UNITED STATES MILITARY ACADEMY
WEST POINT.

Developing Systems Models: An example of Explainable AI

September 2, 2021

Outline

- Introduction to Systems Models as Explainable AI
- How can we increase physical activity in a community?
  - Systems Model Development
  - Data Exploration Informed by Model
  - Model informed Recommendations
- How can we leverage systems models to understand multi-scale influences on outcomes?
  - Systems model for obesity
- Summary

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Systems Models as Explainable AI

REAL WORLD

1. <u>TRANSFORM</u>

Transform the real world problem into a mathematical formulation

- State variables, parameters, assumptions, model formulation

MATHEMATICAL MODEL

<u>2. SOLVE</u>

Numerically fit parameters and initial conditions, perform theoretical analysis, and solve in closed form or numerical simulation

- Describe parameter estimation in terms of its effect on simulations and graphs
- Describe initial conditions estimations
- Determine qualitative model solution properties (non-negativity, intercepts)

MATHEMATICAL SOLUTION

<u>3. INTERPRET</u>

Evaluate how the model informs the solution to the real-world problem

- Conduct sensitivity analysis
- Outline limitations so that the model doesn't get overextended/misinterpreted

Iterative Process

How can we increase physical activity in a community?

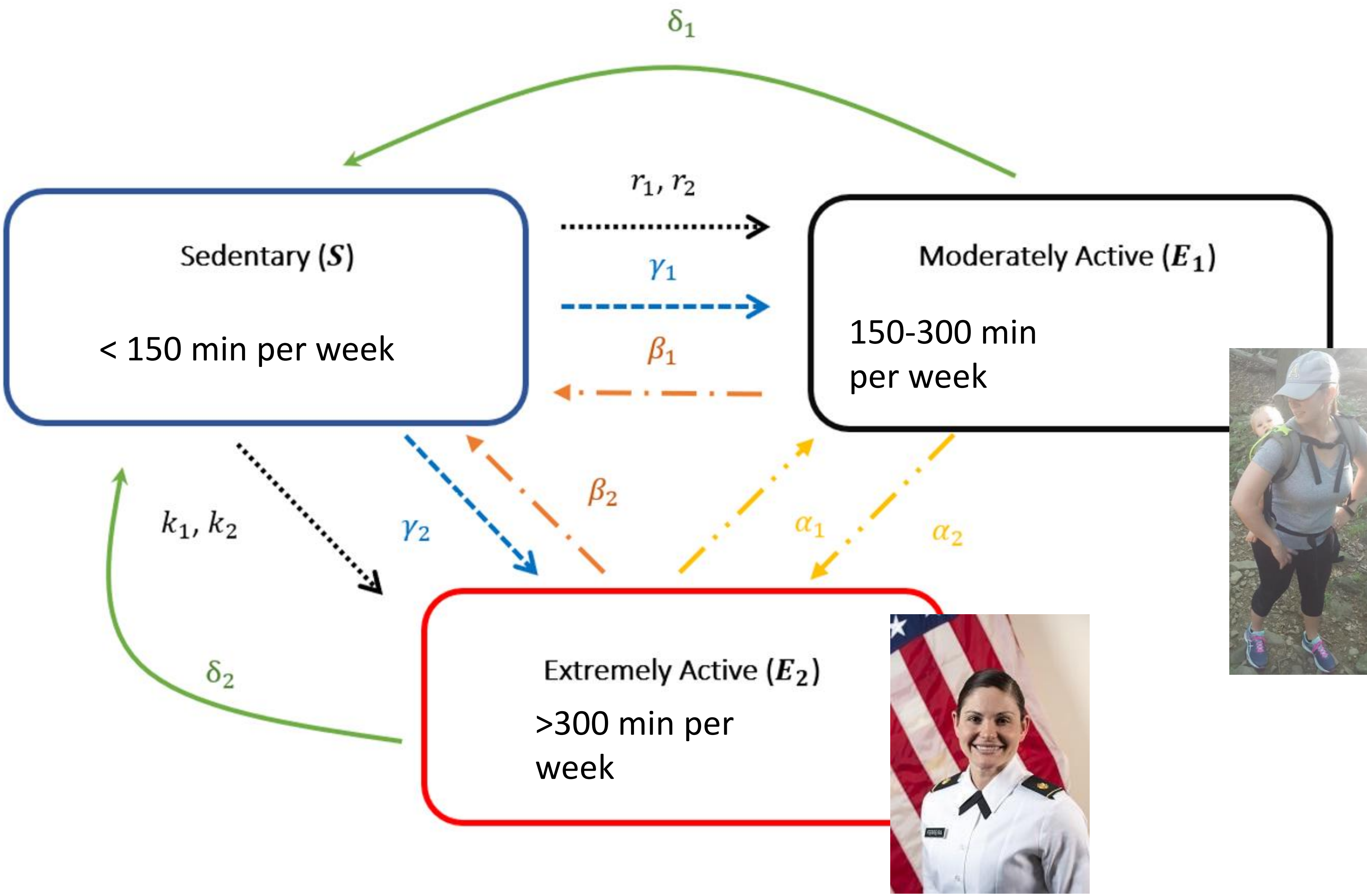
With: Dr. Ensela Mema, LTC Lee Evans, COL Nicholas Gist, COL Everett Spain

