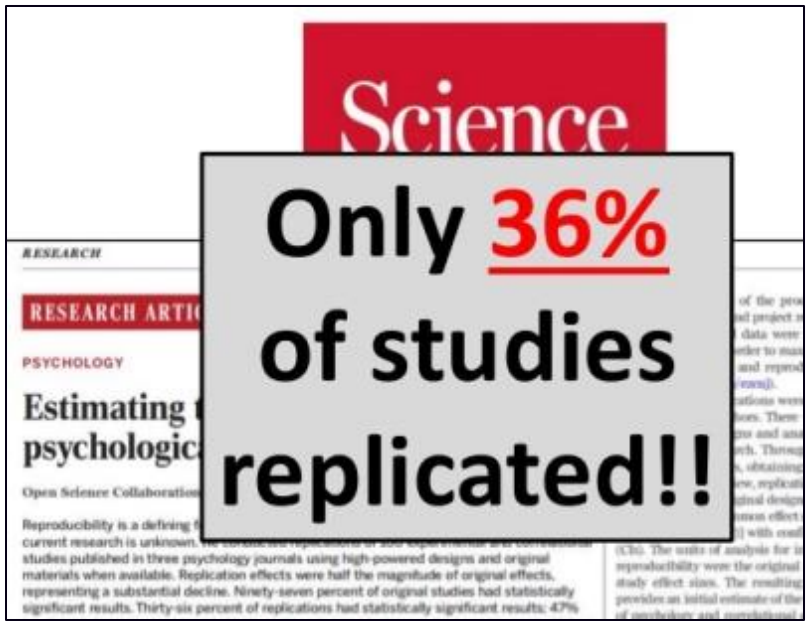
Computational
Clinical Science Lab

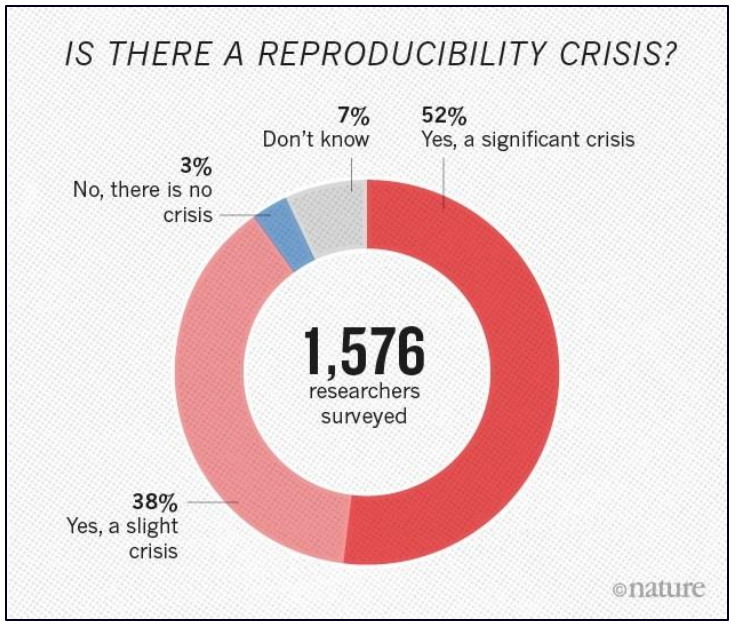
Mathematical and Computational Modeling of Suicide as a Complex Dynamical System

Shirley B. Wang, Ph.D.

Assistant Professor

Dept. of Psychology, Yale University





CENTER FOR OPEN SCIENCE

PREREGISTERED

OPEN DATA

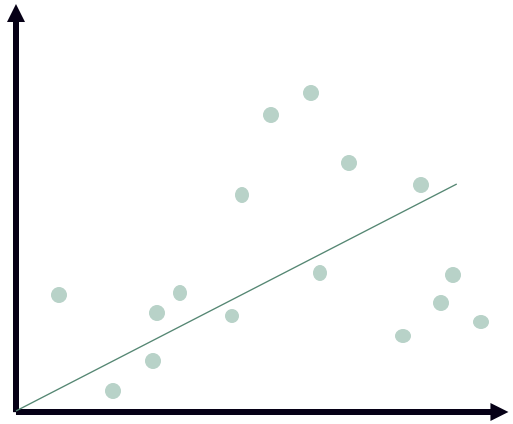
OPEN MATERIALS

"Hopelessness leads to suicidal thoughts."

Scientific Theories

Empirical Research

$p < .05$!



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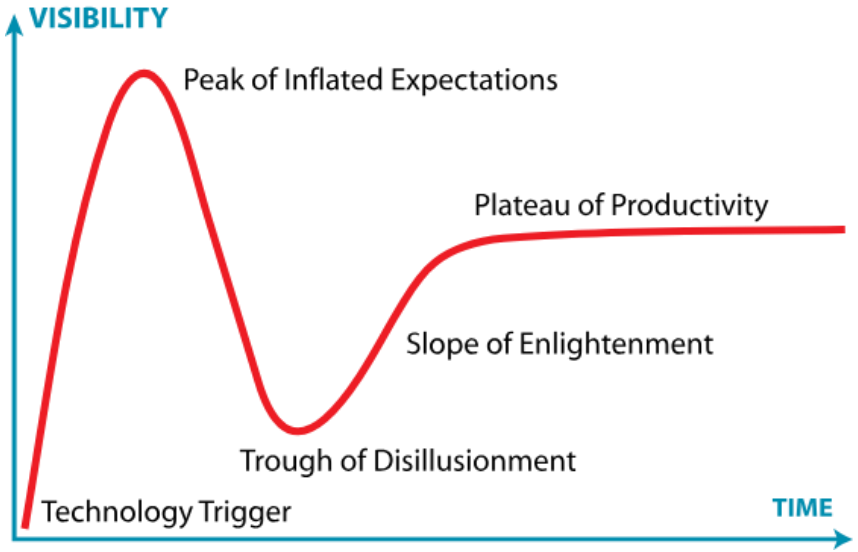
Interventions for Suicide and Self-Injury: A Meta-Analysis of Randomized Controlled Trials Across Nearly 50 Years of Research

"prediction was only slightly better than chance for all outcomes; no broad category or subcategory accurately predicted far above chance levels; ***predictive ability has not improved across 50 years of research****"*



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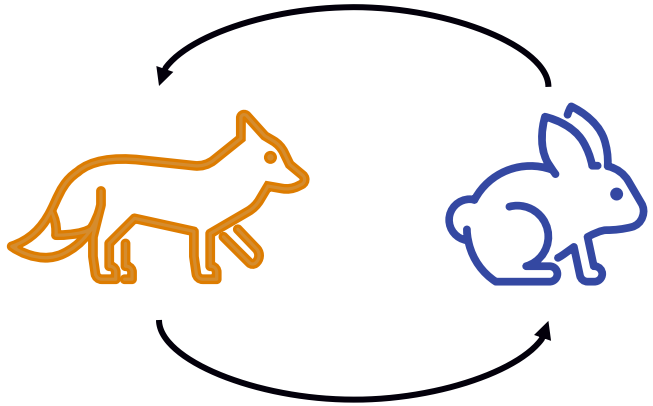
Risk Factors for Suicidal Thoughts and Behaviors: A Meta-Analysis of 50 Years of Research

*"****across five decades, intervention efficacy has not improved****; all interventions produced similarly small effects, and no intervention appeared significantly and consistently stronger than others"*

Verbal vs. *Formal* Theories

"The rate of change in fox & rabbit populations is related to their current population size and frequency of interaction."

