



# What we talk about when we talk about Computational Psychiatry

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wien  
Fakultät für Psychologie

# Outline

- The born and the rise of Computational Psychiatry (CP)
- Three cultures of CP
- Current landscape of CP: institutions and funding opportunities
- A case study: flexible choice behavior in Autism
- Summary

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# Computational Psychiatry (CP): a rapidly growing, highly multidisciplinary field

## Trends in Cognitive Sciences

Volume 16, Issue 1, January 2012, Pages 72-80



### Review

Special Issue: Cognition in Neuropsychiatric Disorders

## Computational psychiatry

P. Read Montague <sup>1, 2</sup>✉, Raymond J. Dolan <sup>2</sup>, Karl J. Friston <sup>2</sup>, Peter Dayan <sup>3</sup>

## THE LANCET Psychiatry

Volume 1, Issue 2, July 2014, Pages 148-158

### Review

Computational psychiatry: the brain as a phantastic organ

Prof Karl J Friston FRS <sup>a</sup>✉, Prof Klaas Enno Stephan PhD <sup>a, b</sup>, Prof Read Montague PhD <sup>a, c</sup>, Prof Raymond J Dolan FRS <sup>a</sup>

## Viewpoint

April 24, 2019

## The Two Cultures of Computational Psychiatry

Daniel Bennett, PhD<sup>1</sup>; Steven M. Silverstein, PhD<sup>2,3</sup>; Yael Niv, PhD<sup>1,4</sup>

» Author Affiliations | Article Information

JAMA Psychiatry. 2019;76(6):563-564. doi:10.1001/jamapsychiatry.2019.0231



## Neural Networks

Volume 24, Issue 6, August 2011, Pages 544-551



2011 Special Issue

Are computational models of any use to psychiatry?

## Neuron

Volume 84, Issue 3, 5 November 2014, Pages 638-654



### Perspective

## Computational Psychiatry

Xiao-Jing Wang <sup>1, 2, 3</sup>✉, John H. Krystal <sup>3, 4, 5, 6</sup>

## Applications

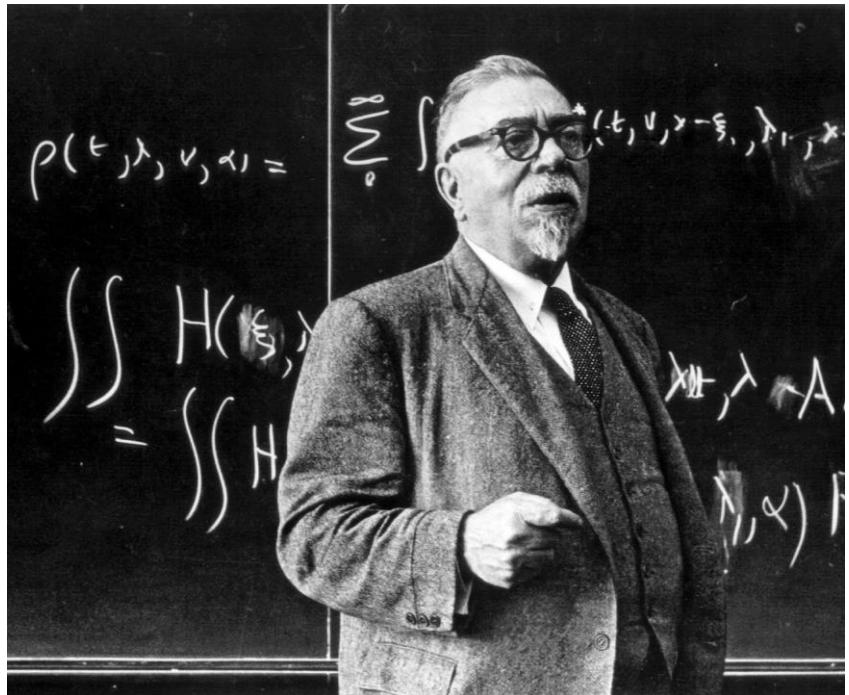
## Molecular Psychiatry

News | Open Access | Published: 27 April 2018

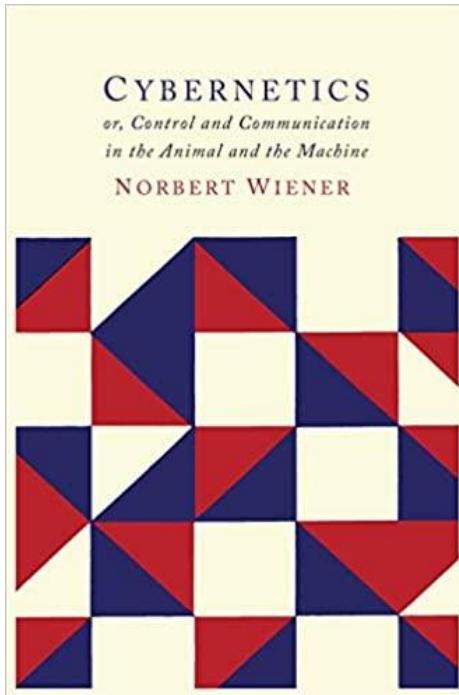
Computational psychiatry: a report from the 2017 NIMH workshop on opportunities and challenges

Michele Ferrante ✉, A. David Redish, Maria A. Oquendo, Bruno B. Averbeck, Megan E. Kinnane & Joshua A. Gordon

# The first (?) idea of CP



Norbert Wiener (1948)



*“Psychopathology has been rather a disappointment to the instinctive materialism of the doctors, who have taken the view that every disorder must be accompanied by actual lesions of some specific tissue involved. [...] This distinction between functional and organic disorders is illuminated by the consideration of the computing machine.”*

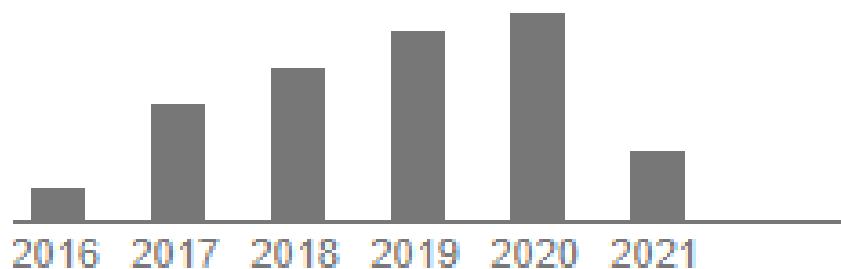
# The rise of CP

Published: 23 February 2016

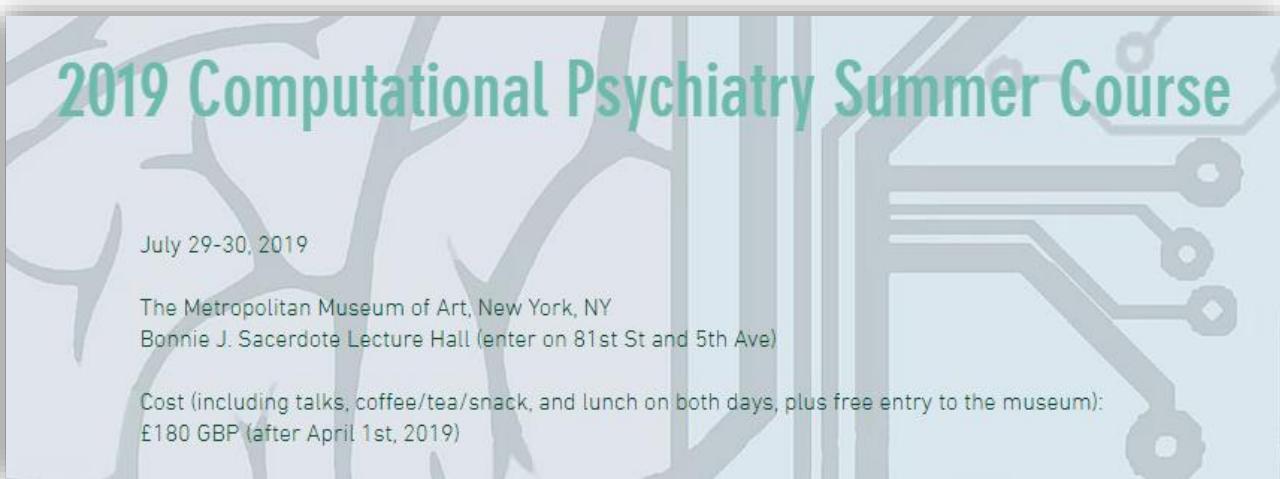
## Computational psychiatry as a bridge from neuroscience to clinical applications

Quentin J M Huys , Tiago V Maia & Michael J Frank

*Nature Neuroscience* 19, 404–413(2016) | [Cite this article](#)



# The rise of CP



2019 Computational Psychiatry Summer Course

July 29-30, 2019  
The Metropolitan Museum of Art, New York, NY  
Bonnie J. Sacerdote Lecture Hall (enter on 81st St and 5th Ave)  
Cost (including talks, coffee/tea/snack, and lunch on both days, plus free entry to the museum): £180 GBP (after April 1st, 2019)



## About this Journal

**Computational Psychiatry** publishes original research articles and reviews that involve the application, analysis, or invention of theoretical, computational and statistical approaches to mental function and dysfunction. Topics include brain and behavioral modeling over multiple scales and levels of analysis, and the use of these models to understand psychiatric dysfunction, its remediation, its relation to social or biological factors, and the development and sustenance of healthy cognition throughout the lifespan.



## ABOUT THE CPC

This course is organized by the [Translational Neuromodeling Unit \(TNU\)](#), University of Zurich & ETH Zurich and is designed to provide students across fields (neuroscience, psychiatry, physics, biology, psychology,...) with the necessary toolkit to master challenges in computational psychiatry research.