How can we increase physical activity in a community?

- 27% of the faculty are civilian academics and the other 73% are active-duty military.
- Military faculty, 50% are serving for only two-to-three years at West Point
- Military faculty also reside on site
- Military and civilian faculty are able to use the gym
- New faculty (civilian and military) participate in a one-and-a-half-month new instructor orientation
  - Includes several physical activities designed to socially connect

The semi-closed and socially connected environment at West Point allows us to investigate **key social dynamics** that motivate **improved physical activity** and to isolate the conditions required to maintain these behaviors

Increase PA: Transform



Increase PA: Transform

$S(t) =$ the number of sedentary individuals in the population on week t

$E_1(t) =$ the number of moderately active individuals in the population on week t

$E_2(t) =$ the number of extremely active individuals in the population on week t

Increase PA: Transform

(A1) A constant population can be **compartmentalized** into Sedentary, Moderately Active, Extremely Active
(A2) **Social interactions** between compartments are **modeled as a product** of population numbers in each compartment.
(A3) Mobility between compartments occurs both from (i) **social interaction** and (ii) **non-social factors**.
(A4) Social interactions between members of the exposed compartment (i.e., mobility between E_1 to E_2 and vice versa) is modeled linearly.
(A5) A fraction of the population will transition from susceptible to exposed due to non-social factors. This transition is modeled linearly.
(A6) Exposed individuals may transition to the susceptible compartment as a result of social interactions or due to non-social factors (e.g. due to an injury).

Social interactions are modeled through the law of mass action while non-social transition is modeled linearly.

