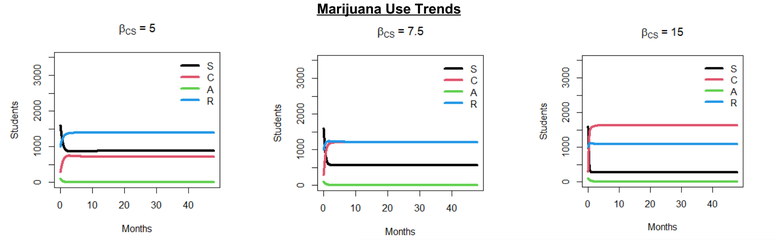
Groups and Assumptions:

- We retain the S, C, A, and R Groups
- We assume that all new students are either S-members or R-members.
- We assume that students cannot skip groups. In other words, they must progress from S to C to A, or from A to C to S to R.
- Again, once students are in the R group, they do not leave.

Parameter Definitions

- μ = ratio of new students to departing students
- ρ = rate of new students in R group
- β_{XY} = spread of smoking habit from interaction between groups X and Y
- δ = marijuana-induced dropout rate
- ϕ = rate of return of rehabilitated marijuana-induced dropout students

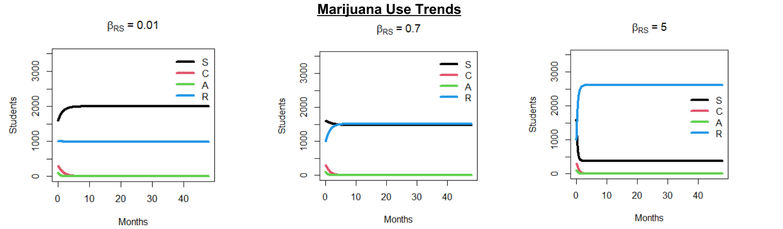
Impact of Group C on Group S (β_{CS})



Parameters:
$N(0) = 3000.$
$S(0) = 1600;\ C(0) = 300;\ A(0) = 100;\ R(0) = 1000.$
$\mu = 1;\ \rho = 0.33; \phi = 0.5; \delta = 0.3.$
All $\beta_{XY} = 1$ (except for β_{CS}).

- There is not sufficient space to show simulation results for all β_{XY}. We simply point out here that β_{CS} is one of the most sensitive β_{XY} parameters.
- This is perhaps to be expected, because the parameter S is relatively large.
- We note that for $\beta_{CS} = 7.5$, C and R become approximately equal in the long term.

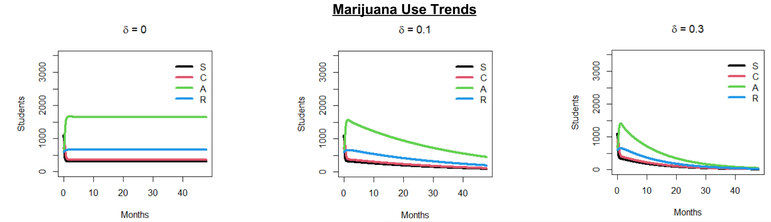
Impact of Group R on Group S (β_{RS})



Parameters:
$N(0) = 3000.$
$S(0) = 1600;\ C(0) = 300;\ A(0) = 100;\ R(0) = 1000.$
$\mu = 1;\ \rho = 0.33; \phi = 0.5; \delta = 0.3.$
All $\beta_{XY} = 1$ (except for β_{RS}).

- β_{RS} is the most sensitive of all the β_{XY} parameters.
- This is because is S and R are relatively large.
- We note that for $\beta_{XY} = 0.7$, C and R become approximately equal in the long term.

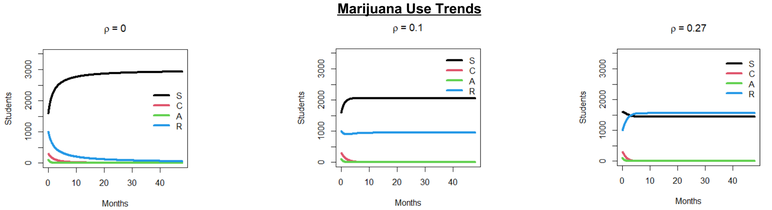
Impact of Marijuana-induced Dropouts (δ)



Parameters:
$N(0) = 3000.$
$S(0) = 1100;\ C(0) = 700;\ A(0) = 600;\ R(0) = 600.$
$\mu = 1;\ \rho = 0.2; \phi = 0.5.$
$\beta_{CS} = \beta_{AS} = \beta_{AC} = 10.$
$\beta_{RS} = \beta_{RC} = \beta_{RA} = 1.$

- The parameter δ was significant under our original assumptions. Thus, for this section only, we chose a more pessimistic scenario.
- Whether δ is zero, small, or large, the A population goes to zero in the long term.
- If the A-group does not drop out, it is eventually influenced down to zero by the $-\frac{\beta_{RA} RA}{N}$ term.

