

# A Dynamical Model of Panic Disorder

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## Team of Collaborators

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**Alex Millner** (Harvard University)

**Jolanda Kossakowski** (University of Amsterdam)

**Eiko Fried** (Leiden University)

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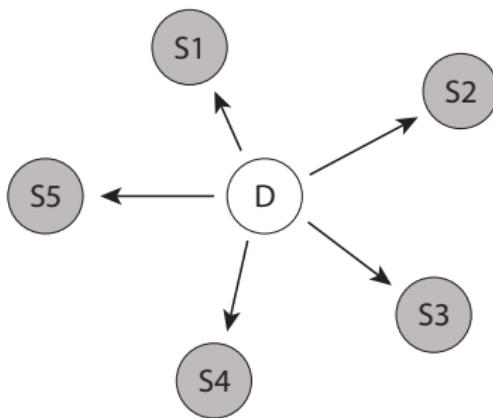
**Ken Kendler** (VTPBG, Virginia)

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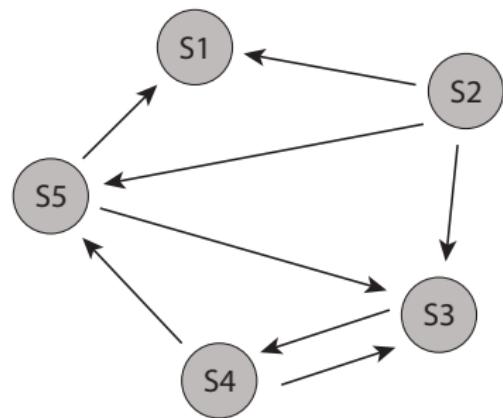
**Denny Borsboom** (University of Amsterdam)



