

Why should we formalize a theory?

What *is* a formal theory?

A formal theory is a theory that is expressed in mathematical equations or computer code.

Verbal theory:

- ▶ The population increases every year by 10%.

Formal theory:

- ▶ $X_t = X_{t-1} + 0.1X_{t-1}$
- ▶ `for(i in 2:n) x[i] = x[i-1] + 0.1*x[i-1]`

Example 1: Diffusion of Responsibility



- ▶ Bystander effect: individuals are less likely to offer help to a victim when there are other people present. (from Wikipedia)
- ▶ Explained by *diffusion of responsibility*

Example 1: Diffusion of Responsibility



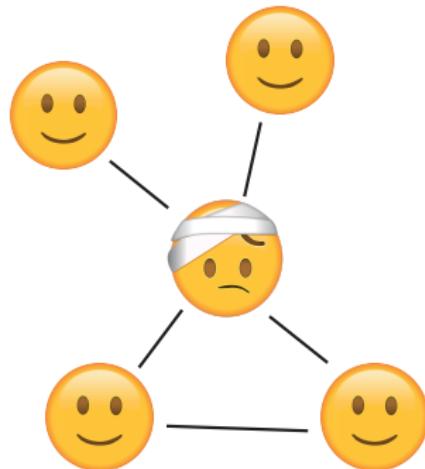
- ▶ Bystander effect: individuals are less likely to offer help to a victim when there are other people present. (from Wikipedia)
- ▶ Explained by *diffusion of responsibility*

Would you be able to formalize diffusion of responsibility?

Diffusion of Responsibility according to Han

Assumptions:

1. Individuals are connected in network
2. Happiness depends partially on how happy my neighbors are
3. Sometimes accidents happen to people
4. I can spend energy either on myself or on helping my neighbors when they have an accident



Notion of Responsibility:

- ▶ Responsibility in terms of altruism

Diffusion of Responsibility according to Don

Assumptions:

1. People differ in how well they can help
2. People want that the most efficacious person helps
3. There is uncertainty about who is how efficacious



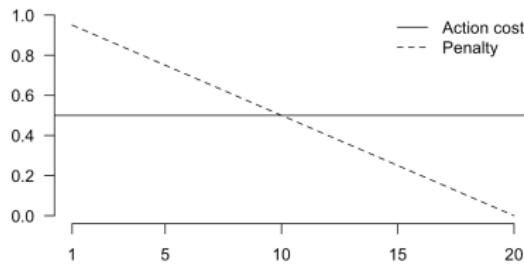
Notion of Responsibility:

- ▶ Everyone feels responsible to help but also wants to ensure that the most efficacious person helps (here responsibility is "built in")

Diffusion of Responsibility according to Jonas

Assumptions:

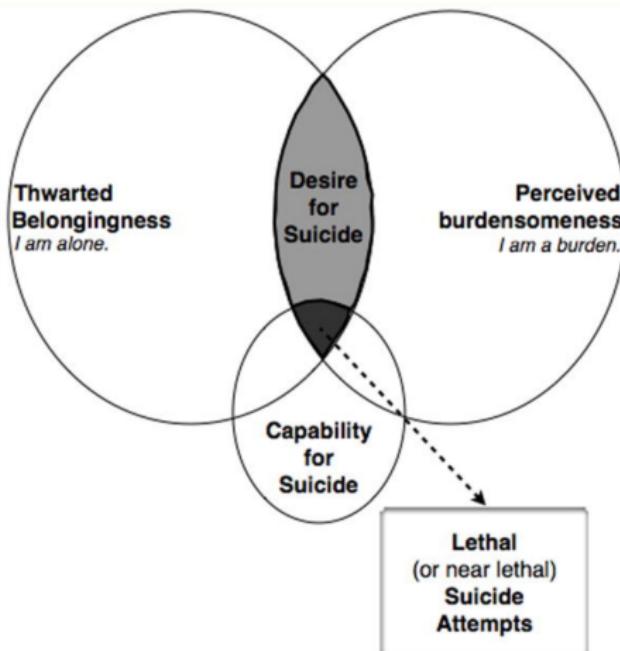
1. There is a cost to helping
2. If I don't help I am subject to a social penalty
3. The social penalty decreases with more people



Notion of Responsibility:

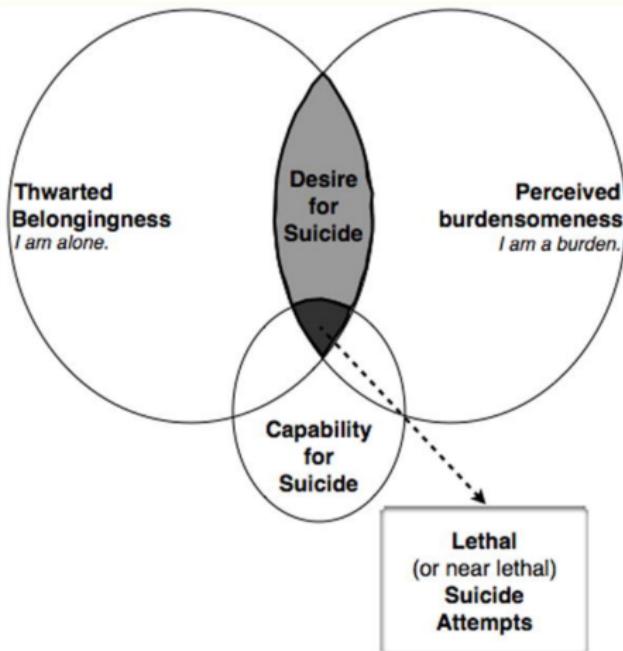
- ▶ Responsibility is defined in terms of behaviors that avoid social penalties

Example 2: Interpersonal Theory of Suicide



(Joiner, 2007; Van Orden et al., 2010; Millner, Robinaugh & Nock, 2020)

Example 2: Interpersonal Theory of Suicide



Would you be able to formalize this theory?

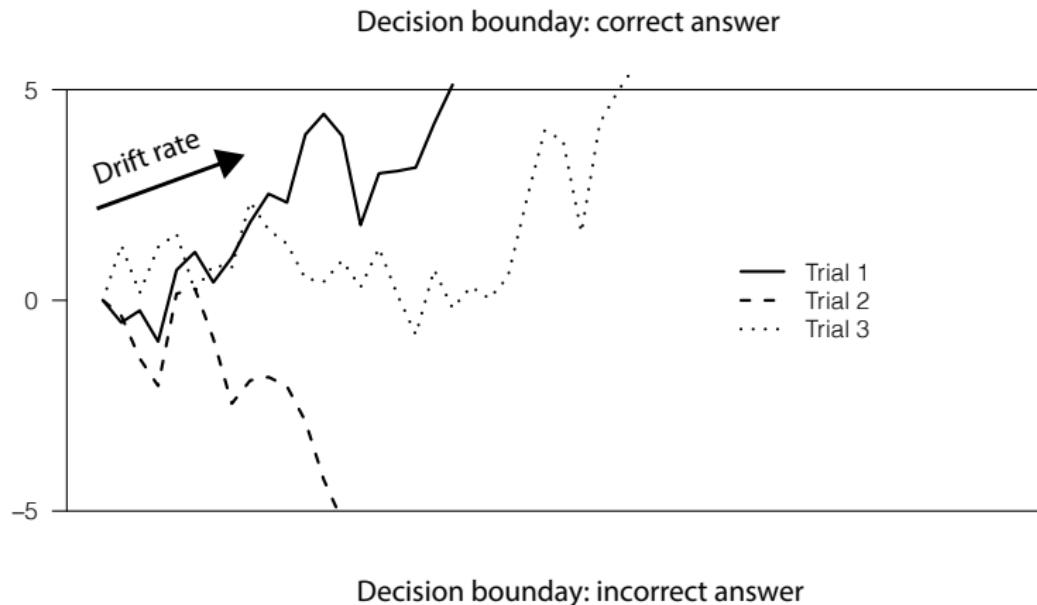
(Joiner, 2007; Van Orden et al., 2010; Millner, Robinaugh & Nock, 2020)

Why Formalize?

Trying to formalize one's theory ...