## Biological Psychiatry: Cognitive Neuroscience and Neuroimaging

Volume 5, Issue 9, September 2020, Pages 835-836

Editorial

## Computational Psychiatry Series

Quentin J.M. Huys  



Quentin Huys

@docqhuys

Very excited to join [@BiologicalPsyc1](#) CNNI as deputy editor and launch the new computational psychiatry series [doi.org/10.1016/j.bpsc....](https://doi.org/10.1016/j.bpsc....)

2:42 PM · Sep 7, 2020 · TweetDeck

# The rise (?) of CP



Eiko Fried @EikoFried · Dec 5, 2017

I see the word 'Computational Psychiatry' being thrown around a lot these days. There is no wikipedia article on the topic yet. I know a few papers, but they don't actually provide a formal definition.

Any thoughts? [@vaughanbell](#) [@Neuro\\_Skeptic](#) [@itschekkers](#) [@michelNivard](#)

## Search results

computational psychiatry ×

[Content pages](#) [Multimedia](#) [Everything](#) [Advanced](#)

*The page "Computational psychiatry" does not exist. You can ask for it to be created, but consider checking the search results below to see whether the topic is already covered.*

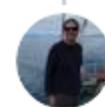


Tobias Hauser

@TobiasUHauser

Replies to [@PhilCorlett1](#) [@Neuro\\_Skeptic](#) and 9 others

Maybe Computational Psychiatry is a field that only consists of opinion papers on what computational psychiatry is supposed to be? 😐



Jon Roiser

@jonroiser

Replies to [@EikoFried](#)

I refer you to Roiser's Golden Rule of Computational Psychiatry



Jon Roiser @jonroiser · Dec 5, 2017

Replies to [@dan\\_marinazzo](#) [@EikoFried](#) and 4 others  
golden rule of CP: N reviews > N empirical papers!



Xiaosi Gu @xiaosigu · Dec 5, 2017

Replies to [@TobiasUHauser](#) [@PhilCorlett1](#) and 9 others

Exactly. We need more doing and less talking. Let's get more empirical papers out as a community!



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# Two cultures of CP

Viewpoint

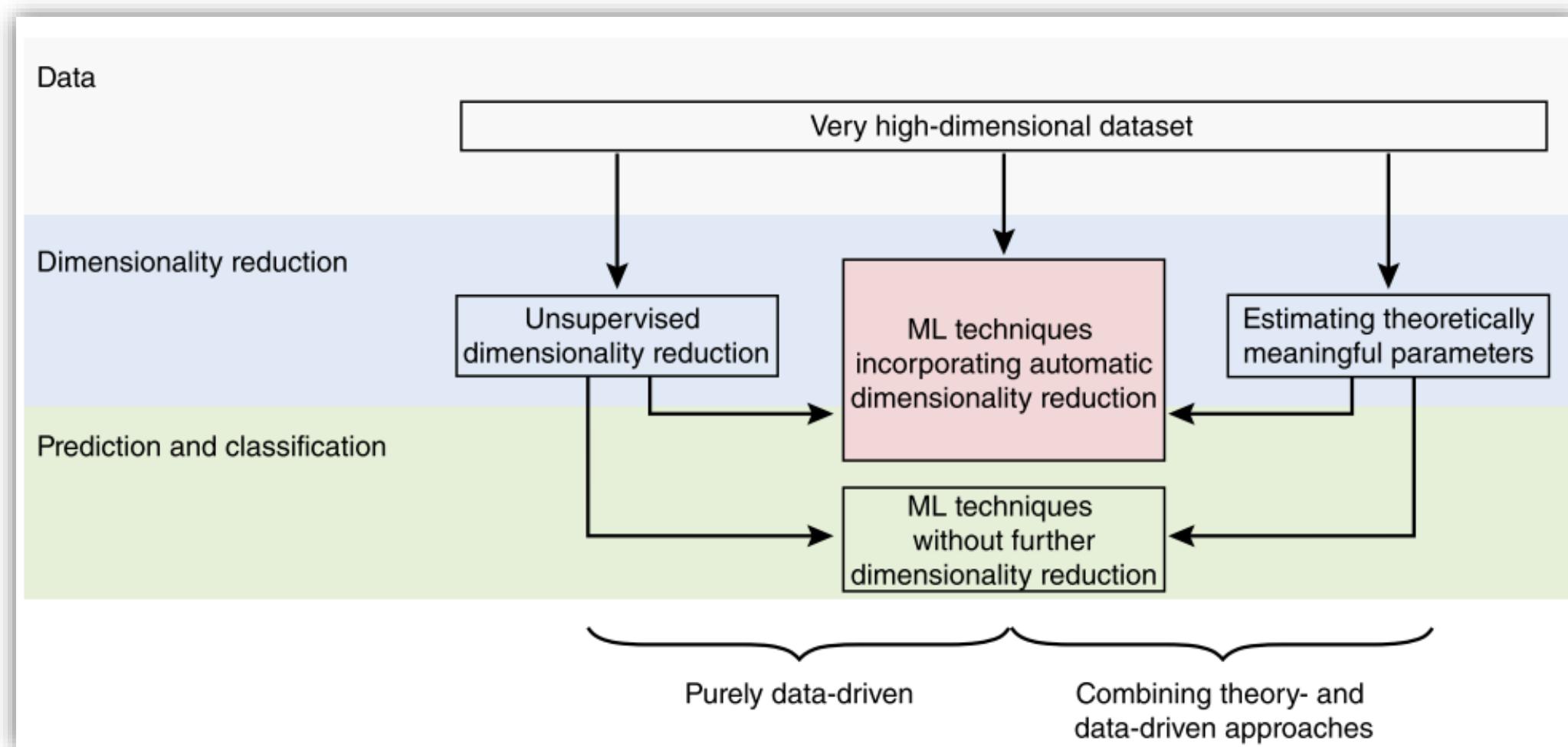
April 24, 2019

## The Two Cultures of Computational Psychiatry

Daniel Bennett, PhD<sup>1</sup>; Steven M. Silverstein, PhD<sup>2,3</sup>; Yael Niv, PhD<sup>1,4</sup>

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JAMA Psychiatry. 2019;76(6):563-564. doi:10.1001/jamapsychiatry.2019.0231