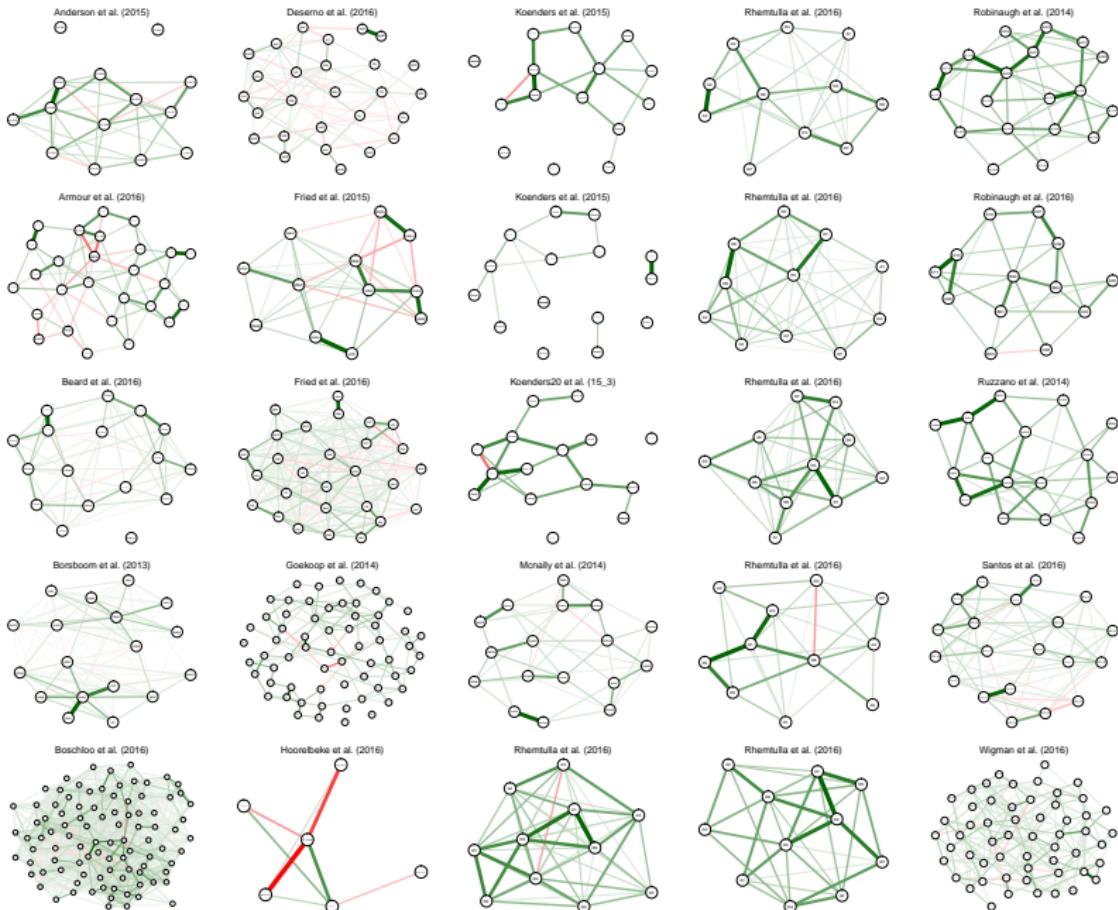
# Two Models for Psychopathology

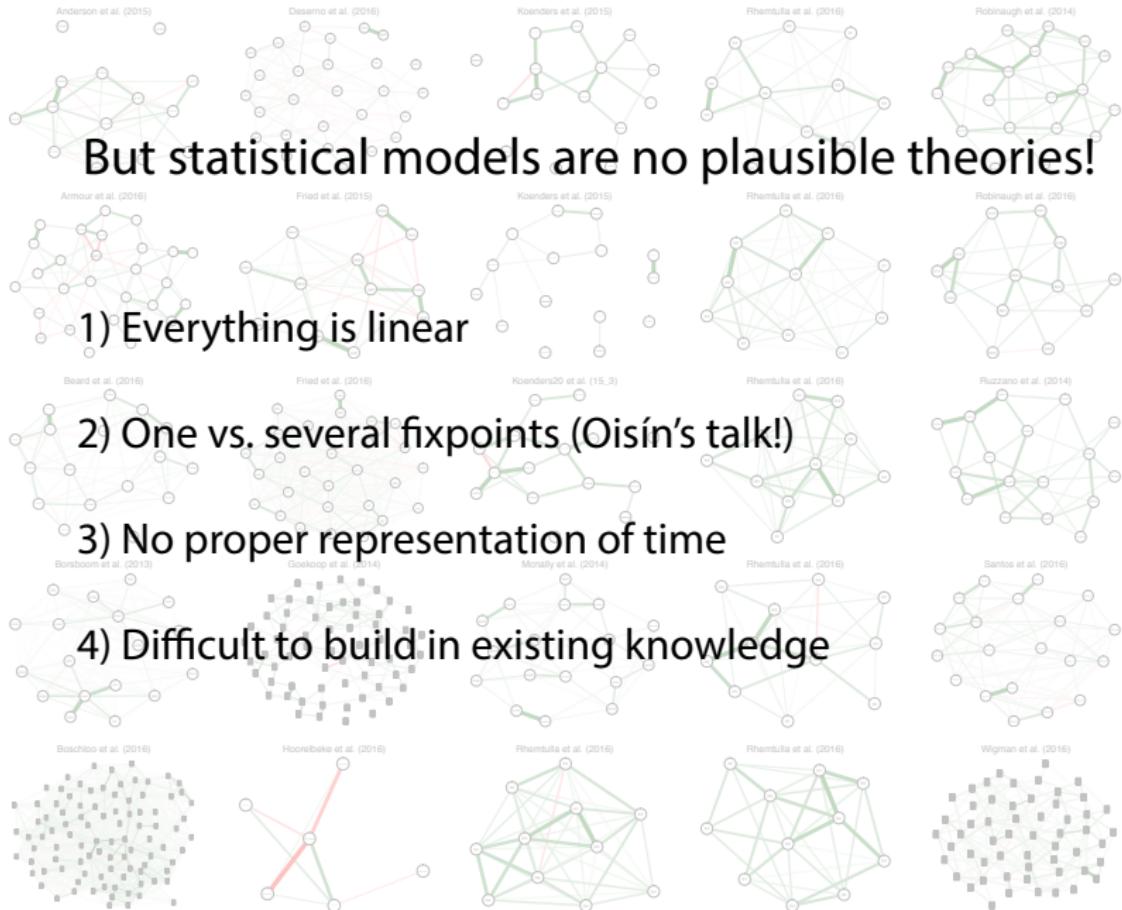


Disease Model

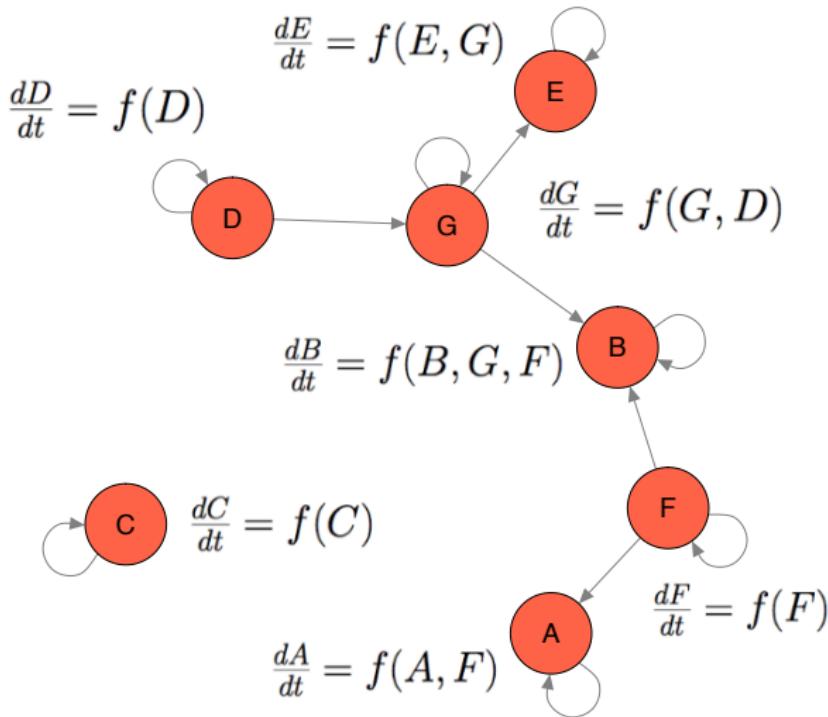


Network Model





# Instead: System of Differential Equations



Starting point: Panic Disorder

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Table 2. DSM-5 Criteria  
for Panic Disorder

Recurrent unexpected panic attacks

At least one of the attacks has been followed by at least 1 month of one or more of the following:

- Persistent concern about having additional panic attacks
- Worry about the implications of the attack or its consequences
- A significant change in behavior related to the attacks