Impact of Removed Population (ρ)



Parameters:
$N(0) = 3000.$
$S(0) = 1600;\ C(0) = 300;\ A(0) = 100;\ R(0) = 1000.$
$\mu = 1;\ \phi = 0.5; \delta = 0.3.$
All $\beta_{XY} = 1$.

- Back to our original scenario - the parameter ρ is more sensitive. We see an important impact across the different simulations shown above.
- With ρ approximtely 0.26 we start to see the R-group become larger that the S group in the long term ($\rho = 0.27$ shown because the graph is clearer).

Conclusions

- From our simulations, we found that the most sensitive β_{XY} parameters (i.e., influence parameters) are β_{CS} and β_{RS}. In other words, the C-group is powerful to influence nonsmokers to begin using marijuana casually, and the R-group is powerful to influence S-members to develop a "no-smoking" attitude. We found that β_{RS} is more sensitive than β_{CS}.
- In conjunction with this, we found that the parameter ρ is relatively sensitive. In other words, the number of students entering the high school with a preexisting, firm "no-smoking" attitude has a powerful long-term effect on the sizes of the groups (S, C, A, R).
- From this, we conclude that an effective strategy at reducing marijuana abuse among adolescents (high school students) is family attitudes, home environment, and early life education about drug abuse, as well as preparation for the temptations which will likely present themselves once young people enter high school life.
- Conversely, the parameter δ had relatively little long-term effect on the group sizes. However, when we ran a more pessimistic simulation, we found that δ is more sensitive: when δ is approximately 0.4 or greater, the school will eventually be empty.

Citations

1. Berke, Jeremy; Gal, Shayanne, Lee, Yeji Jesse. (2023, April 27; ***update**: 2023, November 8*). Delaware just became the latest state to legalize recreational marijuana. See a list of every state where cannabis is legal. *Business Insider*. Retrieved from: https://www.businessinsider.com/legal-marijuana-states-2018-1
2. Bailey, Jennifer A.; et al. (2020, July 9). Marijuana Legalization and Youth Marijuana, Alcohol, and Cigarette Use and Norms. *American Journal of Preventive Medicine. Vol. 59* (Issue 3) p. 309-468. Retrieved from https://www.ajpmonline.org/article/S0749-3797(20)30188-4/fulltext
3. Rideout, Nicole. (2022, December 7). Teen cannabis use has increased 245% over 20 years, study finds. *Oregon Health & Science University News.* Retrieved from https://news.ohsu.edu/2022/12/07/teen-cannabis-abuse-has-increased-245-over-20-years-study-finds
4. Patel, Jason; Marwaha, Raman. (2023, January). Cannabis Use Disorder. *StatPearls Publishing.* Retrieved from https://www.ncbi.nlm.nih.gov/books/NBK538131/
5. Secades-Villa, Roberto; Garcia Rodríguez, Olaya; Jin, Chelsea J.; Wang, Shuai; Blanco, Carlos. (2015, February 26). Probability and predictors of the cannabis gateway effect: a national study. *The International journal on drug policy. Vol. 145* (No. 42). Retrieved from https://pubmed.ncbi.nlm.nih.gov/25168081/
6. Weir, Kirsten. (2015, November). Marijuana and the developing brain. *Monitor on Psychology. Vol. 46* (No. 10) p. 48. Retrieved from https://www.apa.org/monitor/2015/11/marijuana-brain
7. Sultan, Ryan S.; Zhang, Alexander W.; Olfson, Mark; et al. (2023, May 3). Nondisordered Cannabis Use Among US Adolescents. Retrieved from https://jamanetwork.com/journals/jamanetworkopen/fullarticle/2804450
8. Substance Abuse and Mental Health Services Administration. (2021). Preventing Marijuana Use Among Youth p. 5. Retrieved from https://store.samhsa.gov/sites/default/files/pep21-06-01-001.pdf
9. Yusuf, Tunde T. (2014). Marijuana Smoking Epidemics Among Adults: An Optimal Control Panacea. *Columbia International Publishing Journal of Modeling, Simulation, Identification, and Control. Vol. 2* (No. 2) p. 83-97. Retrieved from https://www.academia.edu/54914274/Modelling_Marijuana_Smoking_Epidemics_among_Adults_An_Optimal_Control_Panacea