# Three cultures of CP

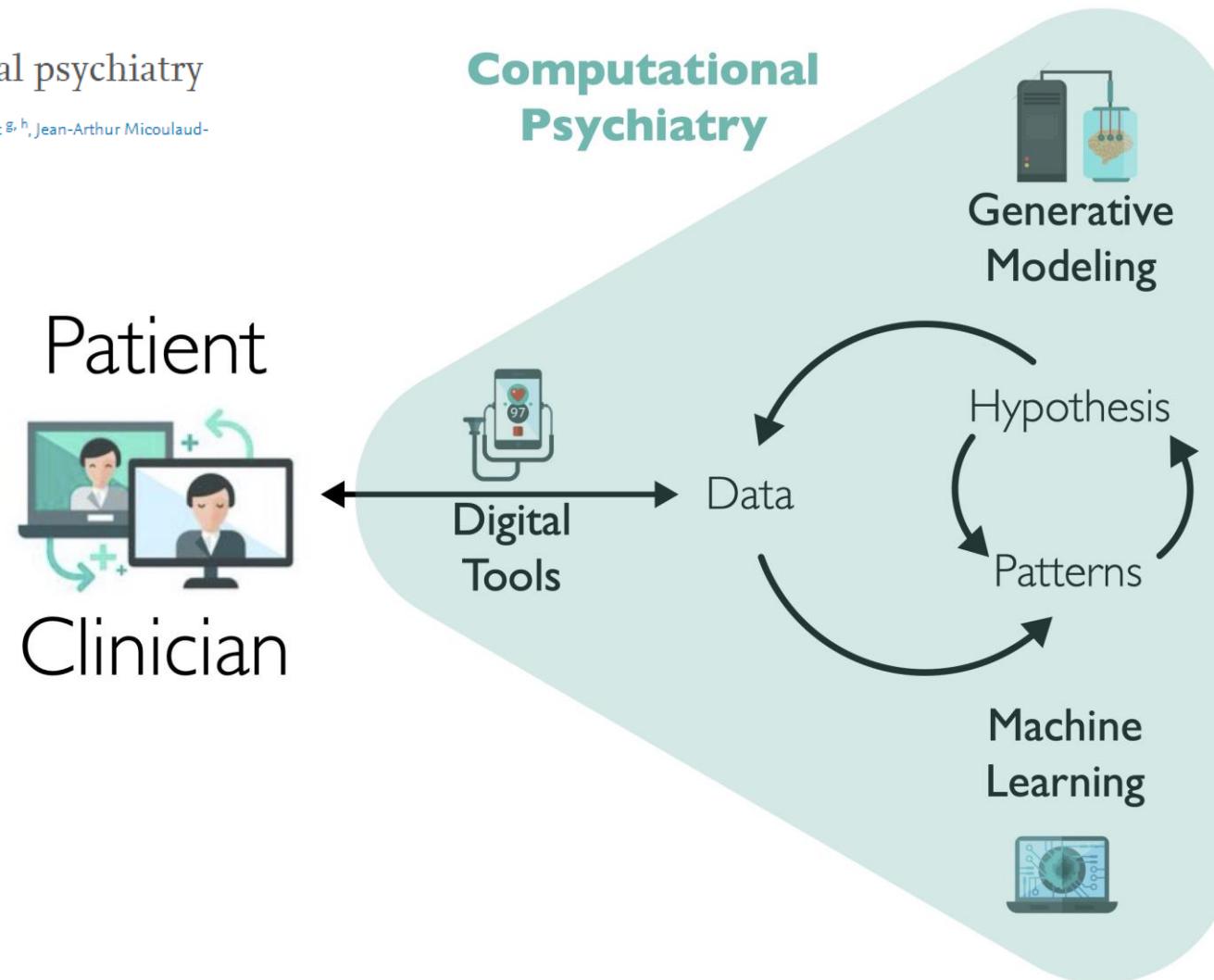
Communication

Les trois cultures de la psychiatrie computationnelle

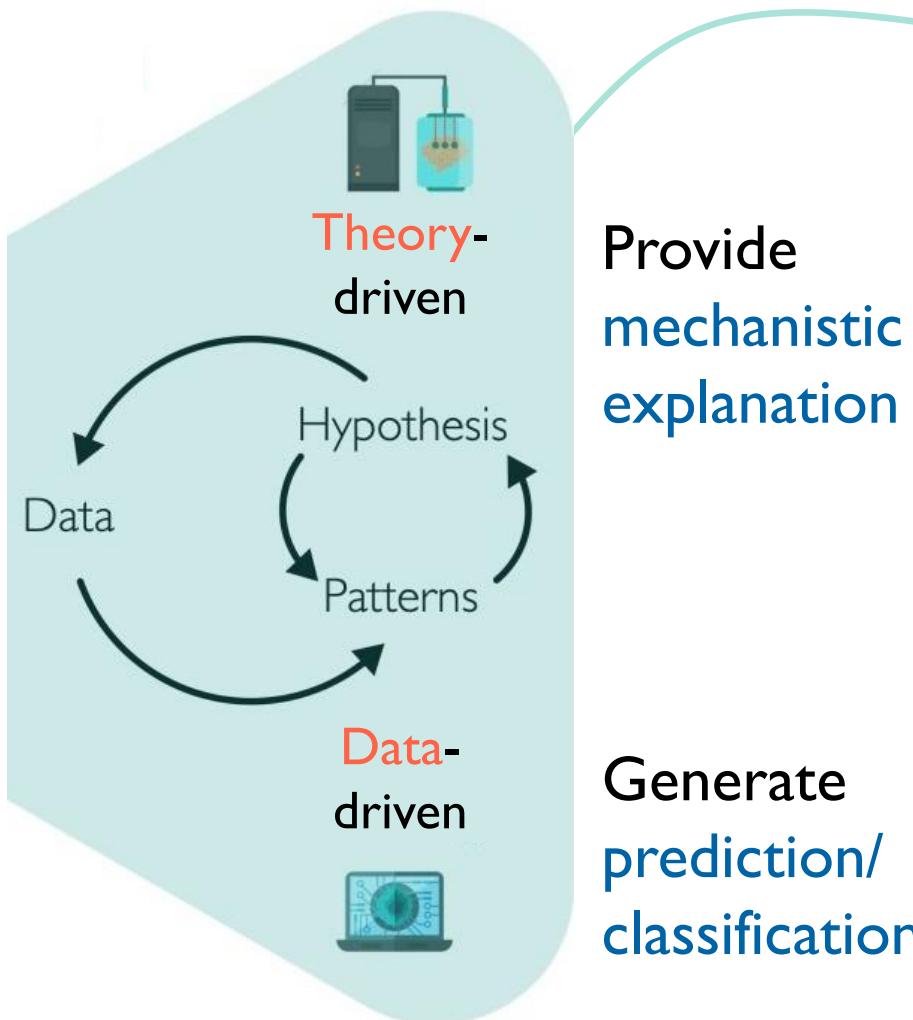
The three cultures of computational psychiatry

Christophe Gauld<sup>a, b, g, h</sup>, Guillaume Dumas<sup>c, d</sup>, Éric Fakra<sup>e, f</sup>, Jérémie Mattout<sup>g, h</sup>, Jean-Arthur Micoulaud-Franchi<sup>i, j</sup>

Show more ▾



# Theory-driven



Provide mechanistic explanation

Generate prediction/ classification

## Construct



- Reward,
- Learning,
- Self v. Other,
- etc.

## Computational modeling

### On the role of theory and modeling in neuroscience

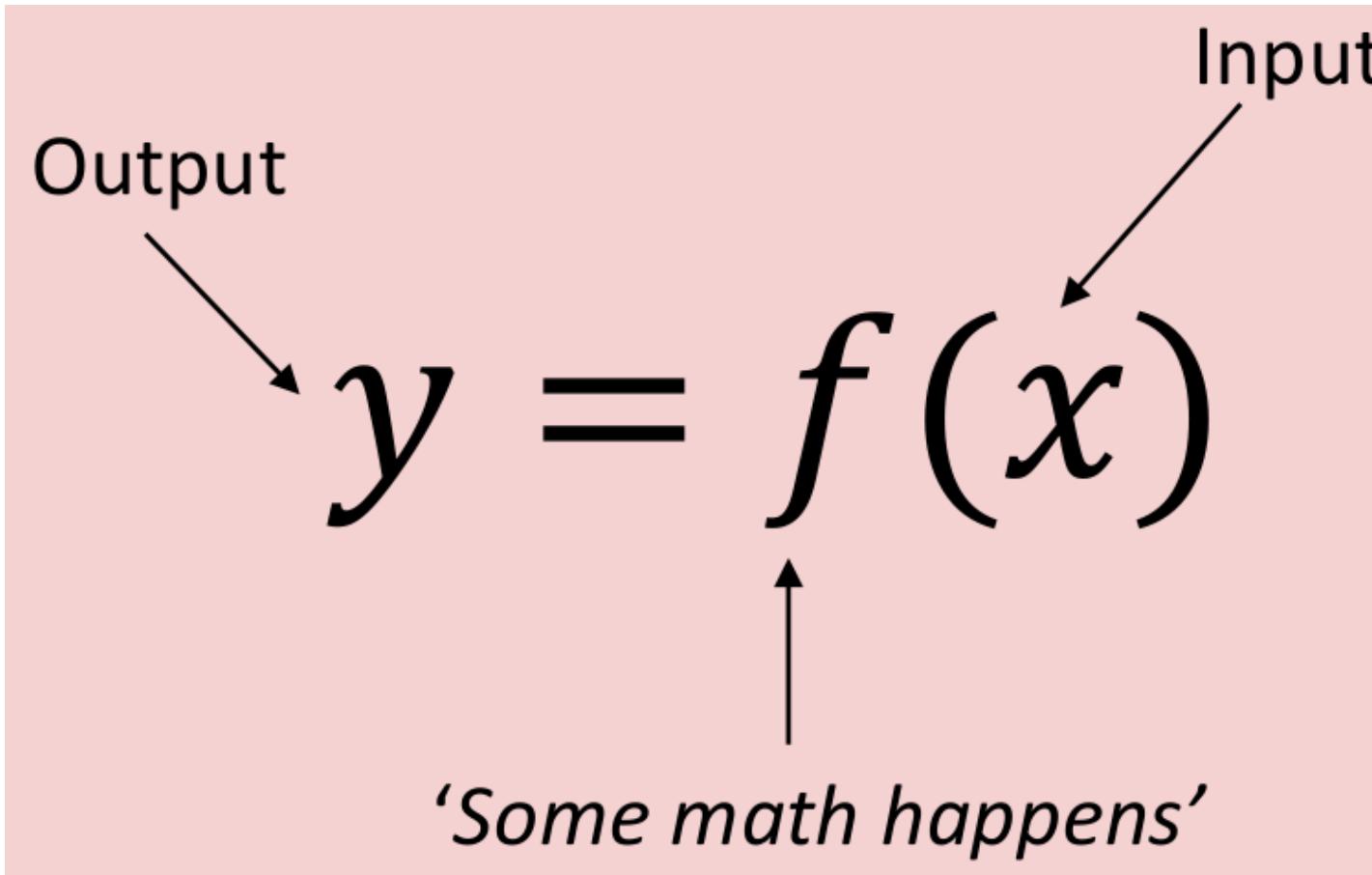
Daniel Levenstein<sup>1</sup>, Veronica A. Alvarez<sup>2</sup>, Asohan Amarasingham<sup>14</sup>, Habiba Azab<sup>3</sup>, Richard C. Gerkin<sup>4</sup>, Andrea Hasenstaub<sup>5</sup>, Ramakrishnan Iyer<sup>6</sup>, Renaud B. Jolivet<sup>7</sup>, Sarah Marzen<sup>12</sup>, Joseph D. Monaco<sup>8</sup>, Astrid A. Prinz<sup>13</sup>, Salma Quraishi, Fidel Santamaría<sup>9</sup>, Sabyasachi Shivkumar<sup>15</sup>, Matthew F. Singh<sup>10</sup>, David B. Stockton, Roger Traub<sup>11</sup>, Horacio G. Rotstein<sup>16,\*</sup>, Farzan Nadim<sup>16,\*</sup>, A. David Redish<sup>17,\*</sup>