Presence or absence of agoraphobia

- In the DSM-5, PD and agoraphobia are now unlinked; this is a change from the previous edition

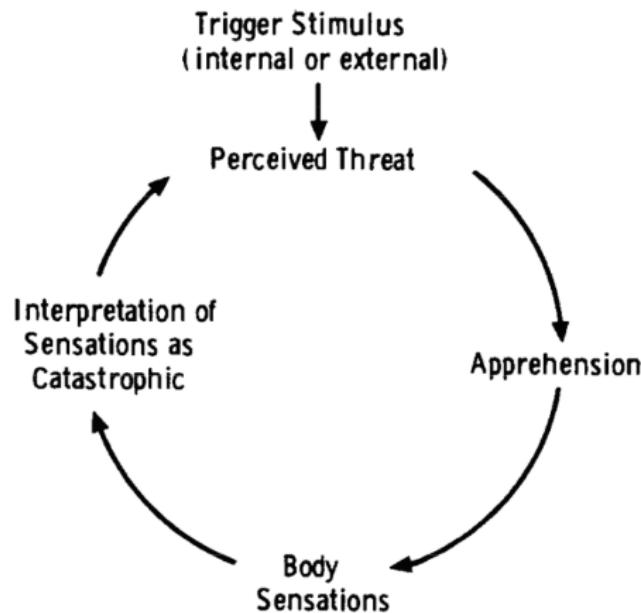
The panic attacks are not due to the direct physiologic effects of a substance (e.g., medication or drug of abuse) or a general medical condition (e.g., hyperthyroidism)

The panic attacks are not better accounted for by another mental disorder

*DSM-5: Diagnostic and Statistical Manual of Mental Disorders, Fifth Edition.*

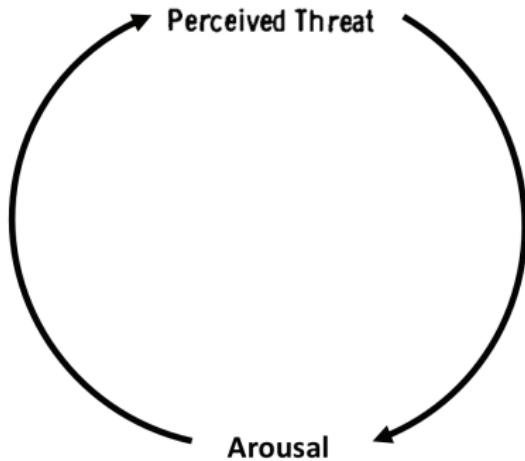
*Source: Reference 17.*

# Positive Feedback Loop: Panic Attack

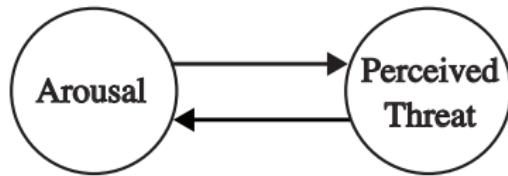


Clark (1986)