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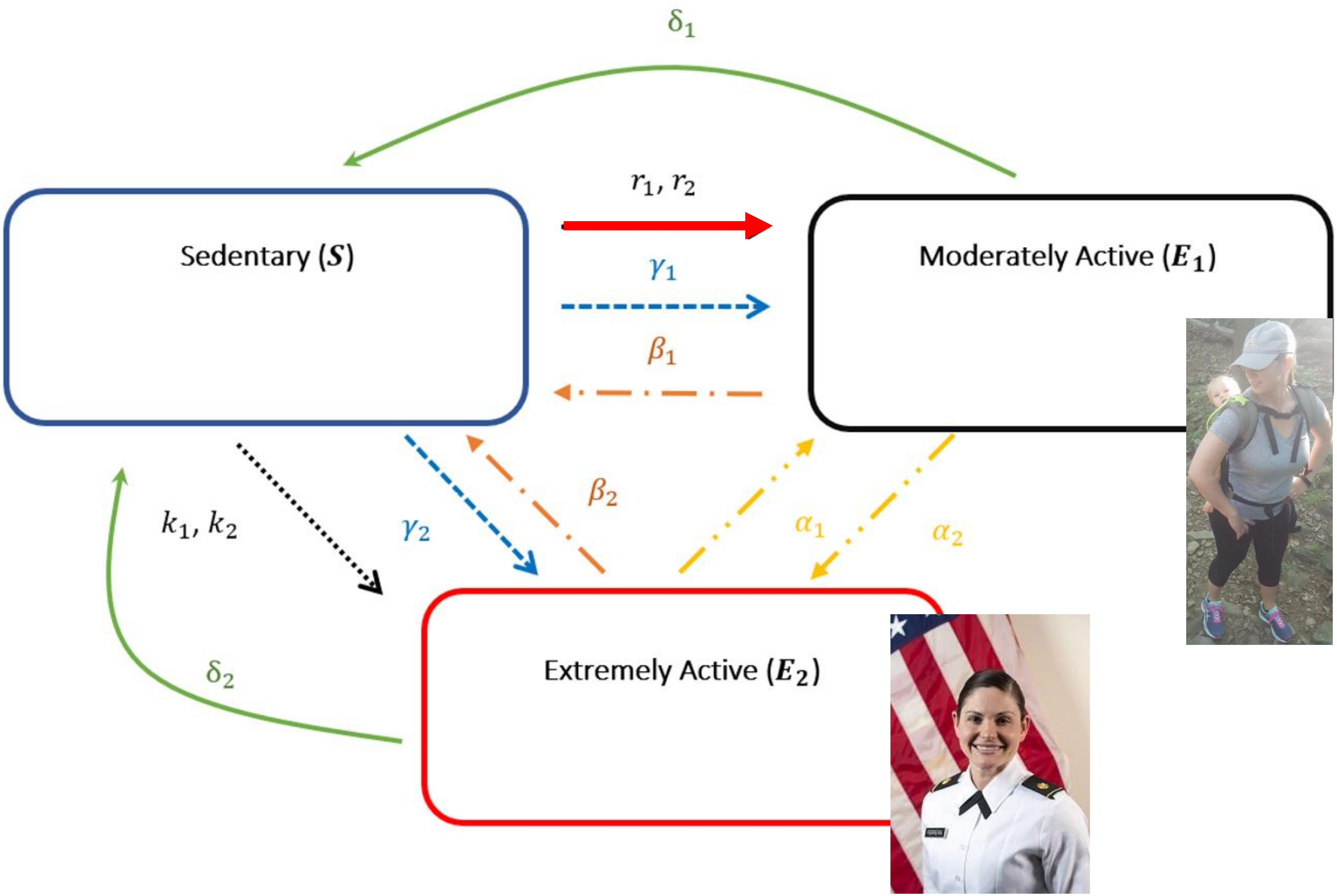
Increase PA: Transform



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Increase PA: Mathematical Model

$\boldsymbol{S'(t)}$

$$= \beta_1 \frac{E_1(t)S(t)}{N} - \boldsymbol{r_1 \frac{S(t)E_1(t)}{N}} - \boldsymbol{r_2 \frac{S(t)E_2(t)}{N}} - \gamma_1 S(t) + \beta_2 \frac{S(t)E_2(t)}{N} - k_1 \frac{S(t)E_1(t)}{N(t)} - k_2 \frac{S(t)E_2(t)}{N} - \gamma_2 S(t) + \delta_1 \mathrm{E}_1(\mathrm{t}) + \delta_2 E_2(t)$$