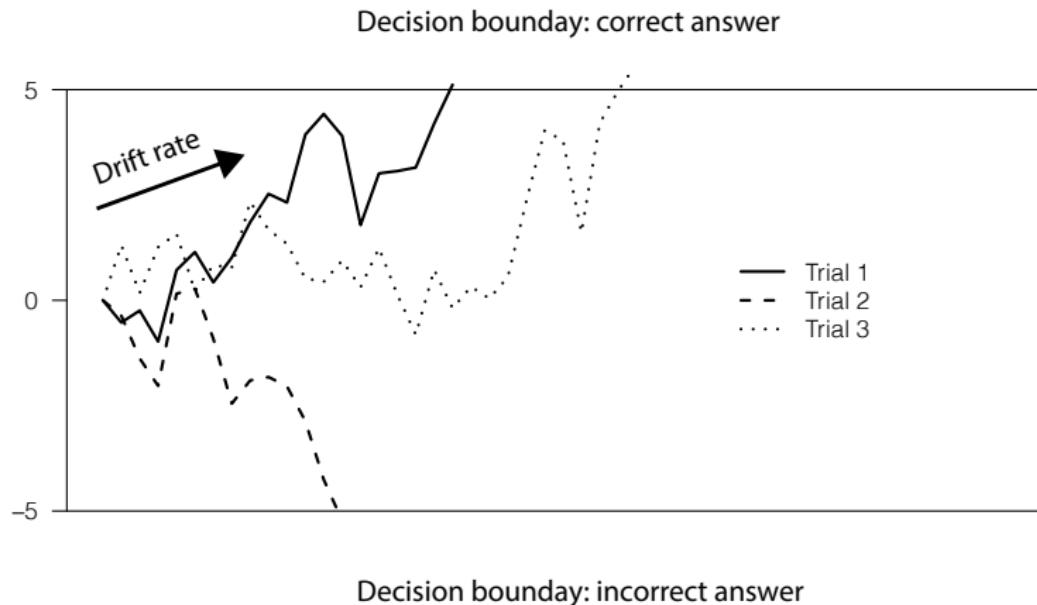
1. Forces one to be clear/specific
2. Identifies missing knowledge

Example 3: Drift Diffusion Model for Binary Decisions



(e.g., Wagenmakers, 2009)

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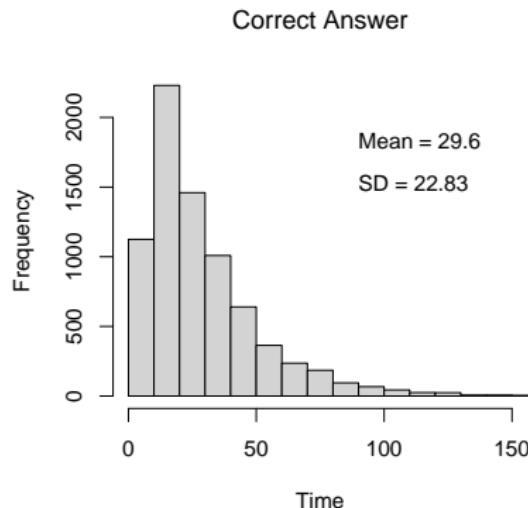
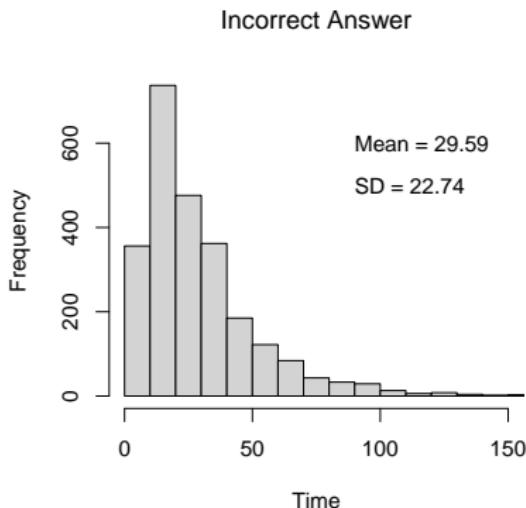


Do you think the correct/incorrect response time distributions are different?

(e.g., Wagenmakers, 2009)

Example 3: Drift Diffusion Model for Binary Decisions

- ▶ 10 000 simulated trials
- ▶ Drift rate = 0.1
- ▶ SD of Gaussian noise = 1



Example 4: Schelling's Segregation Model

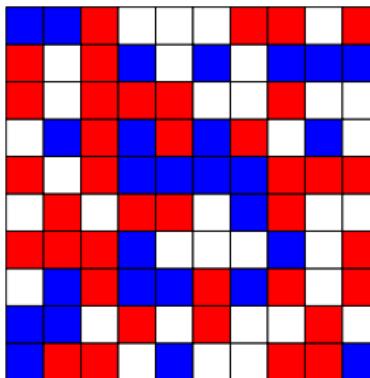


Schelling's model:

1. The parameter $B_t \in [0, 1]$ determines preference for homogeneity (0=no preference, 1=strongest preference)
2. Dynamics: if the proportion of similar neighbors B is *smaller* than B_t , I move to another vacant spot in the city
3. Outcome measure: mean proportion of different neighbors after T iterations

(e.g., Schelling, 2006)

Example 4: Schelling's Segregation Model

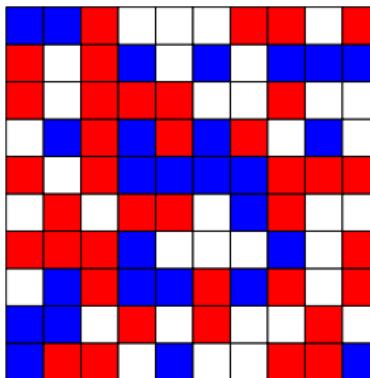


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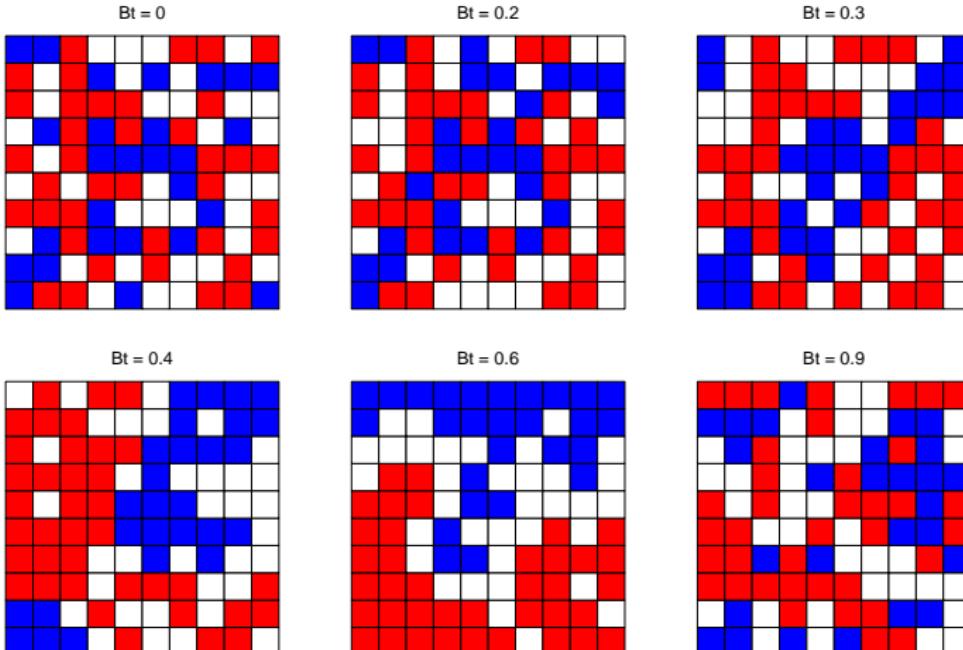
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How does segregation depend on B_t ?

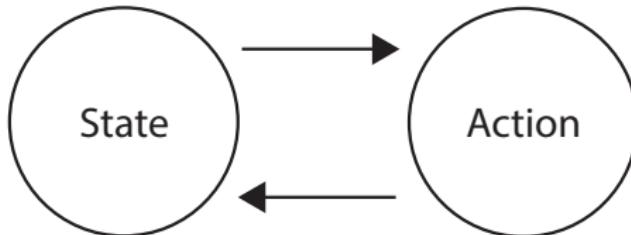
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Example 4: Schelling's Segregation Model



- ▶ Segregation begins already at around $B_t = 0.3$
- ▶ Collapses again when close to $B_t = 1$

Feedback in (biological) Systems



- ▶ Almost any interesting dynamical system will have feedback loops:
 - ▶ Emotion regulation (e.g., motivate agent to get back to equilibrium)
 - ▶ Learning (e.g., the more you learn about X, the easier/harder it becomes to learn more)
 - ▶ Any social interaction (e.g., Schelling's model)
 - ▶ Psychopathology (vicious cycles, short-term reward vs. long-term harm)
- ▶ These create (together with non-linearities and delays) often very counter-intuitive results

Complex Systems Science



Simple local rules create unexpected global behavior

Summary: Why Formalize?

1. Forces one to be clear/specific
2. Identifies missing knowledge
3. We are able to make clear and testable predictions
4. We can demonstrate that the theory produces the phenomenon
5. Theories can be developed in collaboration

(see also Smaldino, Robinaugh et al., 2021)