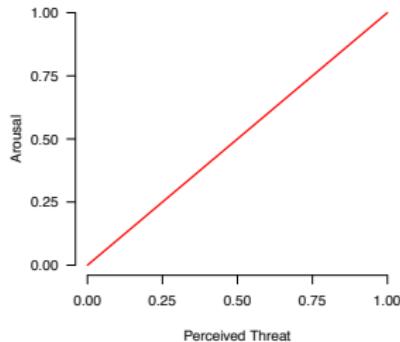
# Positive Feedback Loop: Panic Attack



# Positive Feedback Loop: Implementation

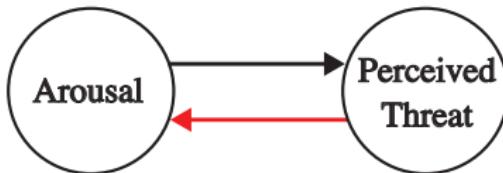


# Feedback Loop: Implementation

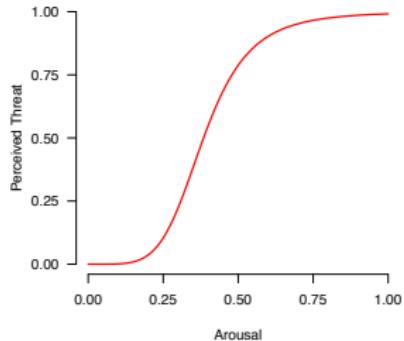
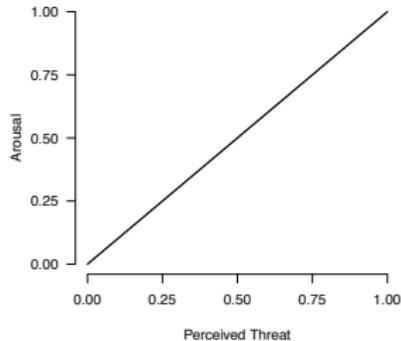


$$A_{eq} = \beta PT$$

$$\frac{dA}{dPT} = r_A(A_{eq} - A)$$



# Feedback Loop: Implementation

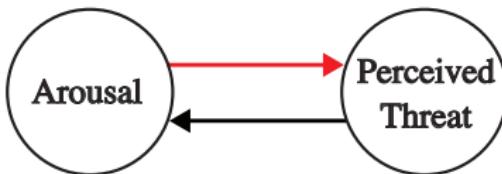


$$A_{eq} = \beta PT$$

$$PT_{eq} = \frac{A^5}{A^5 + h^5}$$

$$\frac{dA}{dPT} = r_A(A_{eq} - A)$$

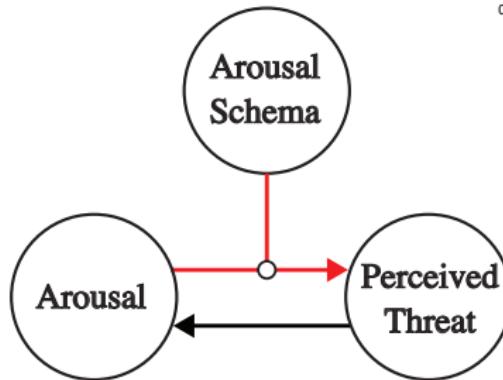
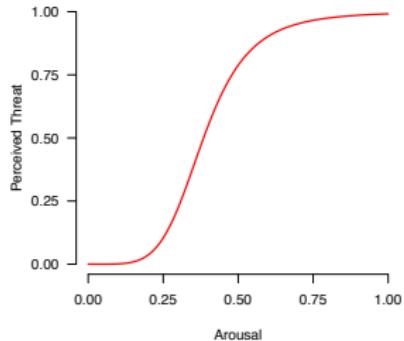
$$\frac{dPT}{dA} = r_{PT}(PT_{eq} - PT)$$