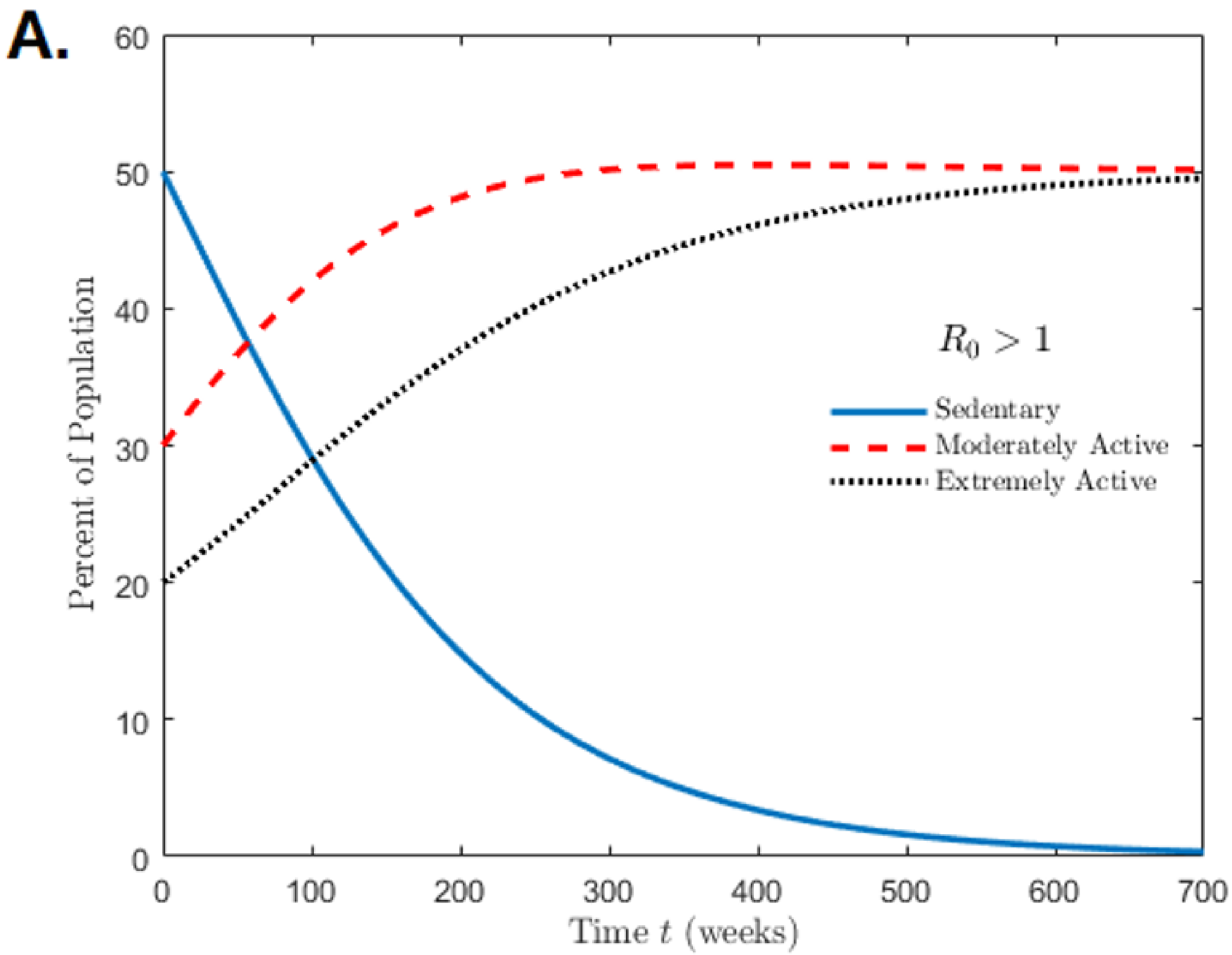
$\boldsymbol{E_1'(t)}$

$$= \boldsymbol{r_1 \frac{S(t)E_1(t)}{N}} + \boldsymbol{r_2 \frac{S(t)E_2(t)}{N}} + \gamma_1 S(t) - \beta_1 \frac{E_1(t)S(t)}{N} - \alpha_2 E_1(t) + \alpha_1 E_2(t) - \delta_1 E_1(t)$$