### How Computational Modeling Can Force Theory Building in Psychological Science

Olivia Guest<sup>ID</sup>, Andrea E. Martin

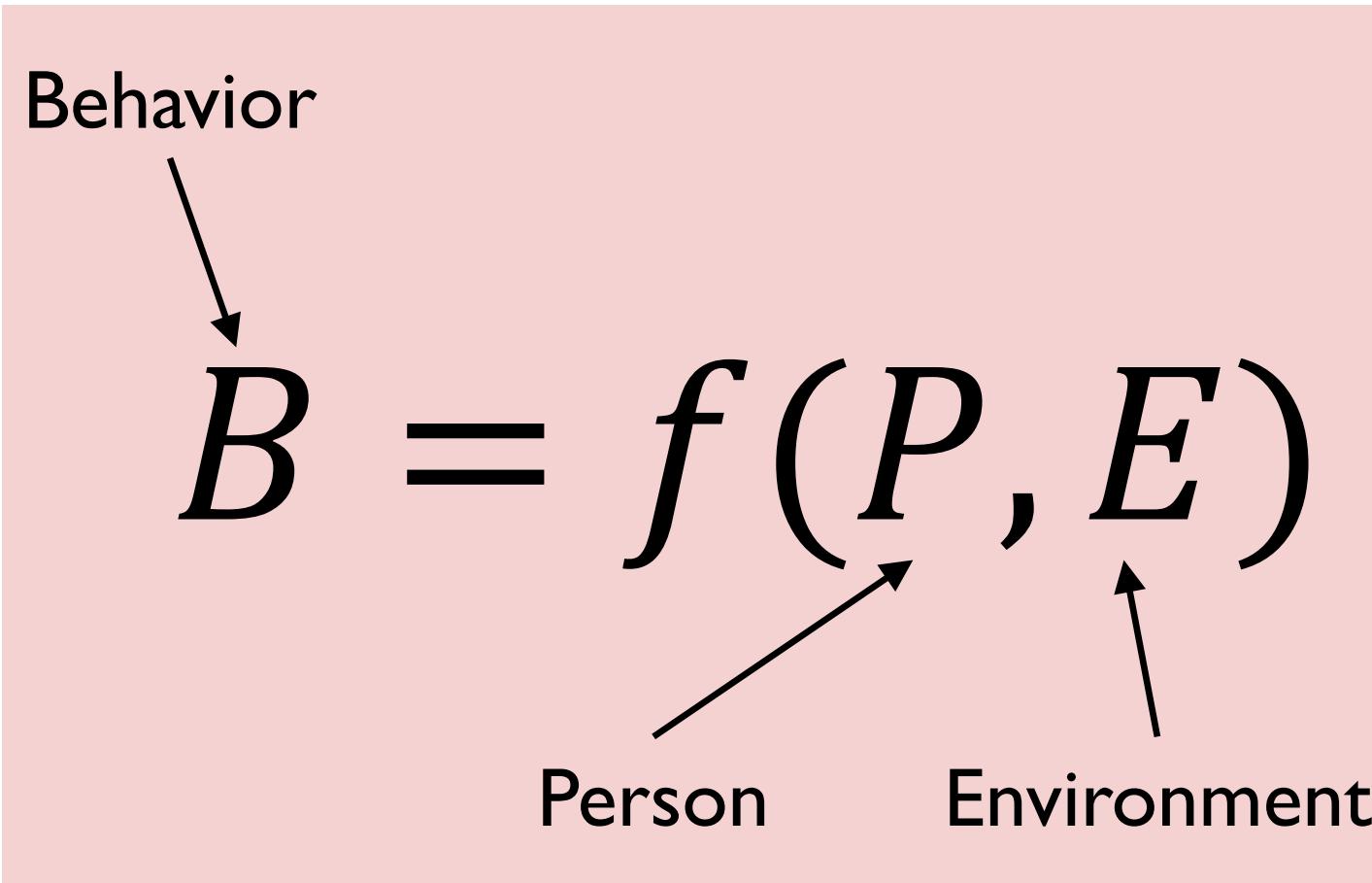
# Computational modeling

Cognition as information processing



# Computational modeling

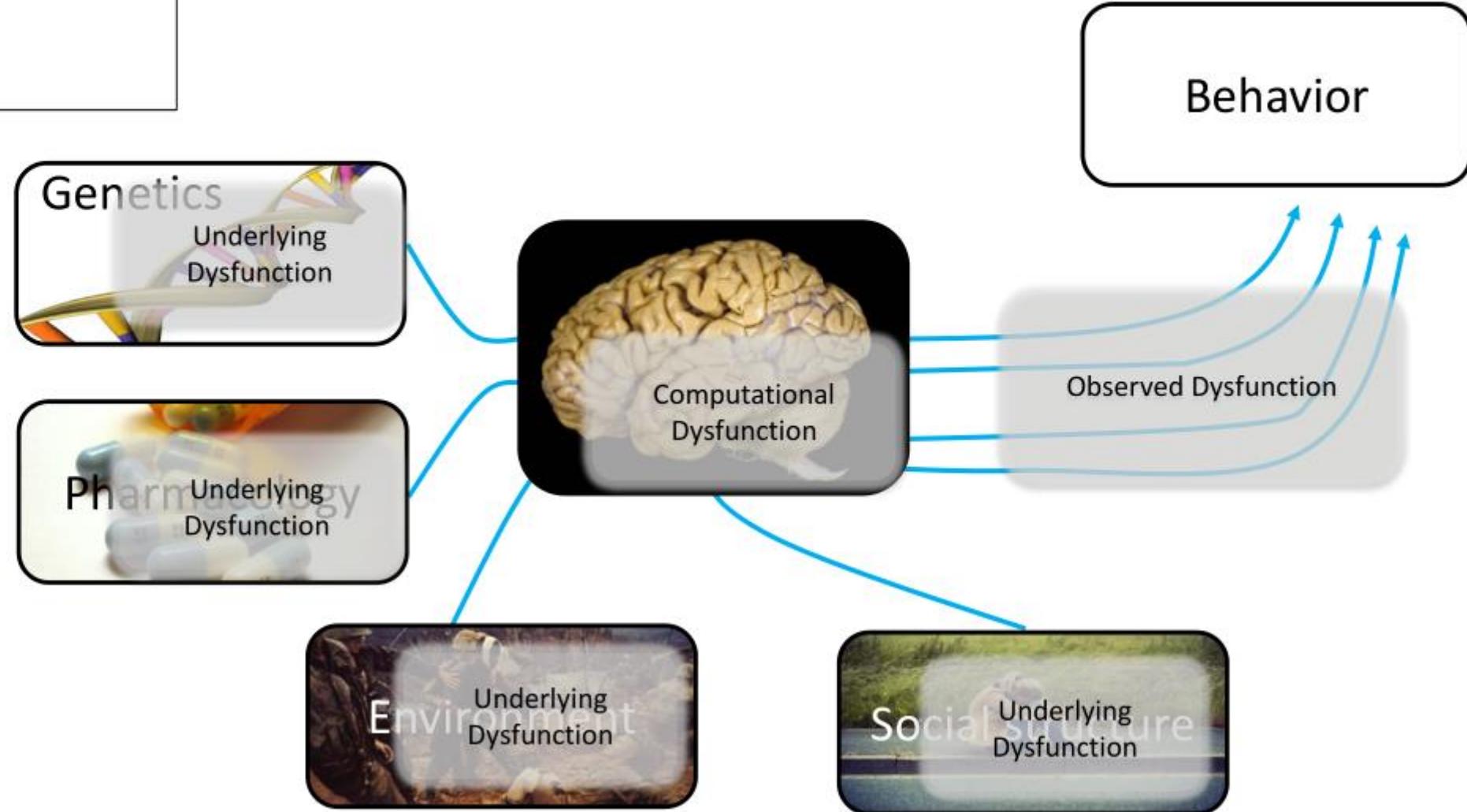
Cognition as information processing



Kurt Lewin, (1936)

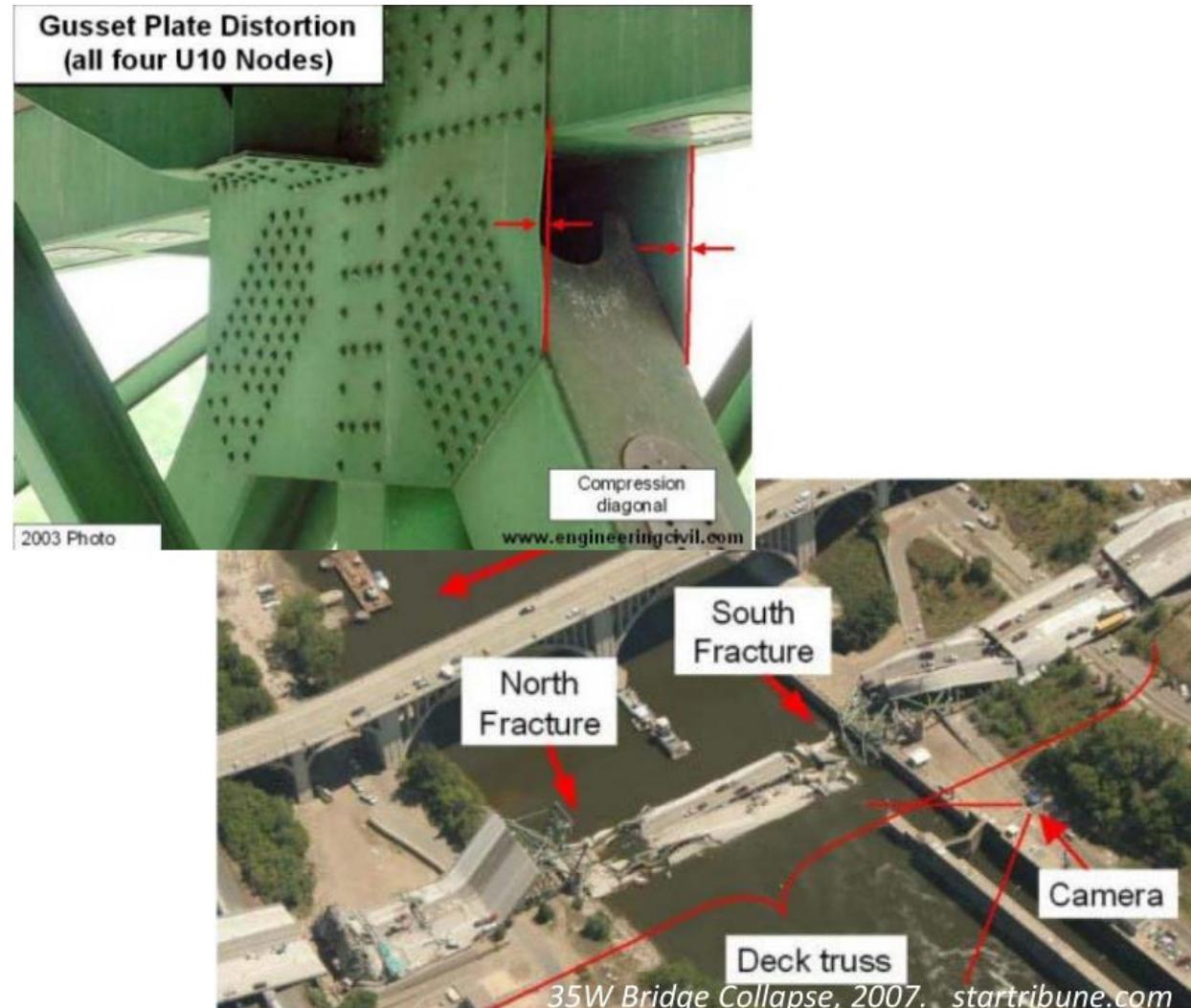
# Behavior depends on computation

This suggests a new view of psychiatry as neurophysiological **computational dysfunctions**