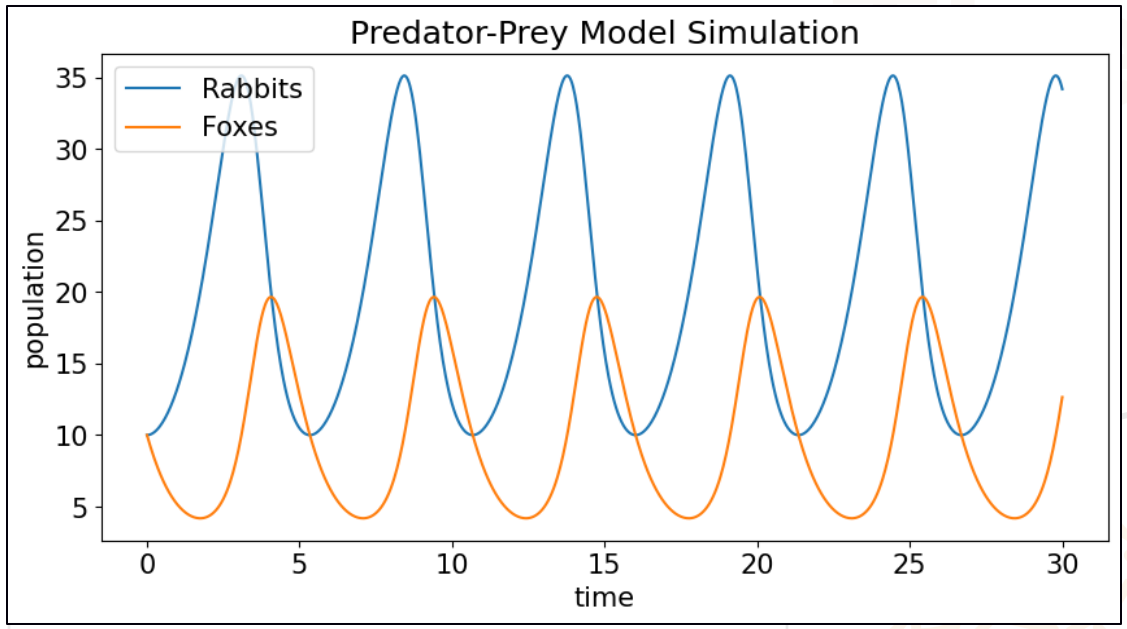


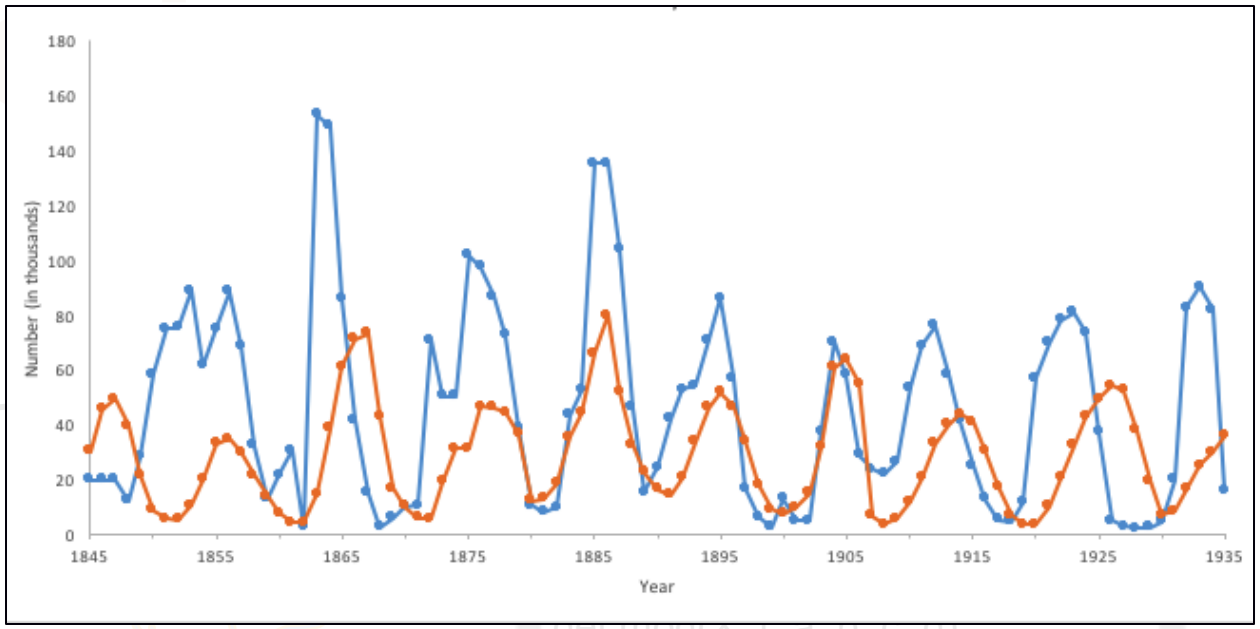
$$\frac{dR}{dt} = \alpha R - \beta RF$$

$$\frac{dF}{dt} = -\gamma F + \delta RF$$

```
def mod(X, t, a, b, c, d):
        dR = a*X[0] – b*X[0]*X[1]
        dF = -c*X[1] + d*X[0]*X[1]
        return(dR, dF)

odeint(mod, X, t, args=(a, b, c, d))
```

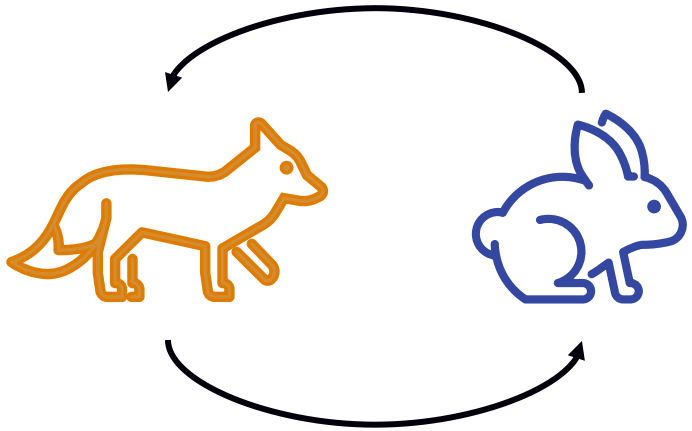


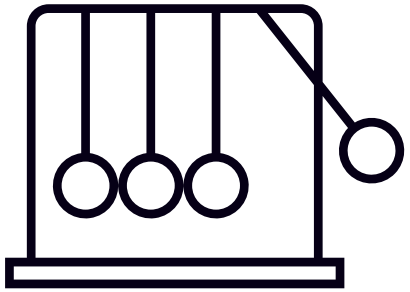


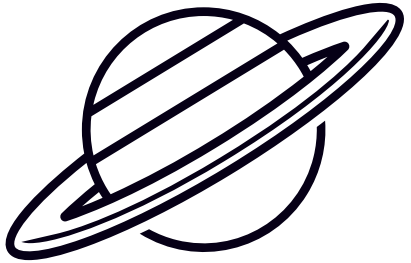
Theory-Implied Data

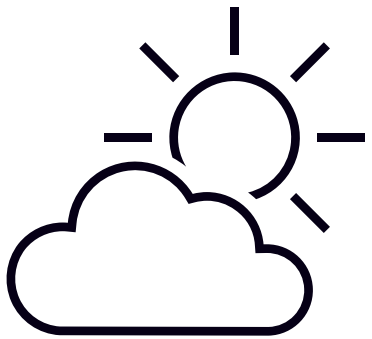
Empirical Data

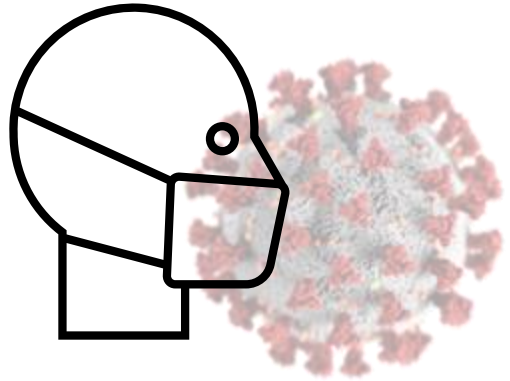
Formal theories guide scientific and clinical discovery