$\boldsymbol{E_2'(t)}$

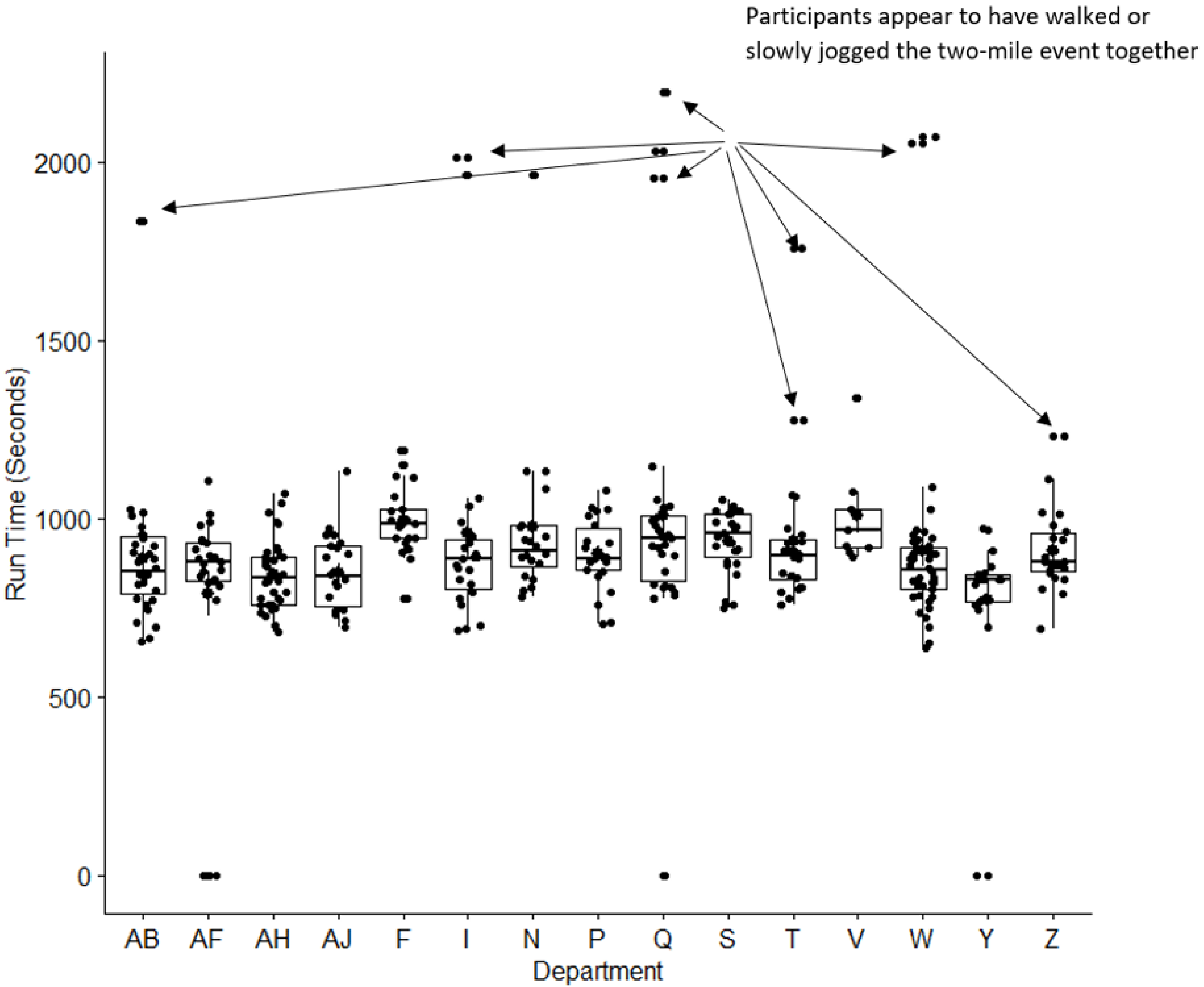
$$= k_1 \frac{S(t)E_1(t)}{N} + k_2 \frac{S(t)E_2(t)}{N} + \gamma_2 S(t) - \alpha_1 E_2(t) + \alpha_2 E_1(t) - \beta_2 \frac{E_2(t)S(t)}{N} - \delta_2 E_2(t)$$