# Failure modes

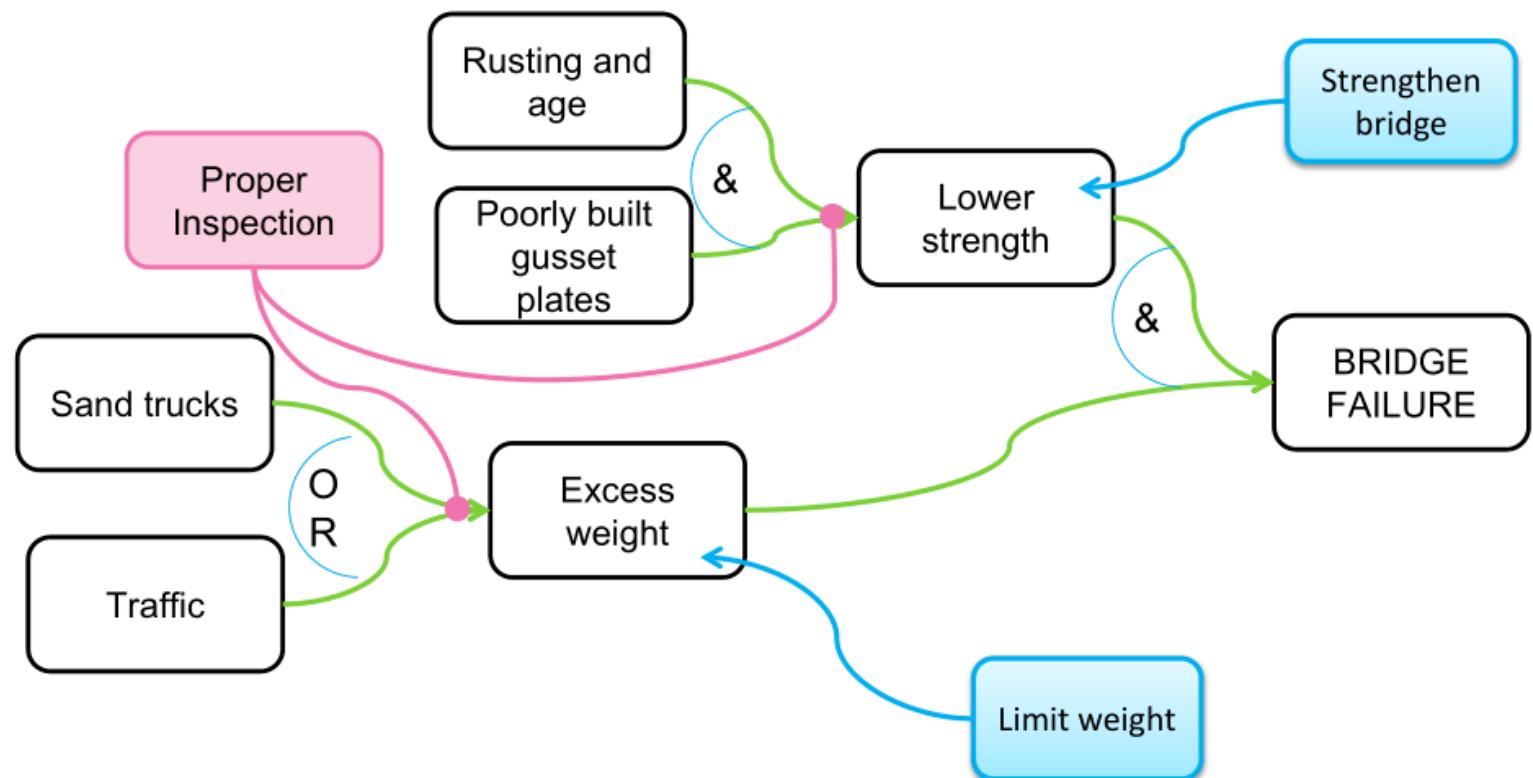
In reliability engineering, a “failure mode” is a vulnerability inherent in the machinery.



# Failure modes

If we know the failure modes,  
we can guide treatment.

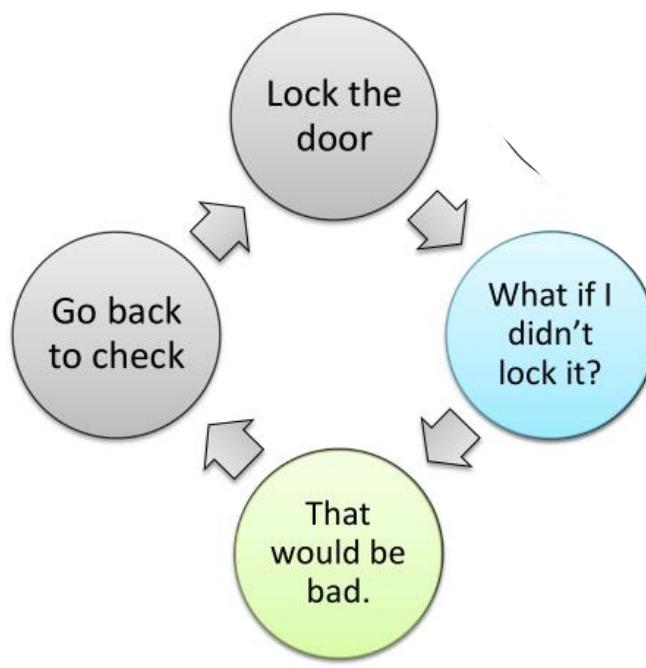
**Computational Psychiatry** is about  
applying **reliability engineering**  
analyses to neural systems