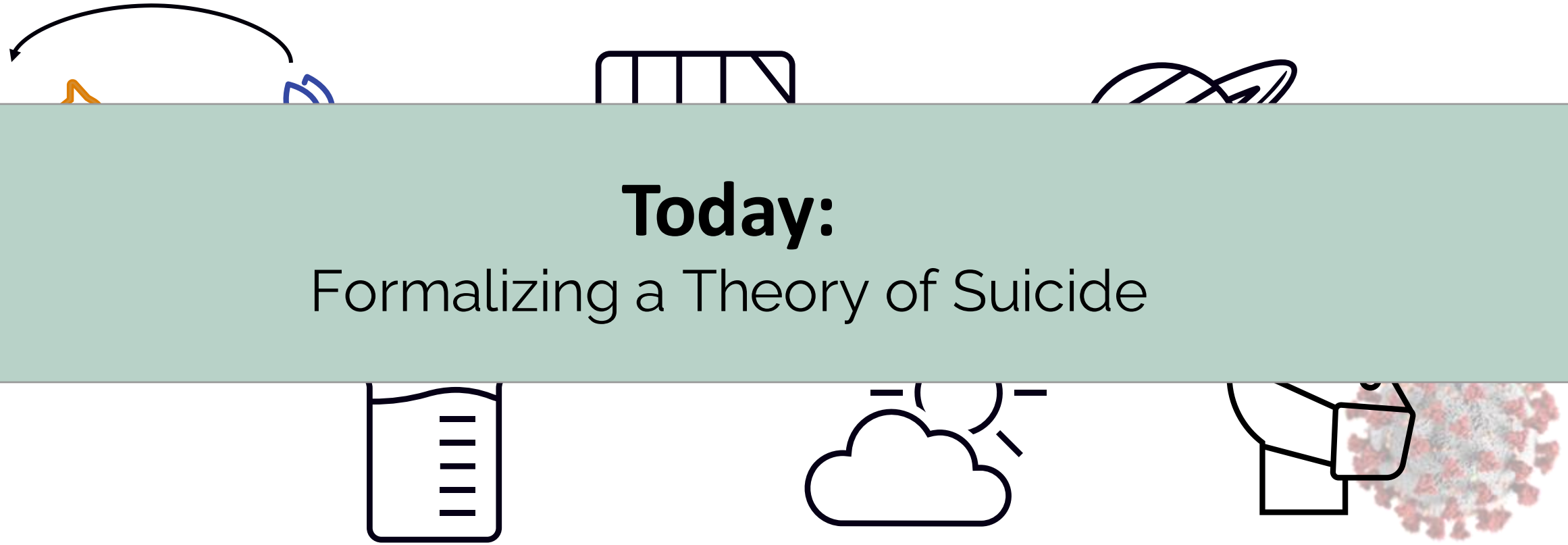








Formal theories guide scientific and clinical discovery



Today:

Formalizing a Theory of Suicide

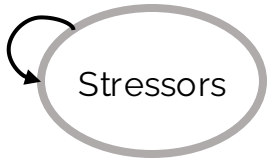
Building a formal theory of suicide

Step 1: Starting with External Stressors

mathematical model (formalization)

$$s_t = s_0 \exp\left(\left(\mu - \frac{\sigma^2}{2}\right)t + \sigma W_t\right)$$

verbal theory



Building a formal theory of suicide

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predictable trends (e.g., chronic, systemic, or structural stressors)

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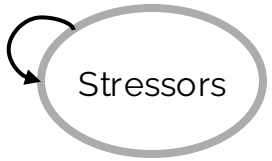

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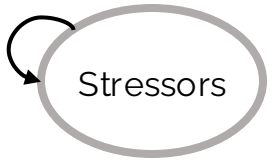
predictable trends (e.g., chronic, systemic, or structural stressors)

unpredictable events (e.g., acute, episodic, or transient stressors)

verbal theory



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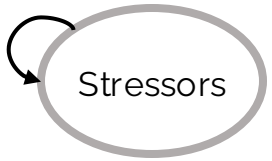
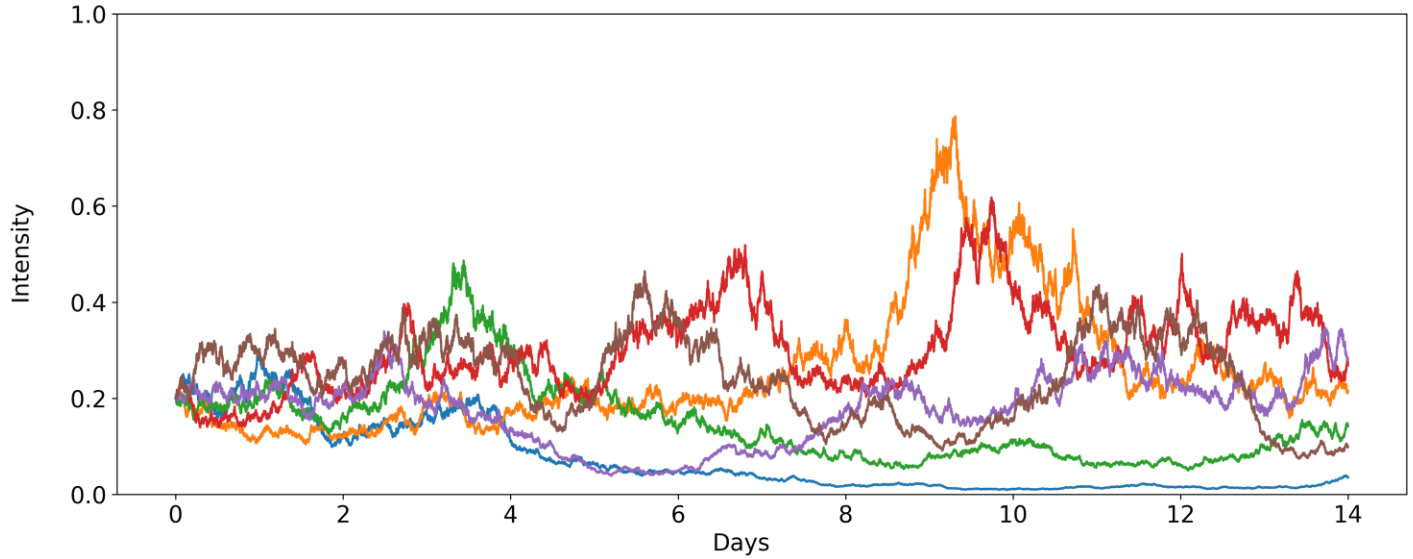


theory-implied data (simulations/realizations)

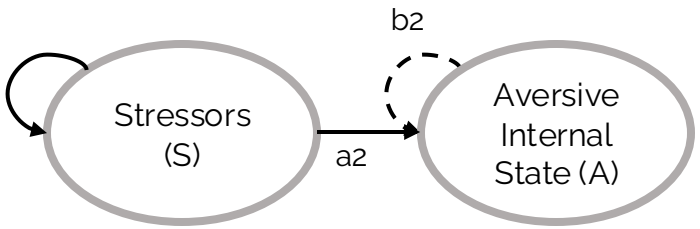


Building a formal theory of suicide

Step 2: Aversive Internal States

$$S_t = S_0 e^{\left(\mu - \frac{\sigma^2}{2}\right)t + \sigma W_t}$$

$$\frac{dA}{dt} = b_2 A(K_2 - A) + a_2 S$$



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(e.g., negative affectivity)

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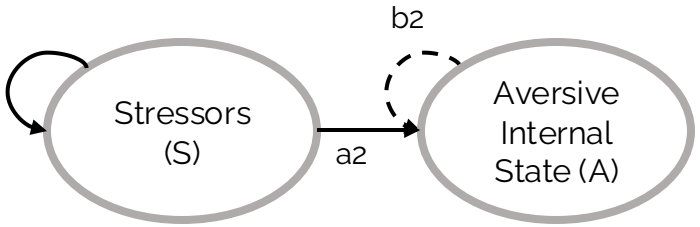

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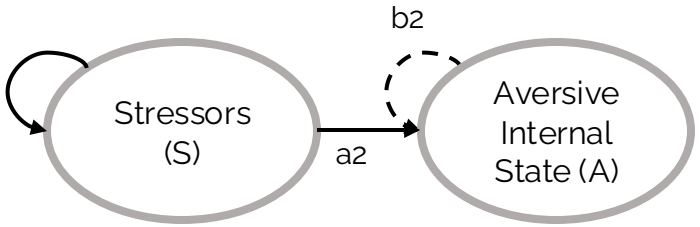

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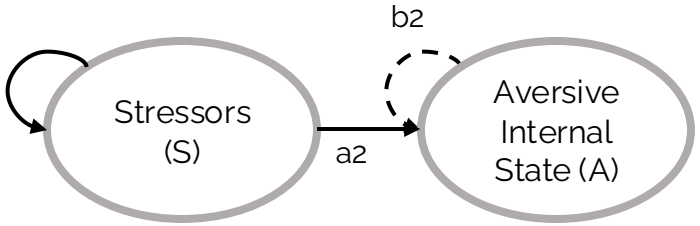