Increase PA: Mathematical Solution

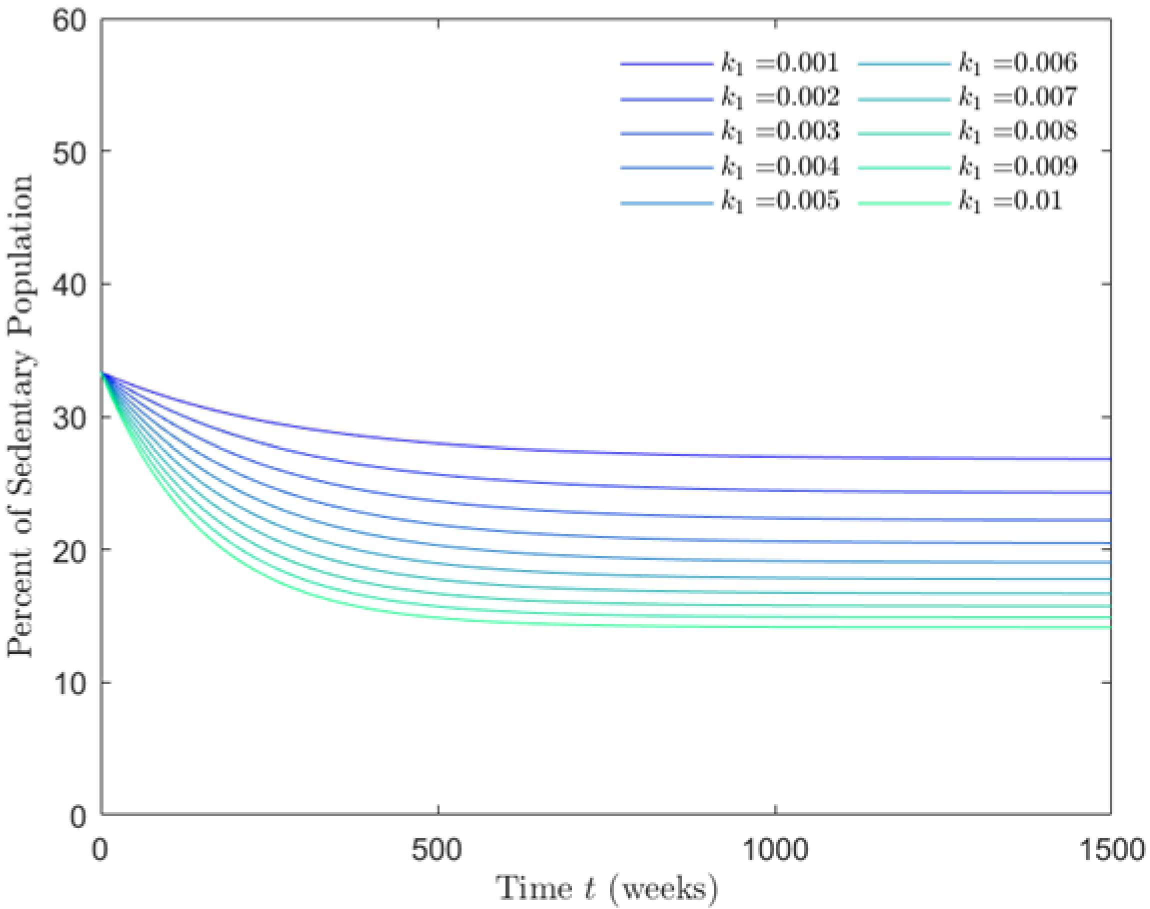


$$R_0 = \frac{(k_1 + r_1)\frac{S_0}{N}}{\beta_1 \frac{S_0}{N} + \delta_1}$$

Social draw to exercise, must **dominate over "drop out"**


Participants appear to have walked or slowly jogged the two-mile event together
Run Time (Seconds)
2000
1500
1000
500
0
AB
AF
AH
AJ
F
I
N
P
Q
S
T
V
W
Y
Z
Department