# Failure modes: OCD example

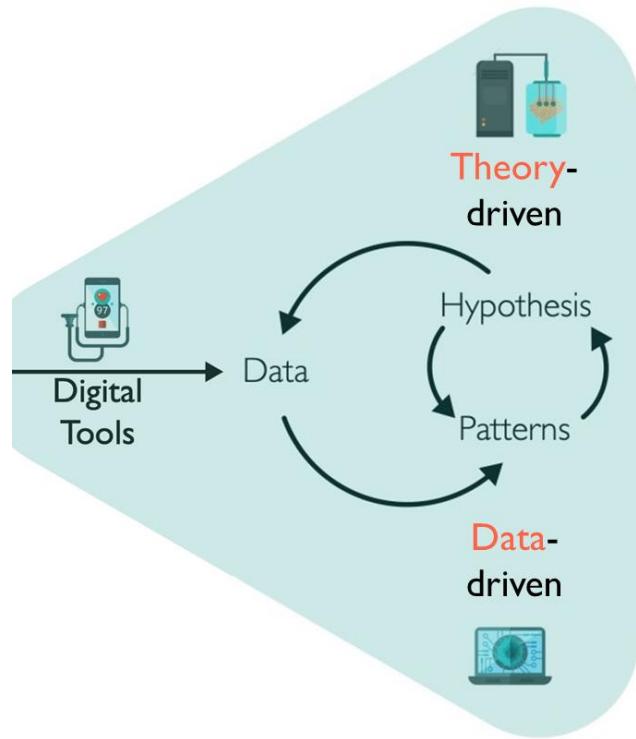


All of these are **computational failure modes**

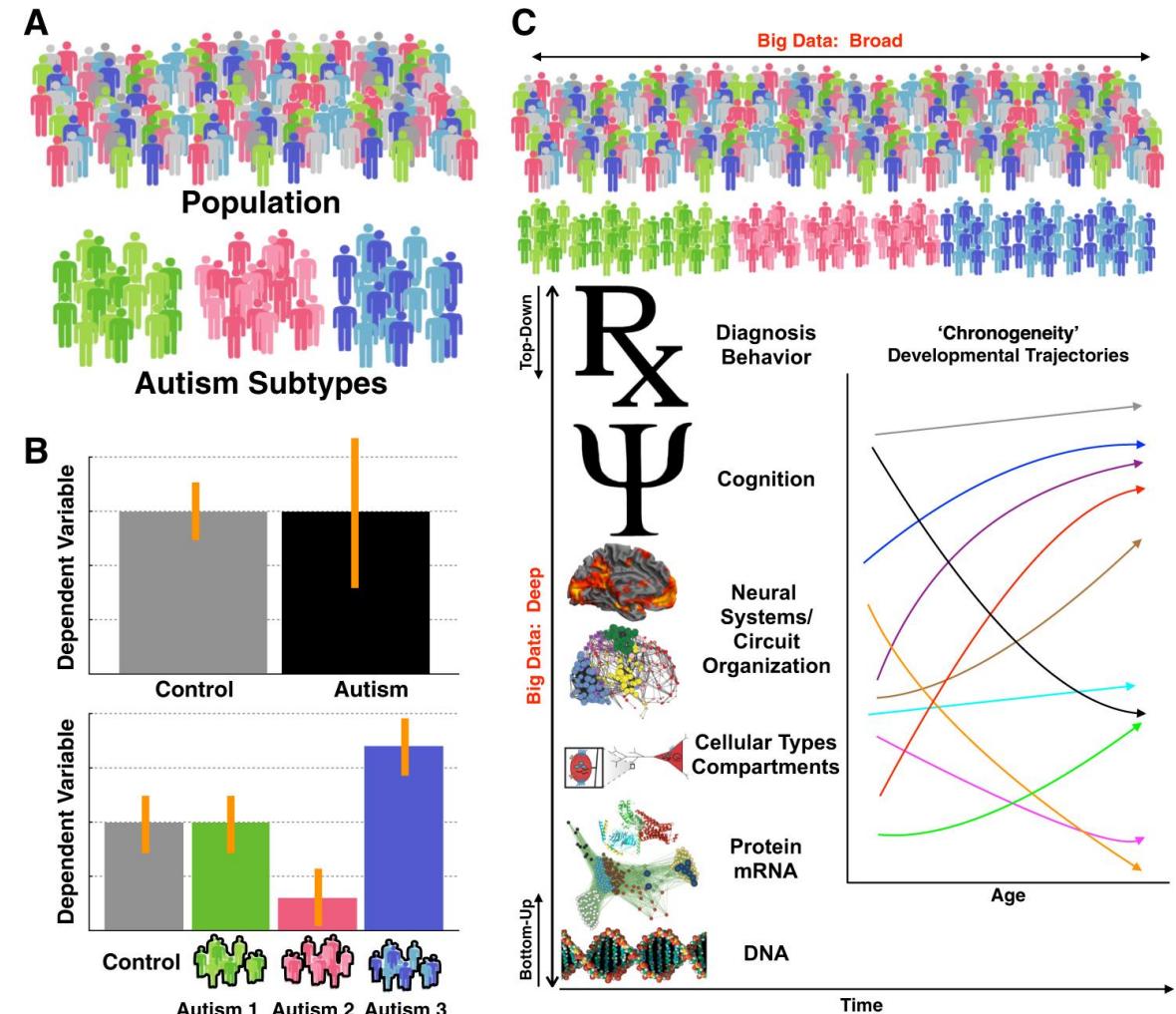


an imbalance between planning and habit modes, perhaps via problems with *response inhibition*, or an inability to recognize completion of a target, or an over-intensity of anxiety predictions?

# Data-Driven



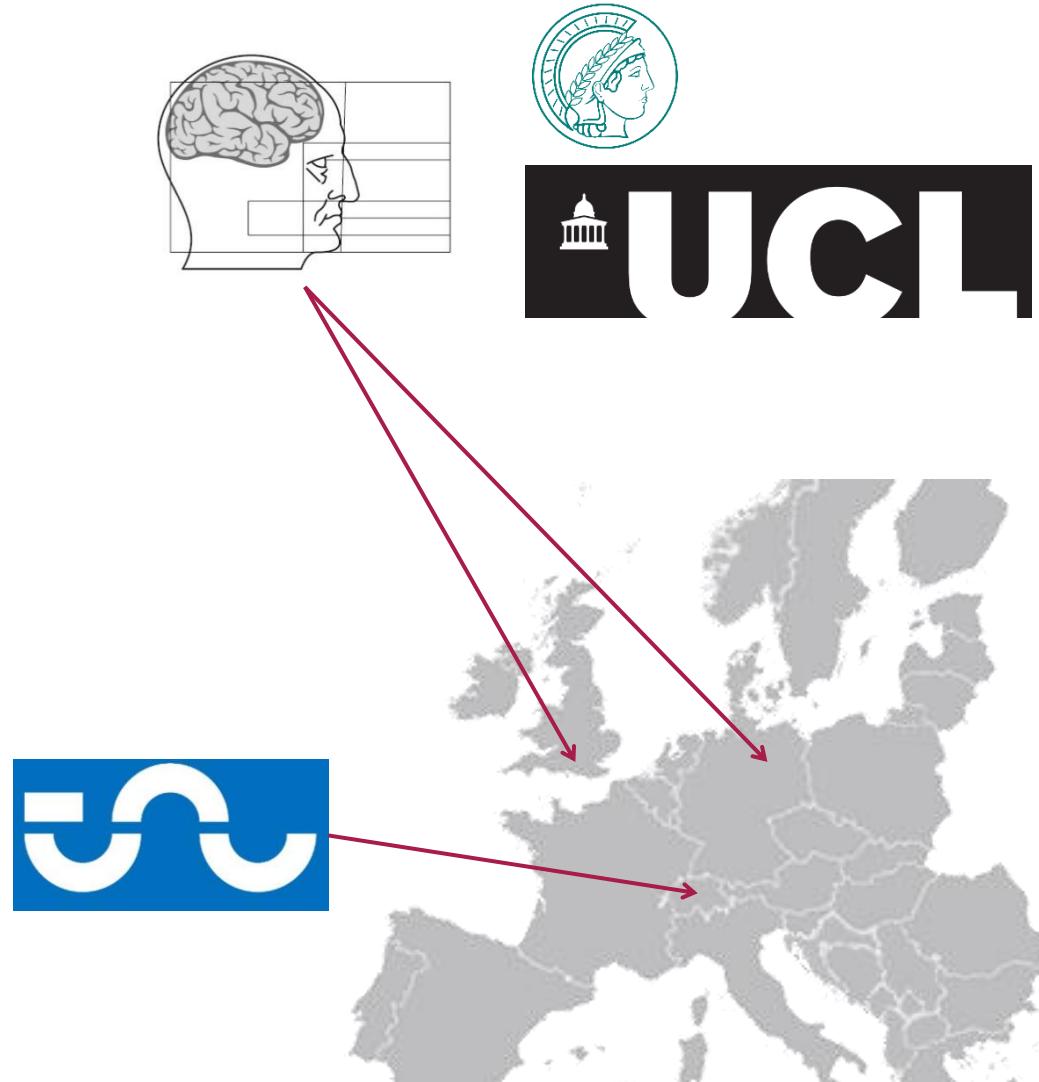
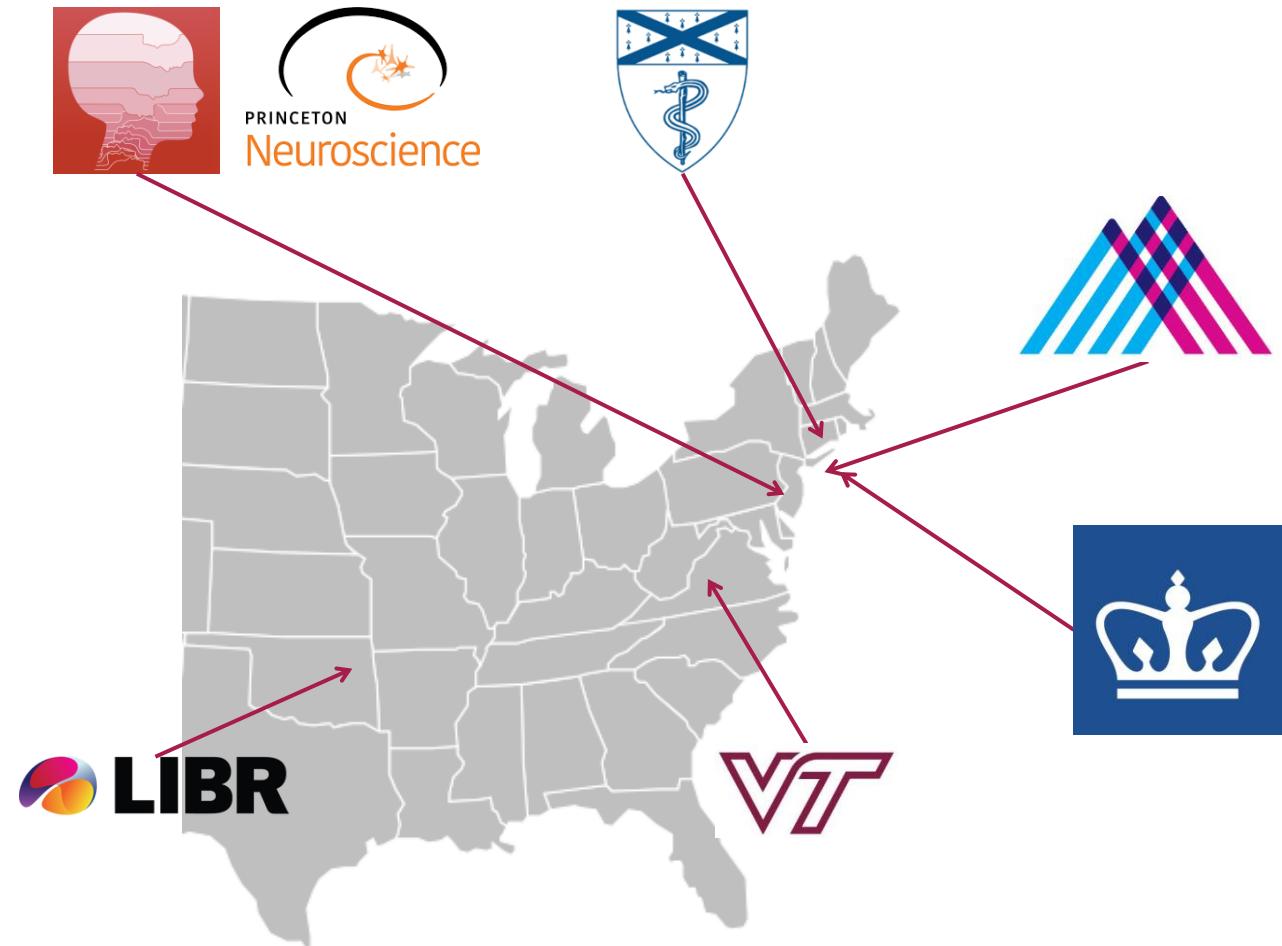
- Diagnostic
- Treatment response
- Identify sub-groups
- Speech analysis



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# CP Landscape: institutions



# CP Landscape: funding opportunities

ERC-2020-STG



[Home](#) > [About NIMH](#) > [Offices and Divisions](#) > [Division of Translational Research \(DTR\)](#) > [Adult Psychopathology and Psychosocial Interventions Research Branch](#)

Adult Psychopathology and Psychosocial Interventions Research Branch

Adult Pathophysiology and Biological Interventions Development Branch

Developmental Mechanisms and Trajectories of Psychopathology Branch

Geriatrics and Aging Processes Research Branch

Biomarker and Intervention Development for Childhood-Onset Mental Disorders Branch

Traumatic Stress Research Program

Small Business Innovation Research (SBIR) Program and Small Business Technology Transfer (STTR) Program (Adult Psychopathology)

## Computational Psychiatry Program

### Overview

The overarching goal of this program is to foster a novel biologically-based computational framework to identify and validate biomarkers and novel treatment targets relevant to the prevention, treatment, and recovery of psychiatric disorders. The program supports translational research utilizing computational models for validating [RDoC](#) constructs in the clinic. The program is interested in analytical approaches for the prediction of risk and treatment response and the understanding of the pathophysiology underlying mental disorders. Research projects combining mathematical and computational tools with neurophysiological, neuroanatomical, neurochemical, and/or neuroimaging techniques are encouraged in order to decipher the function of biological mechanisms implicated in mental disorders.