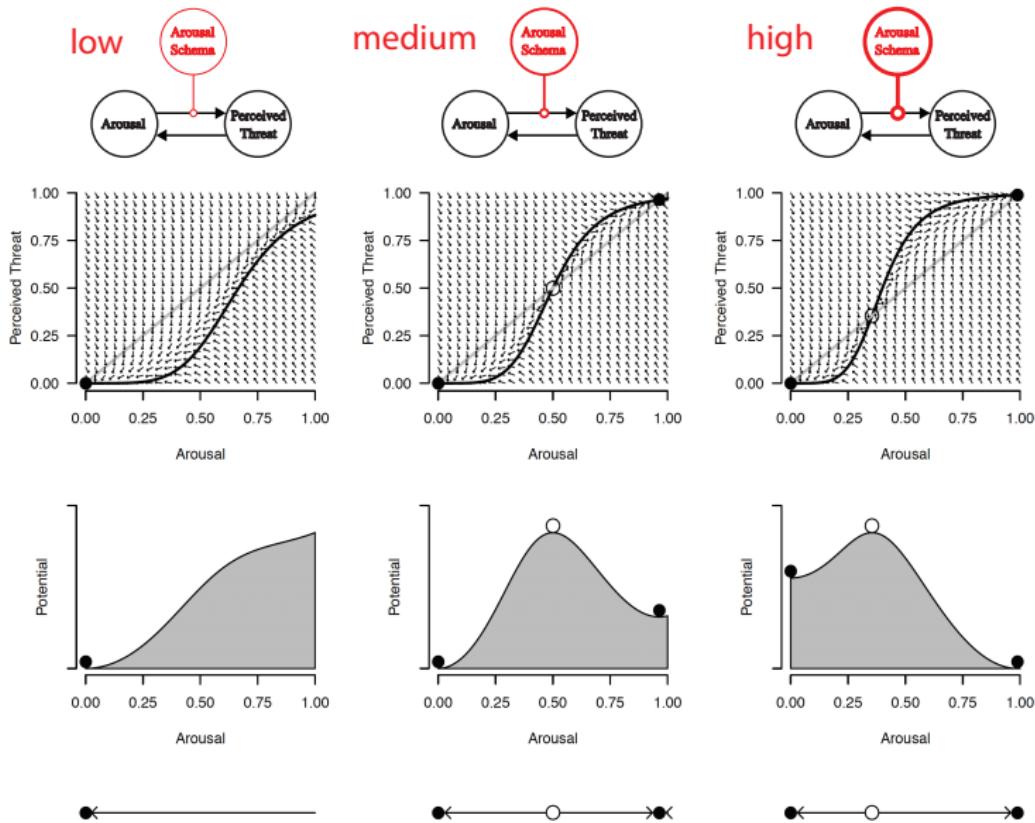


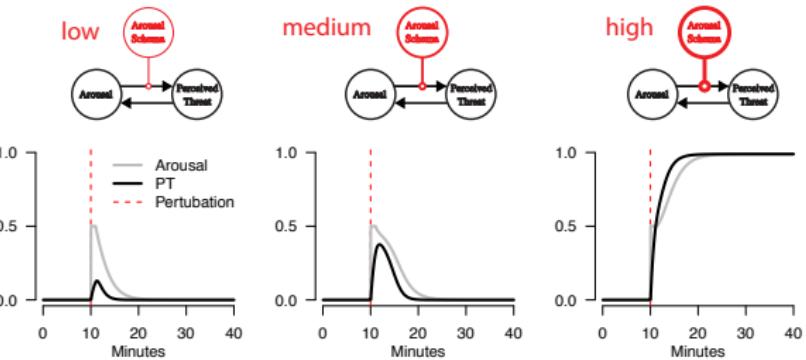
# Feedback Loop: Moderated by Arousal Schema