Increase PA: Mathematical Solution



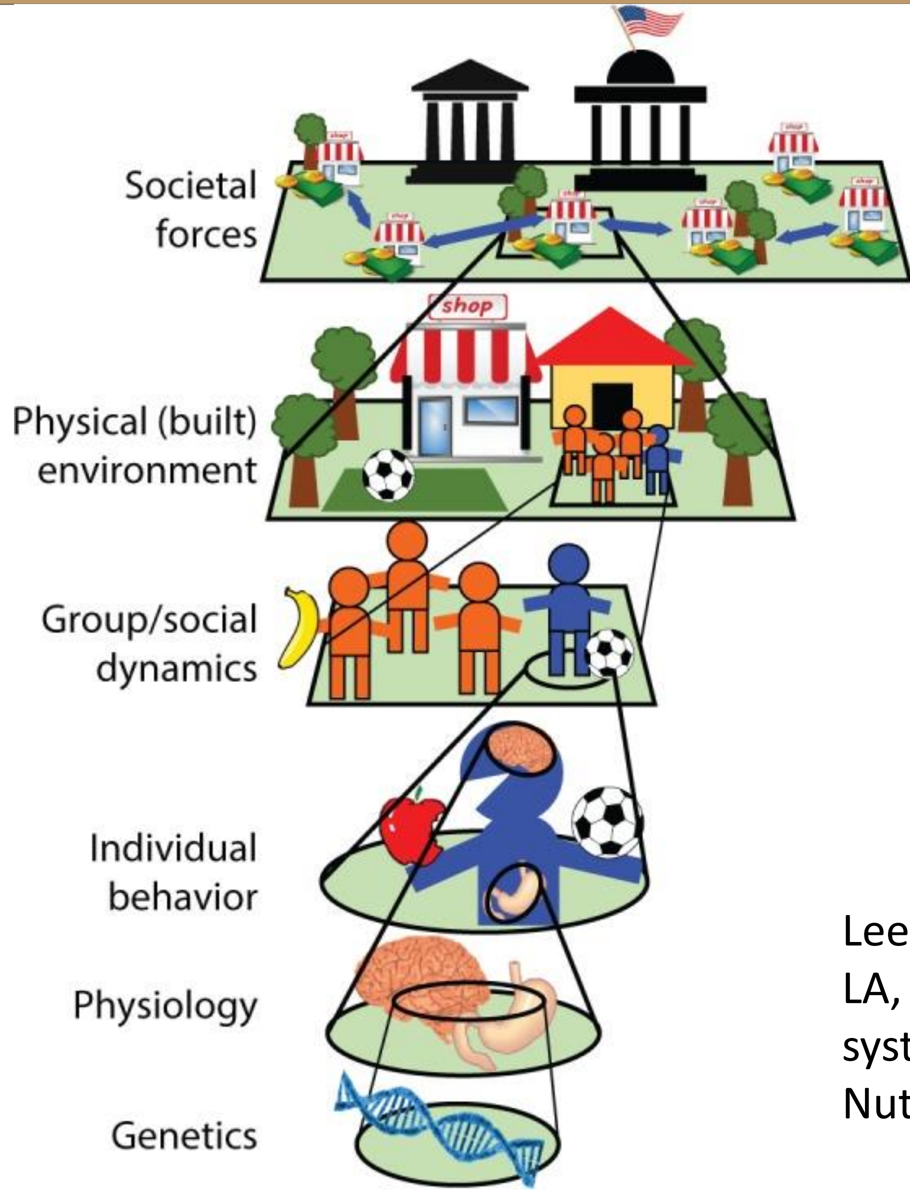
Increasing spontaneous parameters led to a 20% decrease in the sedentary population plateau. **Increasing the social interaction terms** led to **13% to 16% decrease** in the sedentary population plateau. **The spontaneous transition** terms increased the **sedentary individual plateau by 28%** while the **social interaction recidivism** terms **increased the plateau by 21%**.