Project acronym	CalorieRL
Project	Reinforcement learning from post-ingestive calories: from body to brain in health and disease

Project acronym	HABIT
Project	Making and Breaking Habits

Project acronym	NeuroFlux
Project	Understanding the impact of brain fluctuations on decision making

Project acronym	INFORL
Project	Characterizing information integration in reinforcement learning: a neuro-computational investigation

Project acronym	WARN-D
Project	Using Network Theory to Predict Depression Onset and Build a Personalized Early Warning System

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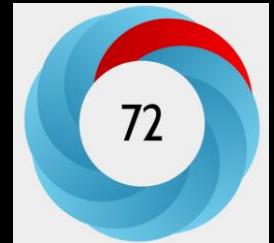
# Case study

## Flexible learning behavior in autism

(Crawley\* & Zhang\* et al., 2020, *Plos Biology*)

\*: joint first author

PLOS BIOLOGY



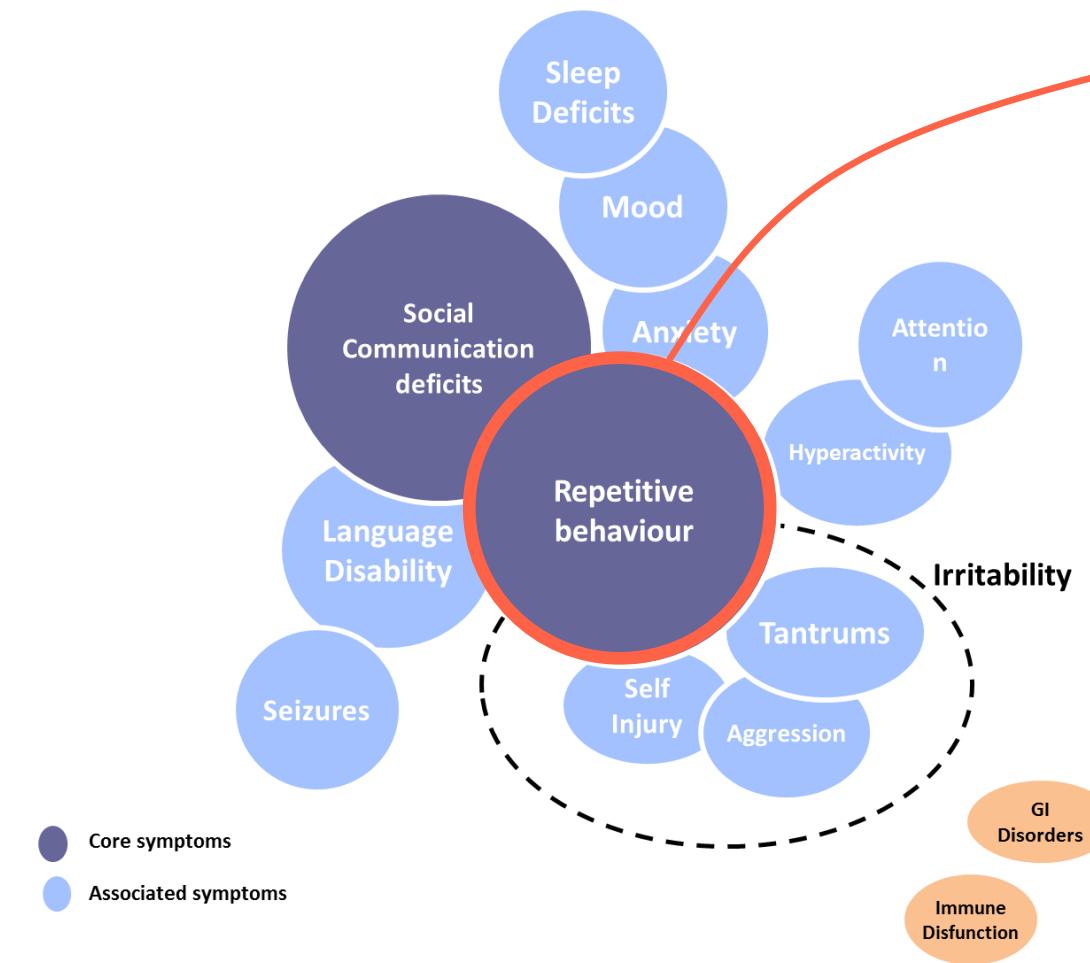
RESEARCH ARTICLE

Modeling flexible behavior in childhood to adulthood shows age-dependent learning mechanisms and less optimal learning in autism in each age group

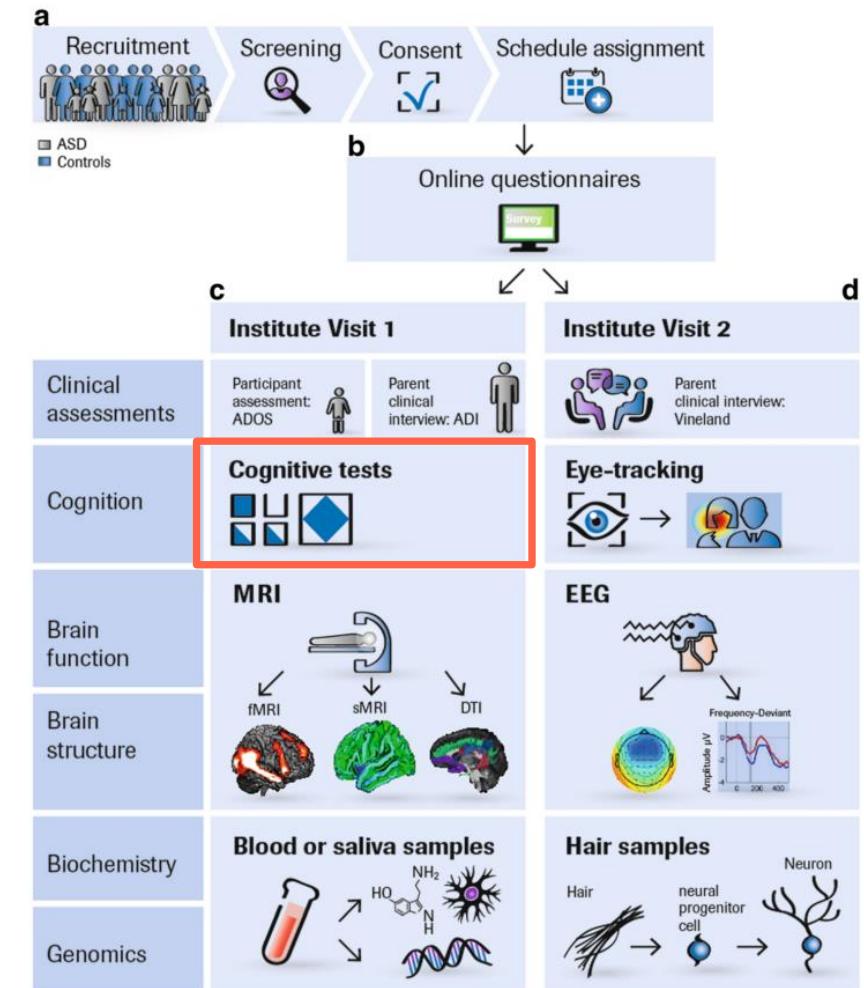
Daisy Crawley<sup>1‡\*</sup>, Lei Zhang<sup>2,3,4‡</sup>, Emily J. H. Jones<sup>5</sup>, Jumana Ahmad<sup>1,6</sup>,  
Bethany Oakley<sup>1</sup>, Antonia San José Cáceres<sup>1,7</sup>, Tony Charman<sup>1,8,9</sup>, Jan  
K. Buitelaar<sup>10,11,12</sup>, Declan G. M. Murphy<sup>1,9,13</sup>, Christopher Chatham<sup>4</sup>, Hanneke den  
Ouden<sup>10‡</sup>, Eva Loth<sup>1,13‡</sup>, the EU-AIMS LEAP group<sup>11</sup>