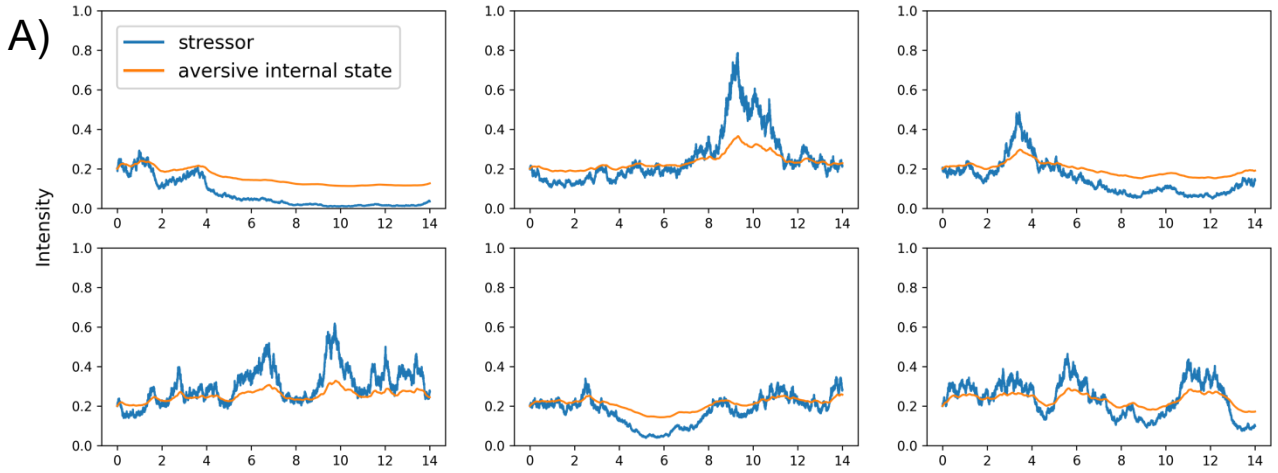

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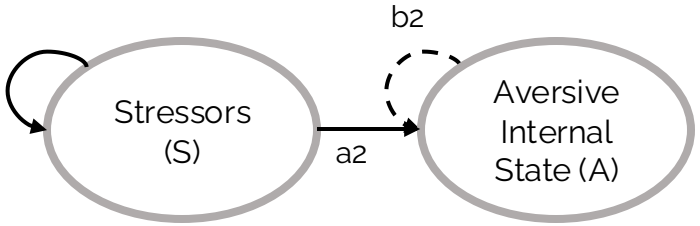
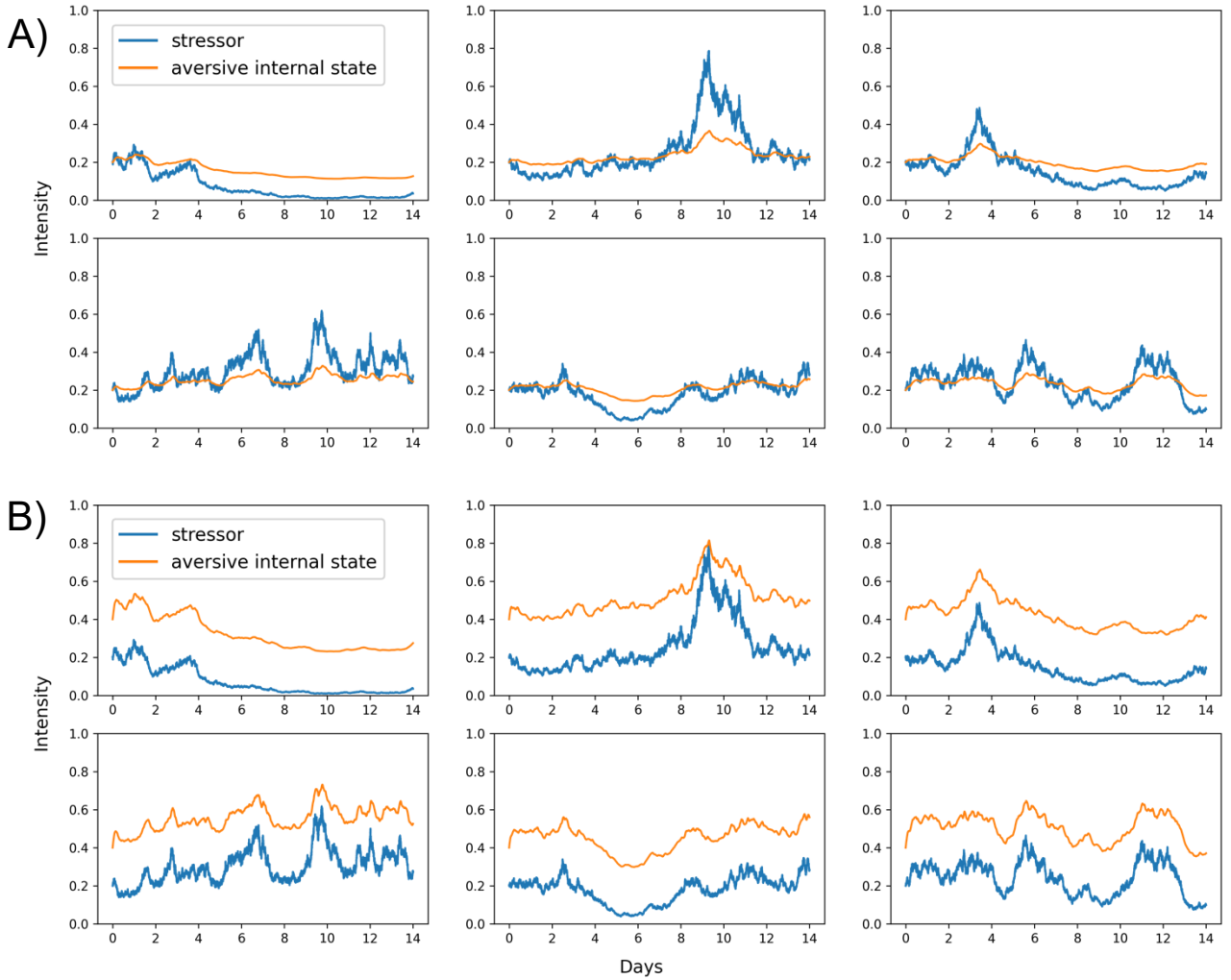