Tells me where to focus attention-where to collect data

Increase PA: Recommendations

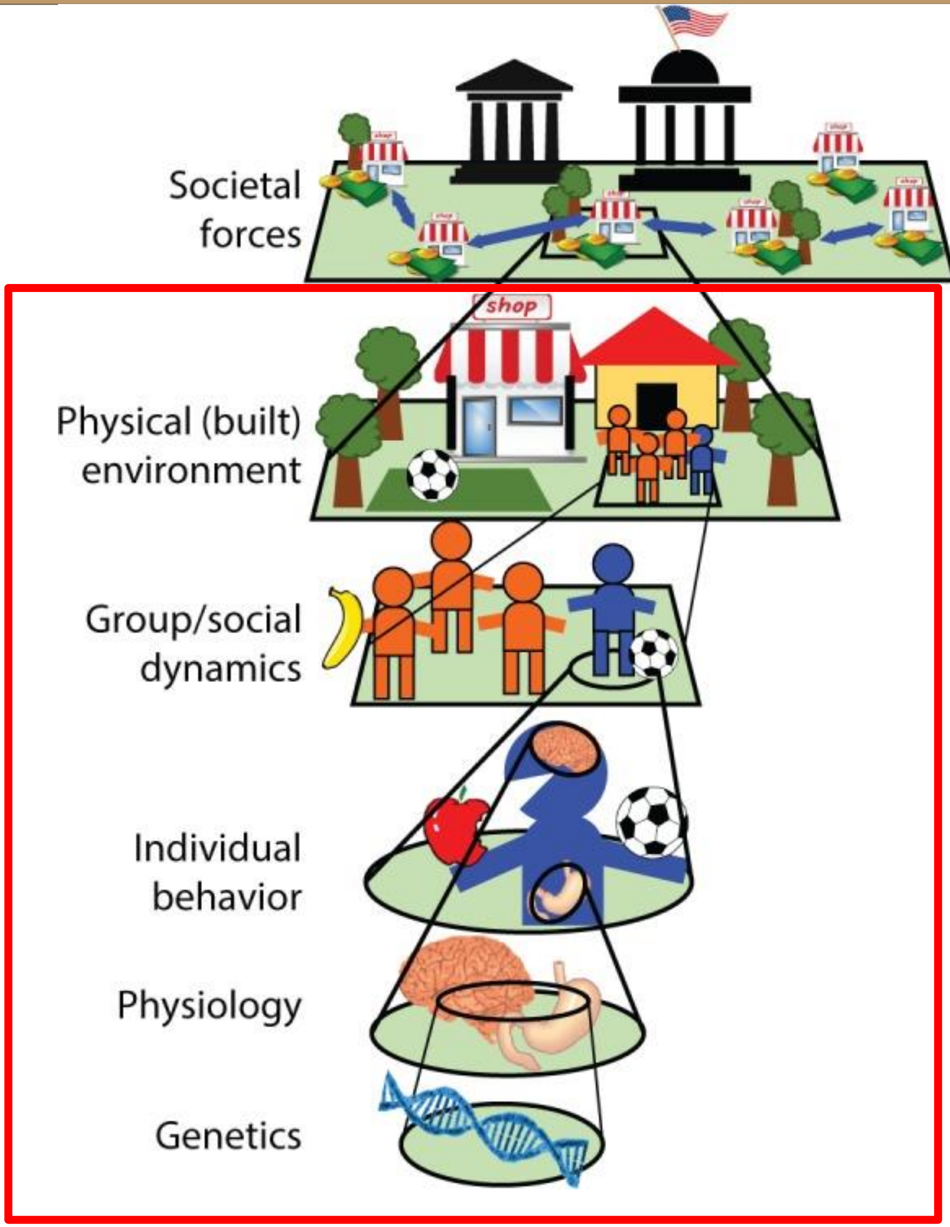
- **Develop social activities engineered** to increase positive interaction between sedentary and moderately active individuals.
  - Design moderately active social events such as volleyball games
  - Informational meetings can be achieved while walking
  - Scavenger hunt or obstacle course type moderately active engagements similar to those designed for West Point new instructor orientation.
- **Reduce participant physical activity burden**
  - Easy access to gyms, recreational facilities, and/or equipment
  - Develop exercise programs that have convenient timings and are feasible for busy schedules
- **Reduce recidivism by moderately active individuals** by increasing participant investment in the process.
  - Develop mechanisms for continually and deliberately obtaining participant feedback on challenges and burdens that impact retention
  - Involve participants in intervention design

Systems Model for Obesity



Lee BY, Bartsch SM, Mui Y, Haidari LA, Spiker ML, Gittelsohn J. A systems approach to obesity. Nutr Rev

Systems Model for Obesity



Thomas DM, et al. Dynamic model predicting overweight, obesity, and extreme obesity prevalence trends. Obesity

Ejima K, Thomas DM, Allison DB. A Mathematical Model for Predicting Obesity Transmission with Both Genetic and Nongenetic Heredity. Obesity

Thank you!

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