$$PT_{eq} = \frac{A^5}{A^5 + (1 - \frac{AS}{AS+.5})^5}$$

$$\frac{dPT}{dA} = r_{PT}(PT_{eq} - PT)$$





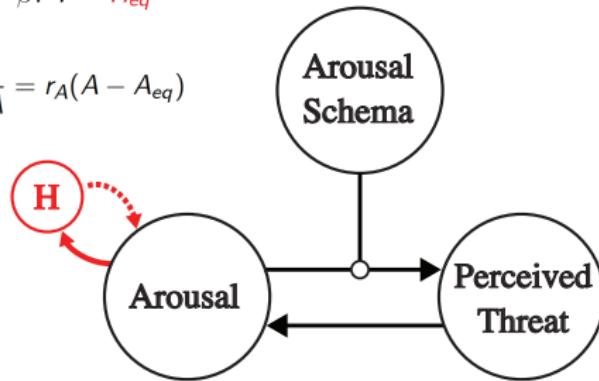


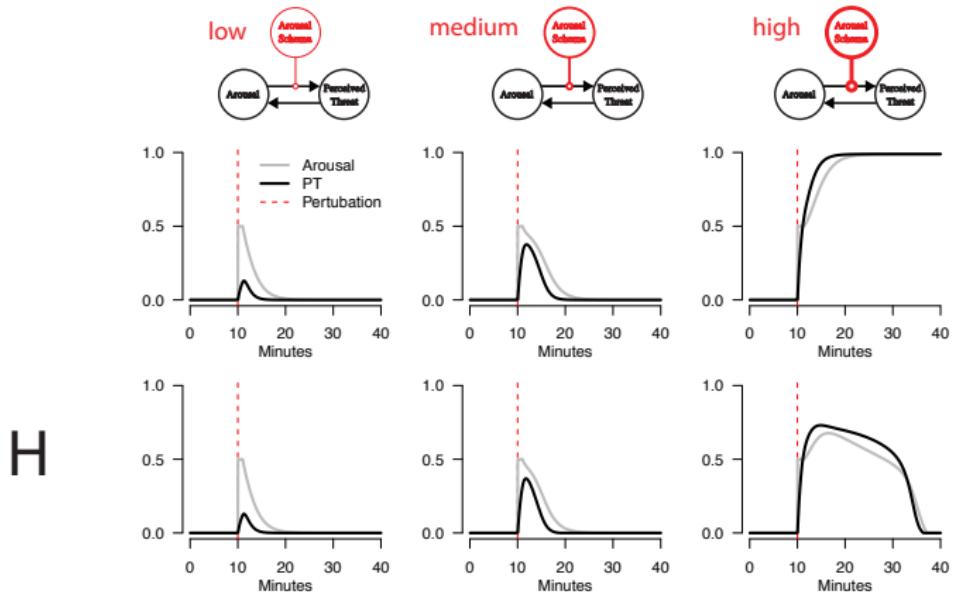
# Add Homeostasis to Feedback Loop

$$H_{eq} = \begin{cases} 0 & \text{for } A < .5 \\ r_{AH}(A - 0.5) & \text{for } A \geq .5 \end{cases}$$

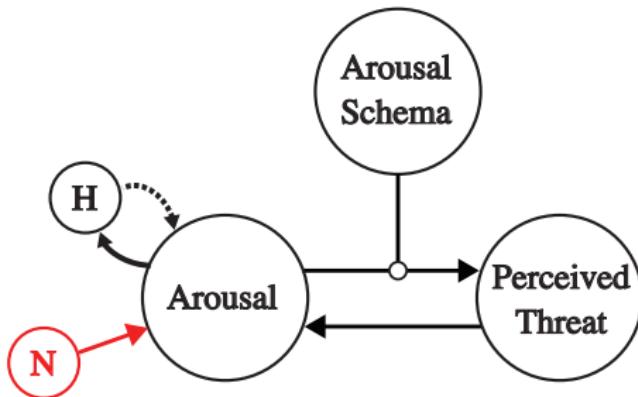
$$A_{eq} = \beta PT - H_{eq}$$

$$\frac{dA}{dPT} = r_A(A - A_{eq})$$

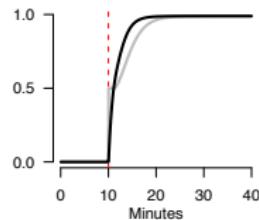
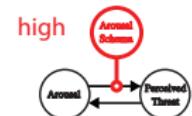
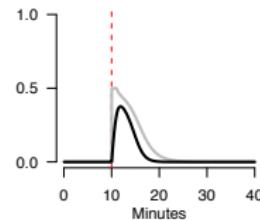
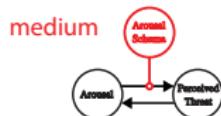
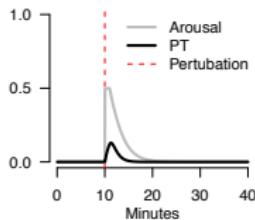
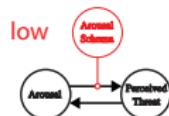




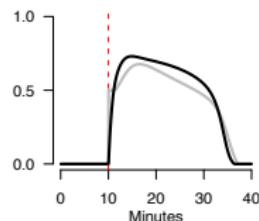
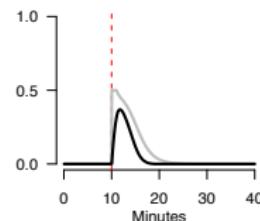
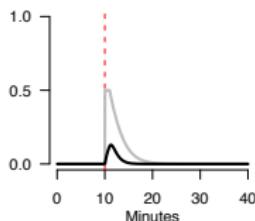
## Add Noise to Feedback Loop



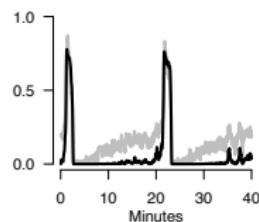
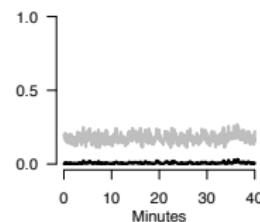
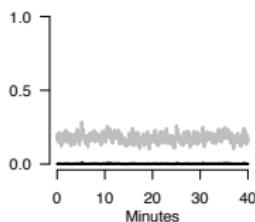
Correlated Gaussian Noise