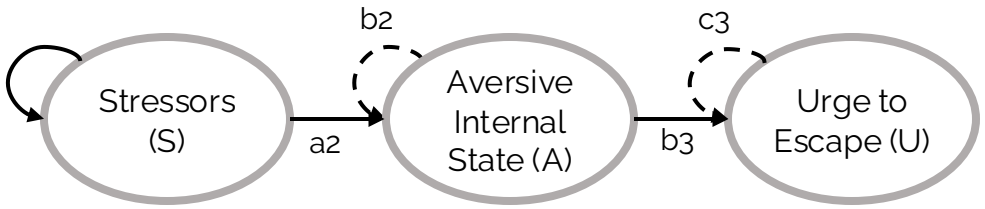
Building a formal theory of suicide

Step 3: Urge to Escape

$$S_t = S_0 e^{\left(\mu - \frac{\sigma^2}{2}\right)t + \sigma W_t}$$

$$\frac{dA}{dt} = b_2 A(K_2 - A) + a_2 S$$

$$\frac{dU}{dt} = -c_3 U + b_3 A$$



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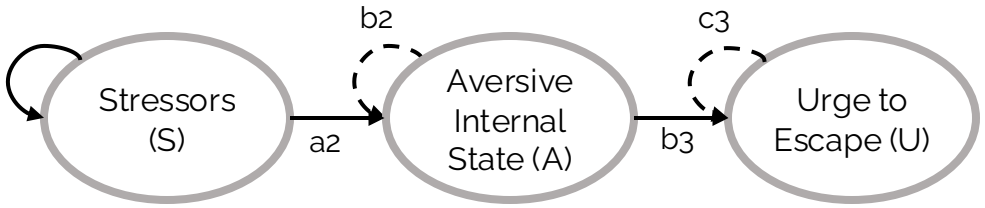
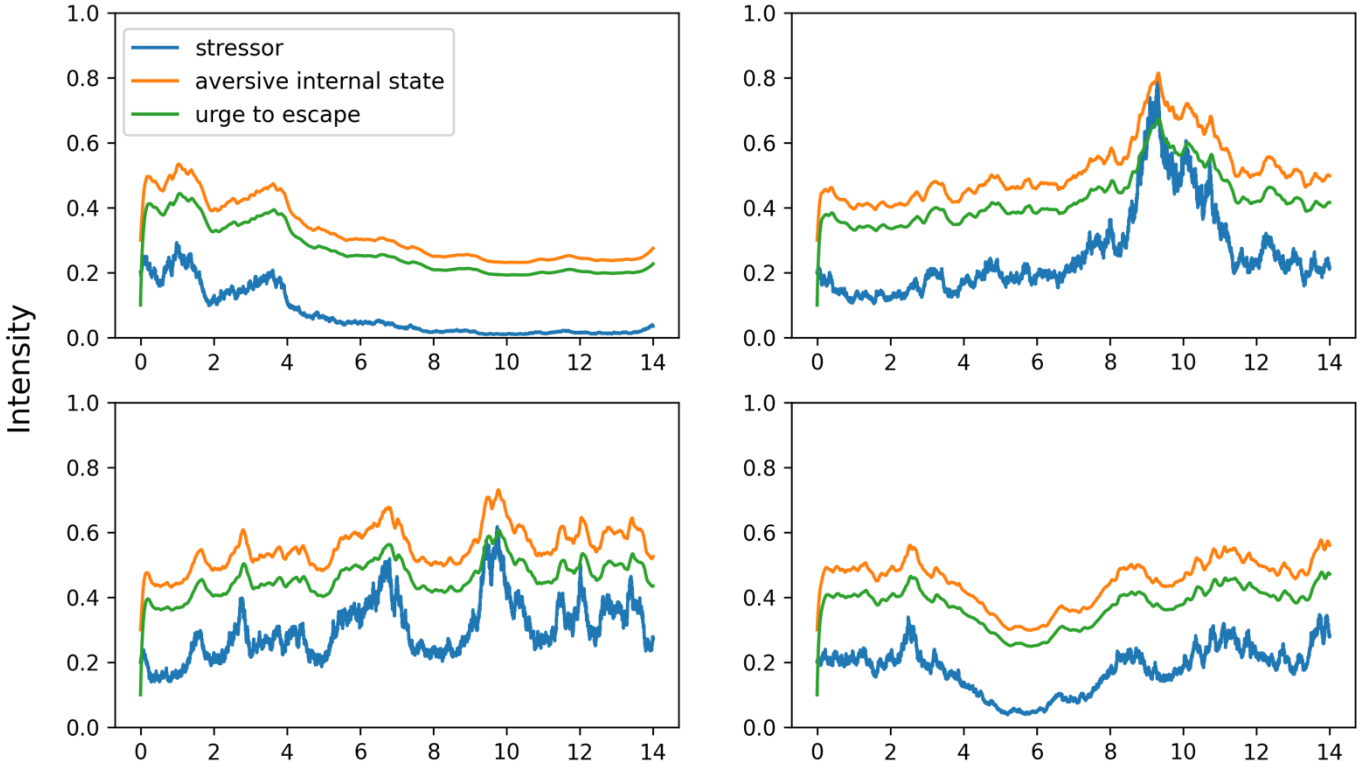




Building a formal theory of suicide

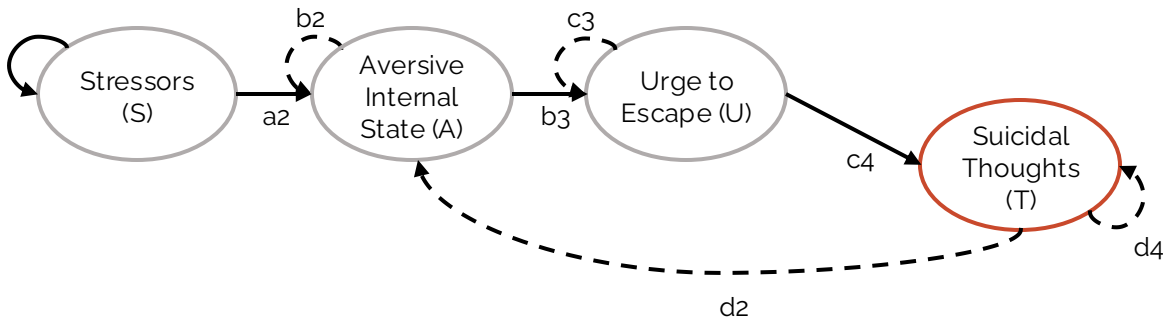
Step 4: Suicidal Thoughts

$$S_t = S_0 e^{\left(\mu - \frac{\sigma^2}{2}\right)t + \sigma W_t - f_1 E}$$

$$\frac{dA}{dt} = b_2 A(K_2 - A) + a_2 S - d_2 T$$

$$\frac{dU}{dt} = -c_3 U + b_3 A$$

$$\frac{dT}{dt} = -d_4 T + \frac{1}{1 + e^{-c_{41}(U - c_{42})}}$$



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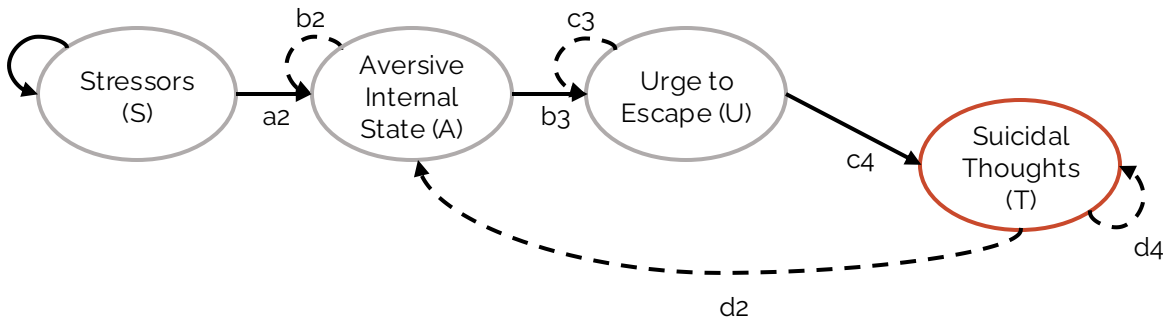

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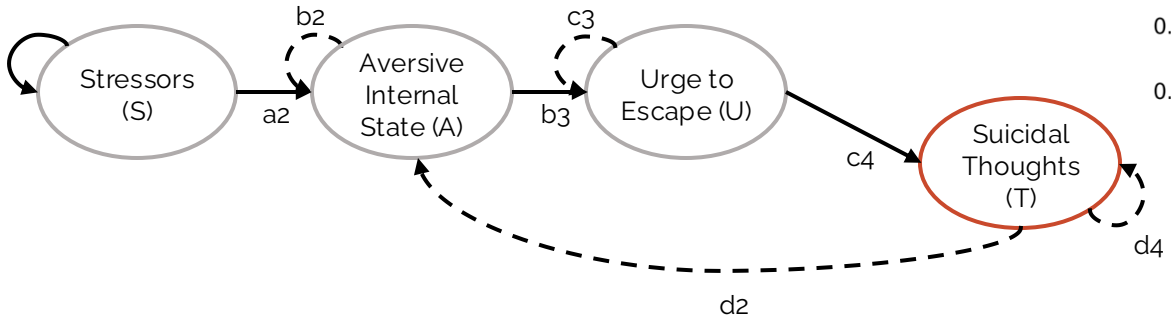
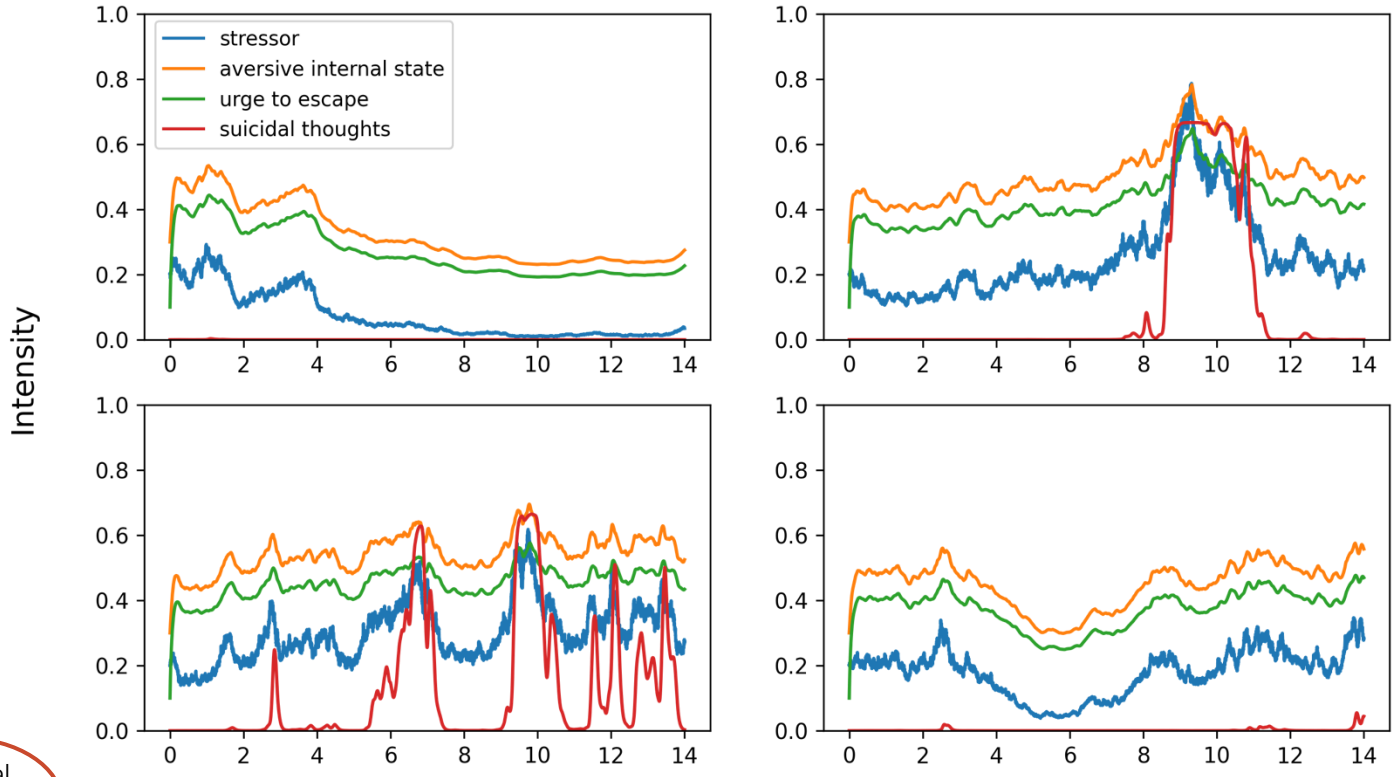