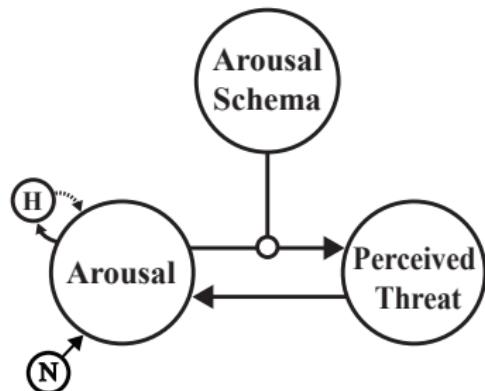
H



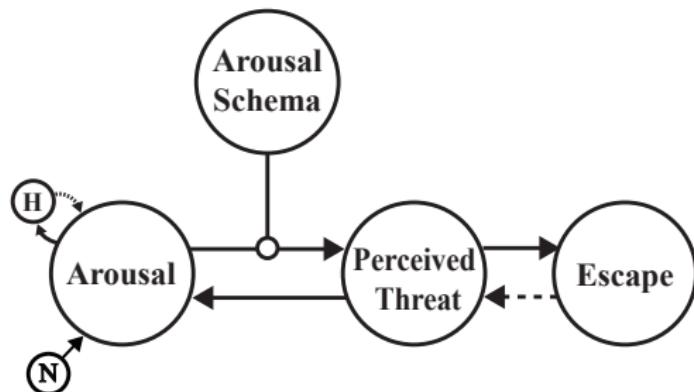
H + N



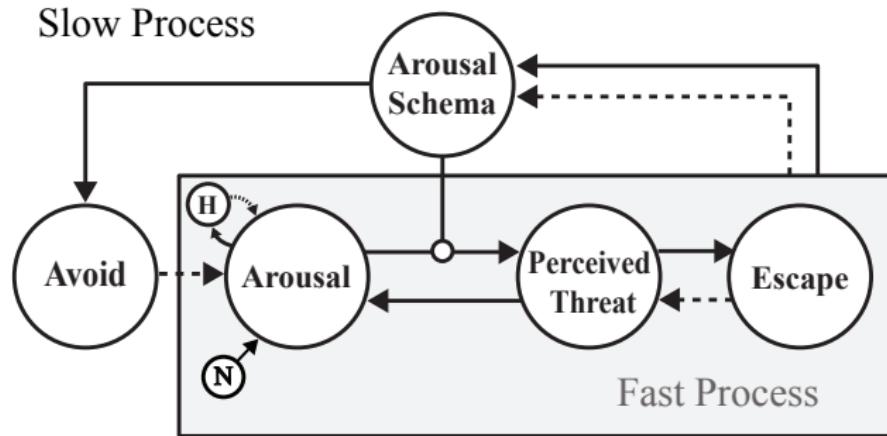
# From Panic Attacks to Panic Disorder



# From Panic Attacks to Panic Disorder: Escape behavior

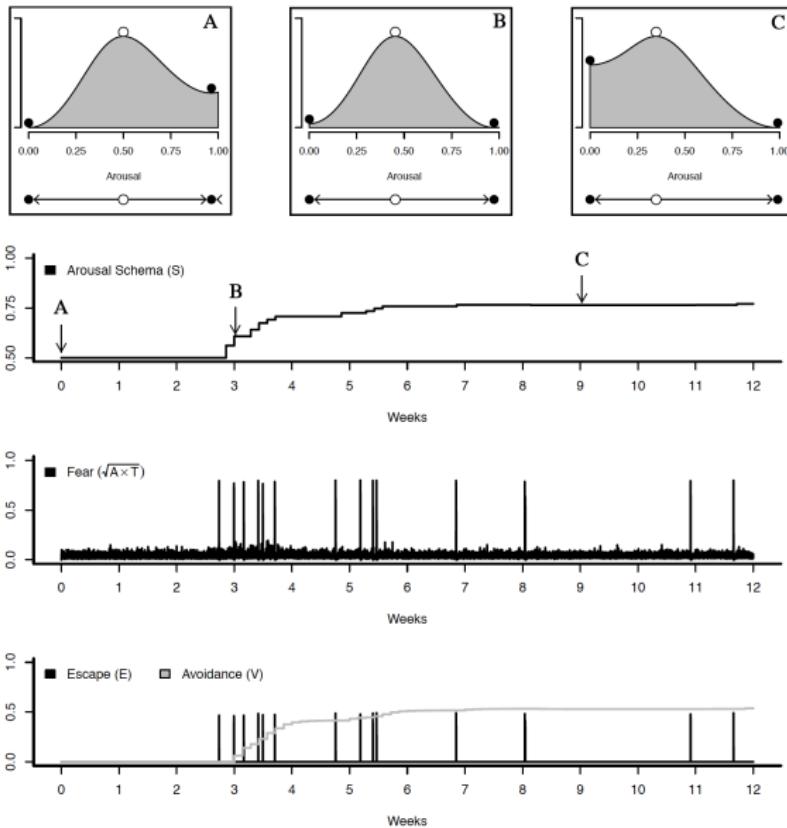


# From Panic Attacks to Panic Disorder: Learning



Beck, (1985); Casey, Oei, & Newcombe (2004); Klein & Klein (1989)