Building a formal theory of suicide

Final Step (for today): Escape behaviors

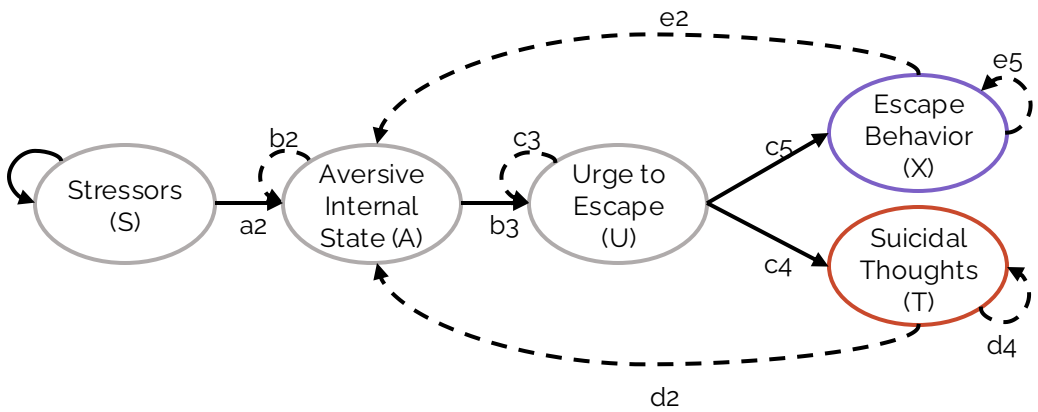
$$S_t = S_0 e^{\left(\mu - \frac{\sigma^2}{2}\right)t + \sigma W_t - f_1 E}$$

$$dA/dt = b_2 A(K_2 - A) + a_2 S - d_2 T - e_2 X$$

$$dU/dt = -c_3 U + b_3 A$$

$$dT/dt = -d_4 T + \frac{1}{1 + e^{-c_{41}(U - c_{42})}}$$

$$dX/dt = -e_5 X + \frac{1}{1 + e^{-c_{51}(U - c_{52})}}$$



Wang et al. (2023)

Simulating a case

Escape behaviors ARE effective

$$S_t = S_0 e^{\left(\mu - \frac{\sigma^2}{2}\right)t + \sigma W_t - f_1 E}$$

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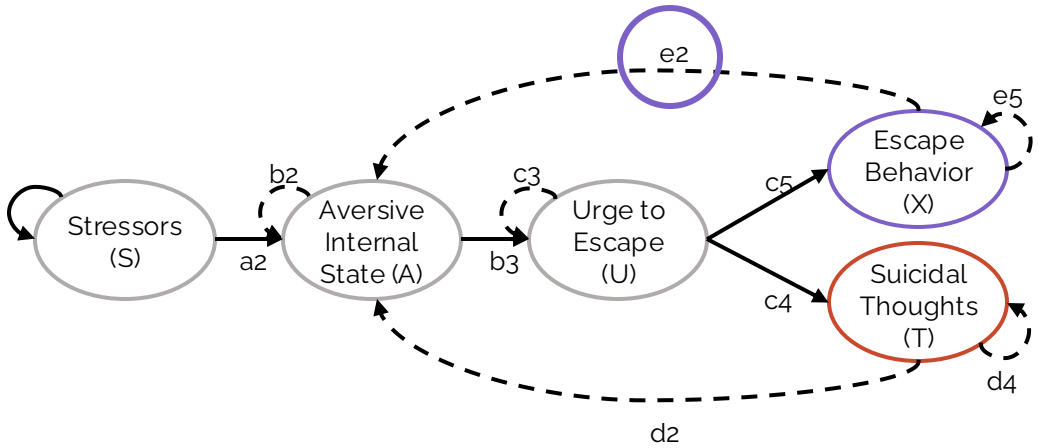

Wang et al. (2023)

Simulating a case

Escape behaviors ARE effective: no suicidal thoughts

$$S_t = S_0 e^{\left(\mu - \frac{\sigma^2}{2}\right)t + \sigma W_t - f_1 E}$$

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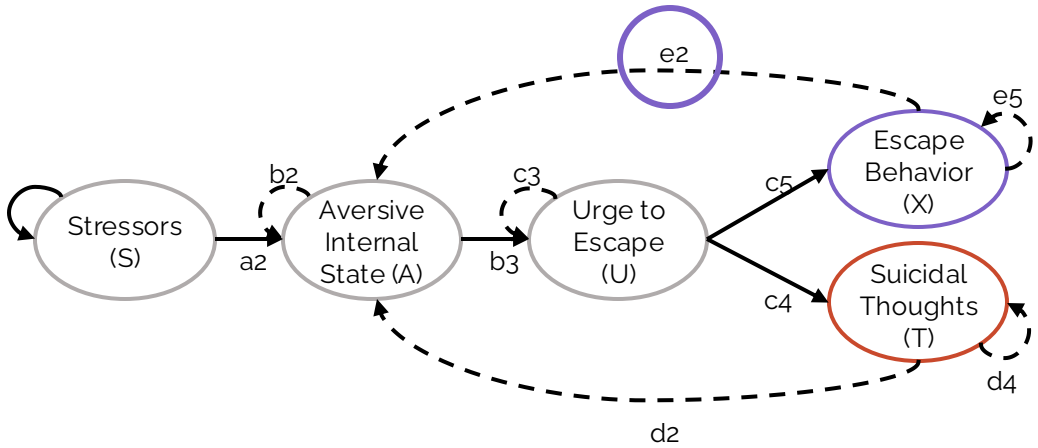