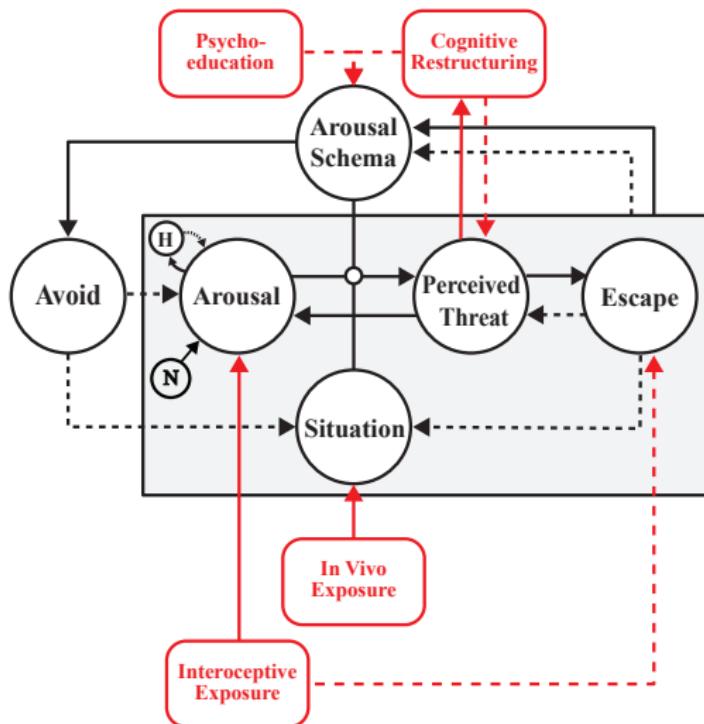
# Simulated Onset of Panic Disorder



## How is this model useful?

1. **Organizes knowledge, identifies gaps** E.g.: How can non-clinical panic attacks occur?
2. **Implies testable predictions**  
E.g.: Recovery time of perturbation should predict occurrence of panic attacks and therefore also the development of panic disorder
3. **Allows to understand and evaluate interventions**

# Understanding and Evaluating Interventions



# Moving forward: Modeling more Complex Disorders

**TABLE 1** DSM-5 criteria for major depressive disorder and persistent depressive disorder

**Major depressive disorder (in children and adolescents, mood can be irritable)**

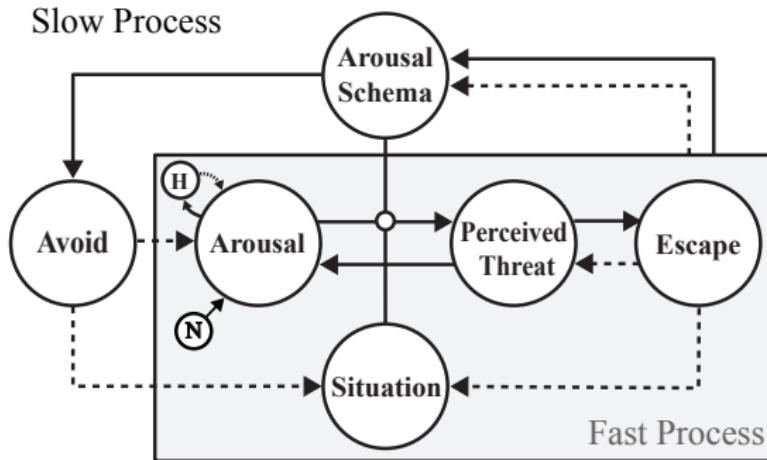
5 or more of 9 symptoms (including at least 1 of depressed mood and loss of interest or pleasure) in the same 2-week period; each of these symptoms represents a change from previous functioning

- Depressed mood (subjective or observed)
- Loss of interest or pleasure
- Change in weight or appetite
- Insomnia or hypersomnia
- Psychomotor retardation or agitation (observed)
- Loss of energy or fatigue
- Worthlessness or guilt
- Impaired concentration or indecisiveness
- Thoughts of death or suicidal ideation or suicide attempt

More difficult:

1.  $\binom{9}{5} + \binom{9}{6} + \binom{9}{7} + \binom{9}{8} + 1 = 256$  pathological states instead of 1
2. Much less theory on *mechanistic* etiology available

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