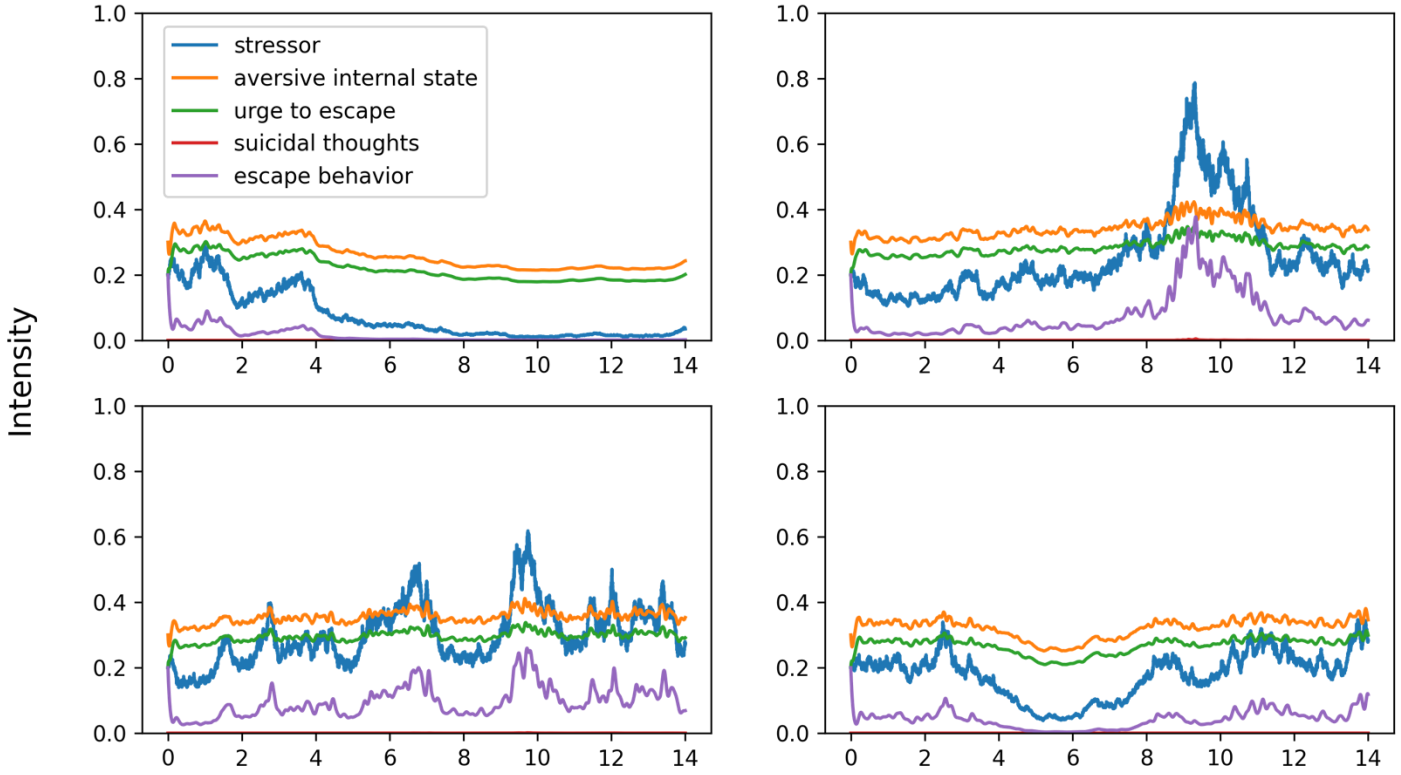

Wang et al. (2023)

Simulating a case

Escape behaviors ARE NOT effective:

$$S_t = S_0 e^{\left(\mu - \frac{\sigma^2}{2}\right)t + \sigma W_t - f_1 E}$$

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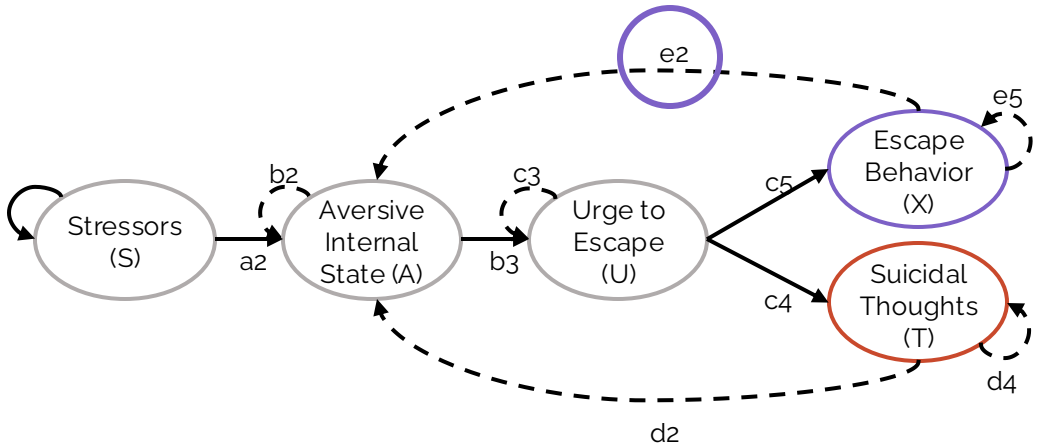

Wang et al. (2023)

Simulating a case

Escape behaviors ARE NOT effective: suicidal thoughts emerge

$$S_t = S_0 e^{\left(\mu - \frac{\sigma^2}{2}\right)t + \sigma W_t - f_1 E}$$

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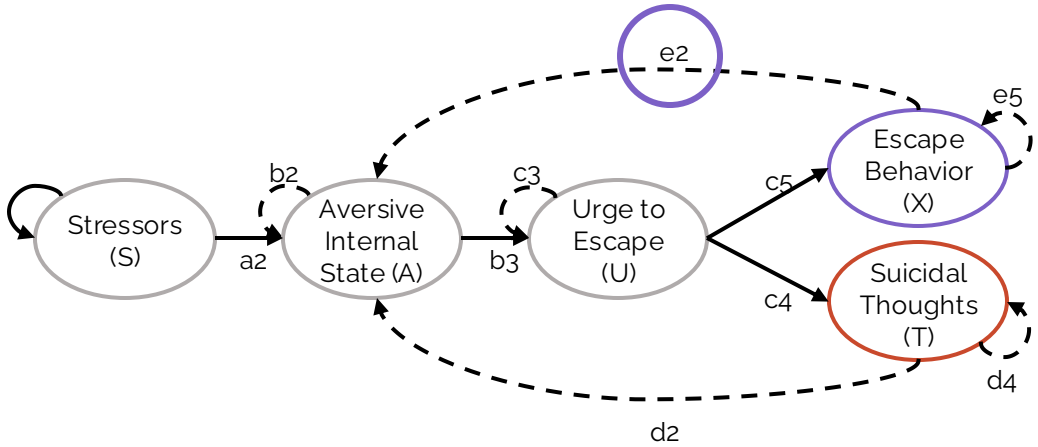
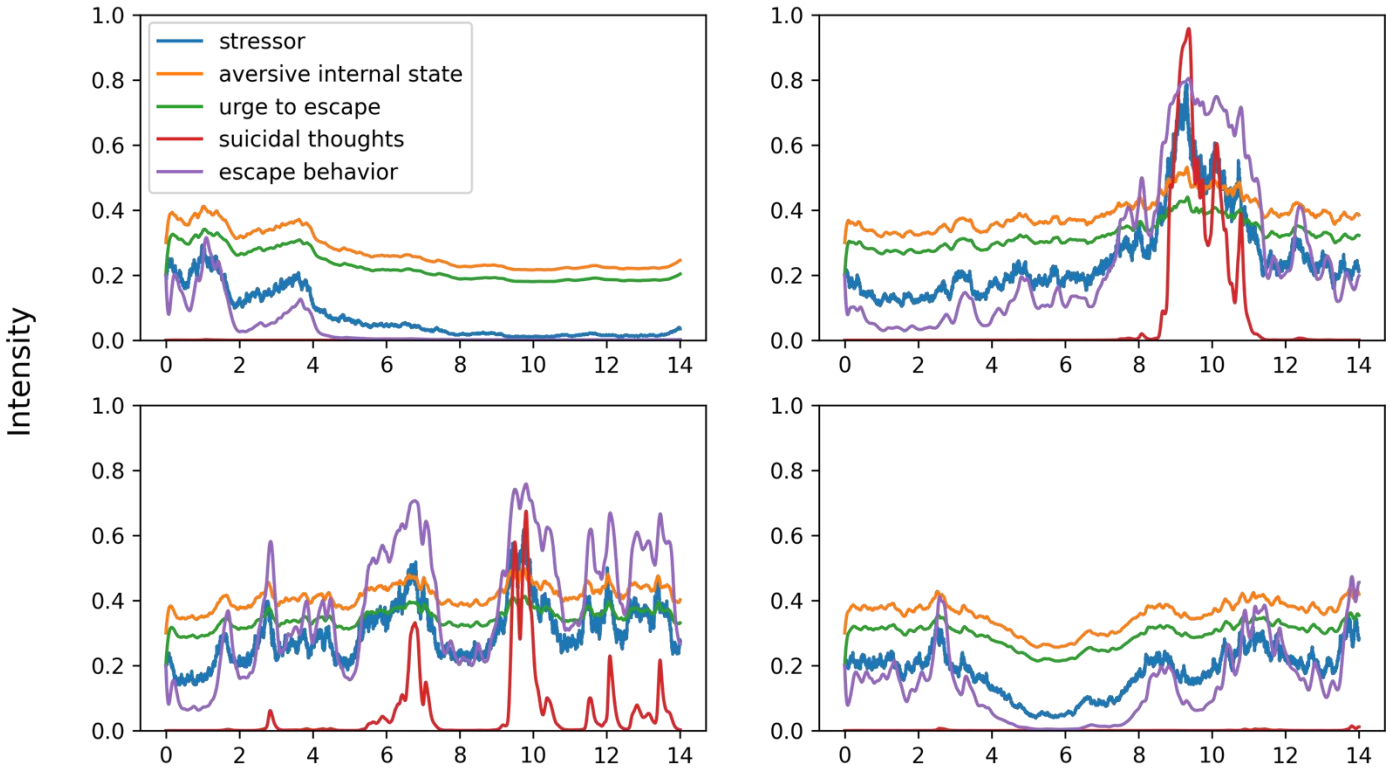
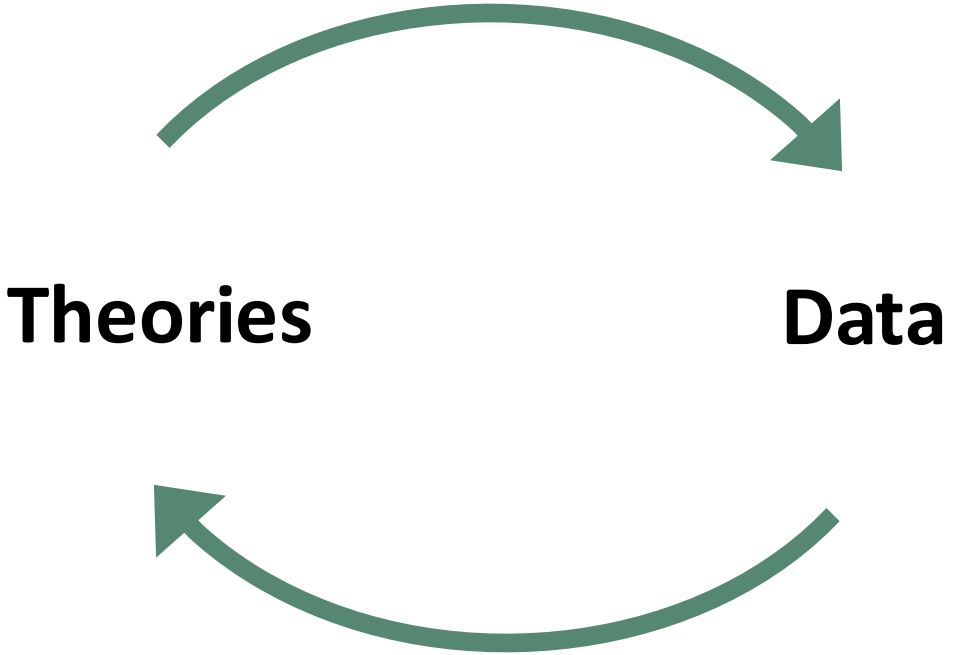




Wang et al. (2023)


Theories
Data

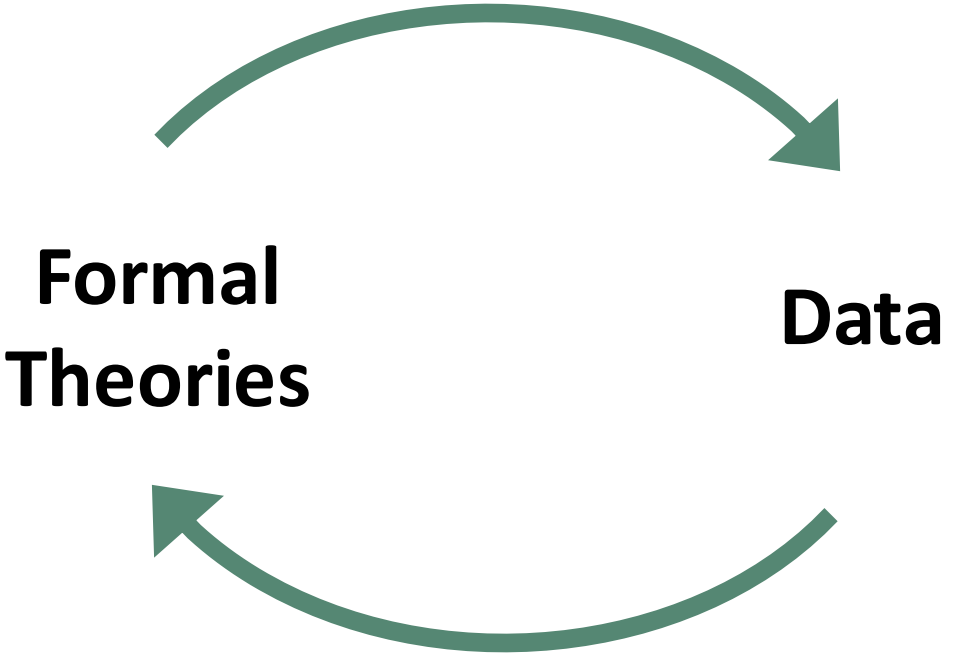
Formal Theory

$$S_t = S_0 e^{\left(\mu - \frac{\sigma^2}{2}\right)t + \sigma W_t}$$

$$\frac{dA}{dt} = b_2 A(K_2 - A) + a_2 S - d_2 T$$

$$\frac{dU}{dt} = -c_3 U + b_3 A$$

$$\frac{dT}{dt} = -d_4 T + \frac{1}{1 + e^{-c_{41}(U - c_{42})}}$$



Epistemic iteration

Formal Theory

$$S_t = S_0 e^{\left(\mu - \frac{\sigma^2}{2}\right)t + \sigma W_t}$$

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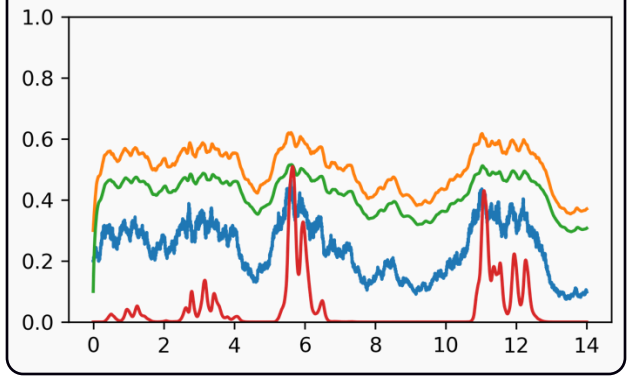
Simulations



Formal Theories

Data

Epistemic iteration

Shari Hamm

Formal Theory

$$S_t = S_0 e^{\left(\mu - \frac{\sigma^2}{2}\right)t + \sigma W_t}$$

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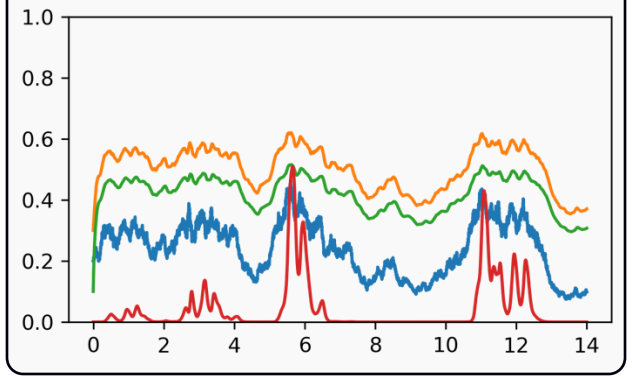
Simulations



Formal Theories ⇄ **Digital Phenotyping**

TRACE STUDY

Tracking Real-time Actions, Contexts, and Emotions

CCS LAB @ YALE

Thank you!

Computational Clinical Science Lab | Capturing and modeling the complex dynamics of mental health


Shari Hamm


Leily Behbehani


Adanya Johnson


Grace Hart

CCS Lab

Sharina Hamm

Leily Behbehani

Adanya Johnson

Grace Hart

Coby Barrow

Gaeun Gwon Lee

Brandon Felcher

Hannah Owens Pierre

Yale

Collaborators

Kathryn Fox (Univ of Denver)

Annie Haynos (VCU)

Matthew Nock (Harvard)

Jordan Smoller (MGH)

Ruben Van Genugten (Northeastern)

Donald Robinaugh (Northeastern)

Rebecca Fortgang (MGH)

Alexander Millner (Harvard)

Christine Cha (Yale)

ccslab.yale.edu

shirley.wang@yale.edu

@shirleybwang