# Impaired cognitive flexibility in Autism

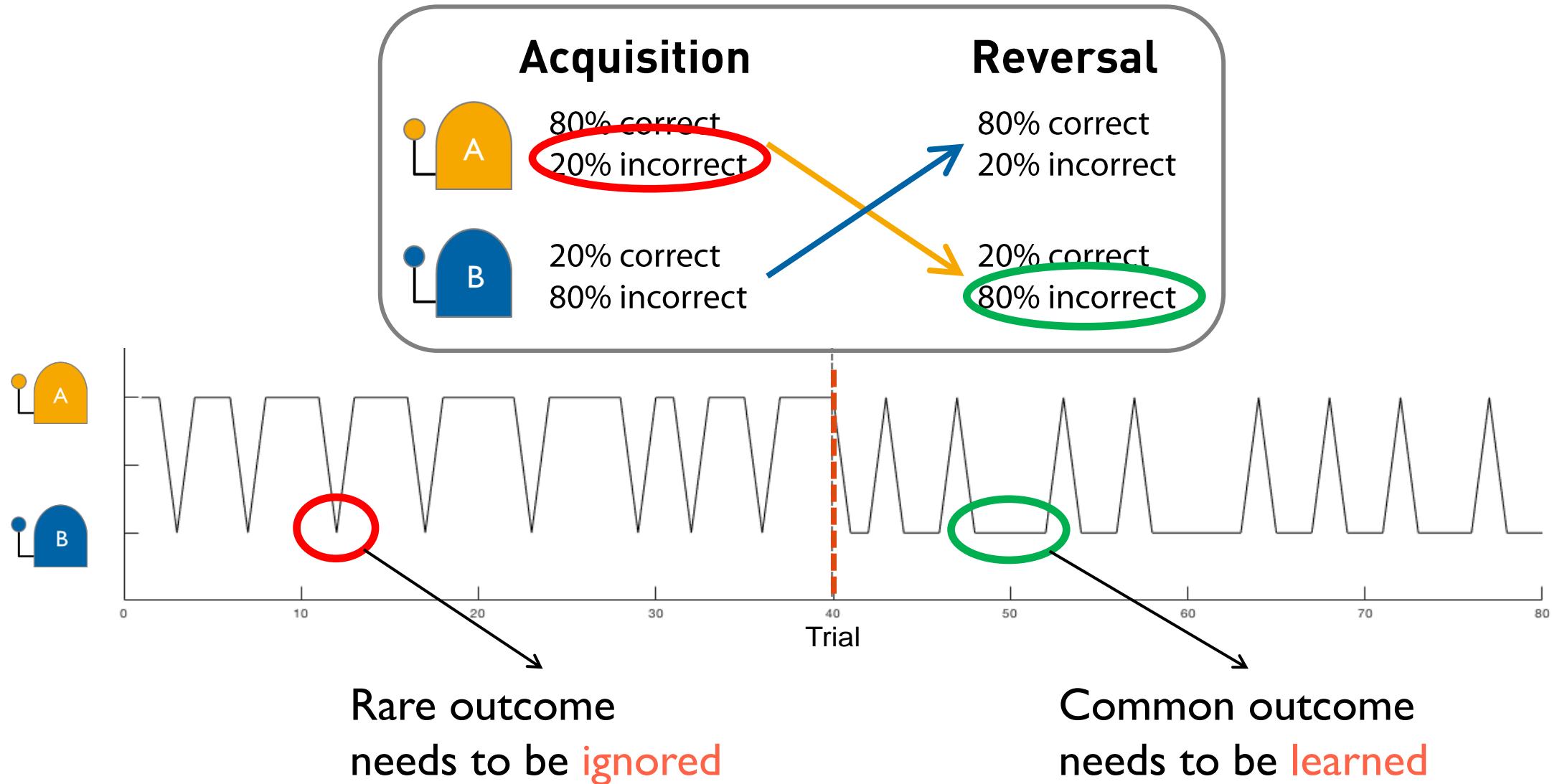
Behavioral rigidity is underpinned by cognitive (in)flexibility



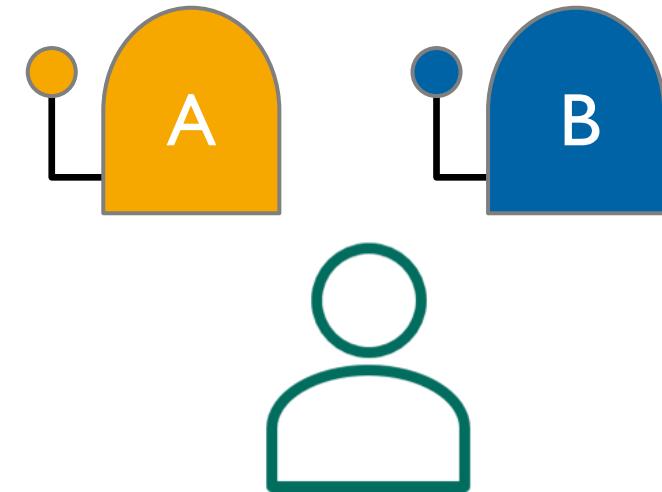
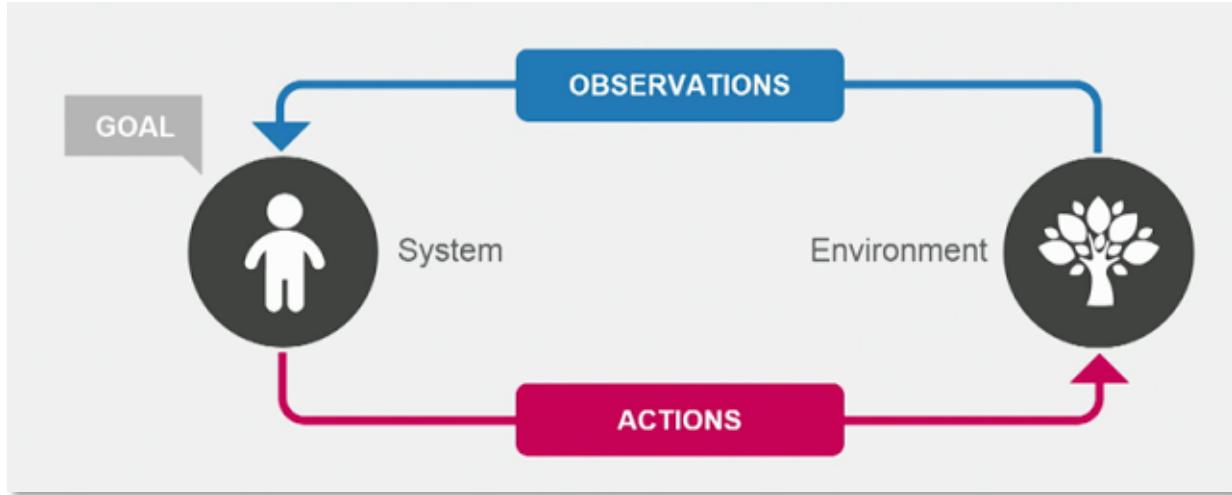
DSM-V; Loth et al., (2017)



# Cognitive flexibility in reversal learning



# Computational focus



## Reinforcement learning

- gain reward/avoid punishment
- feedback-driven, trial-and-error

## Rescorla-Wagner Model

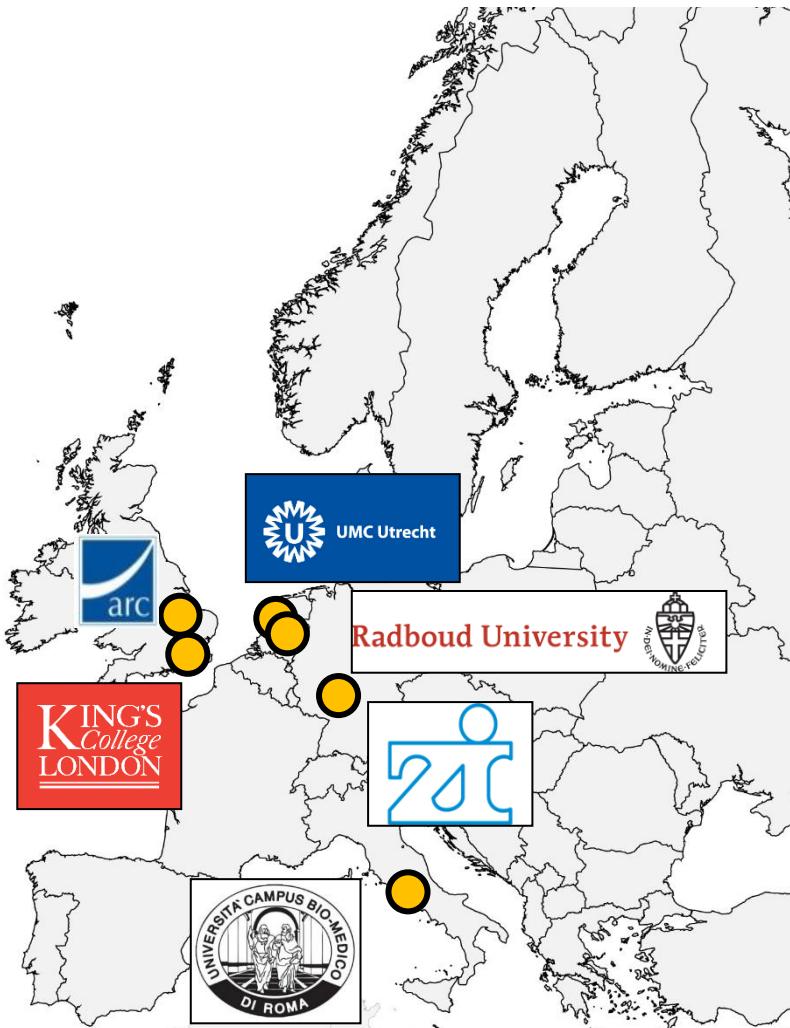
Value update:  $V_t = V_{t-1} + \alpha * PE_{t-1}$

Prediction error:  $PE_{t-1} = R_{t-1} - V_{t-1}$

*Expectations on the next trial = the expectation on the current trial + learning rate \* prediction error (reward – current expectation)*

# EU-AIMS LEAP

## Longitudinal European Autism Project

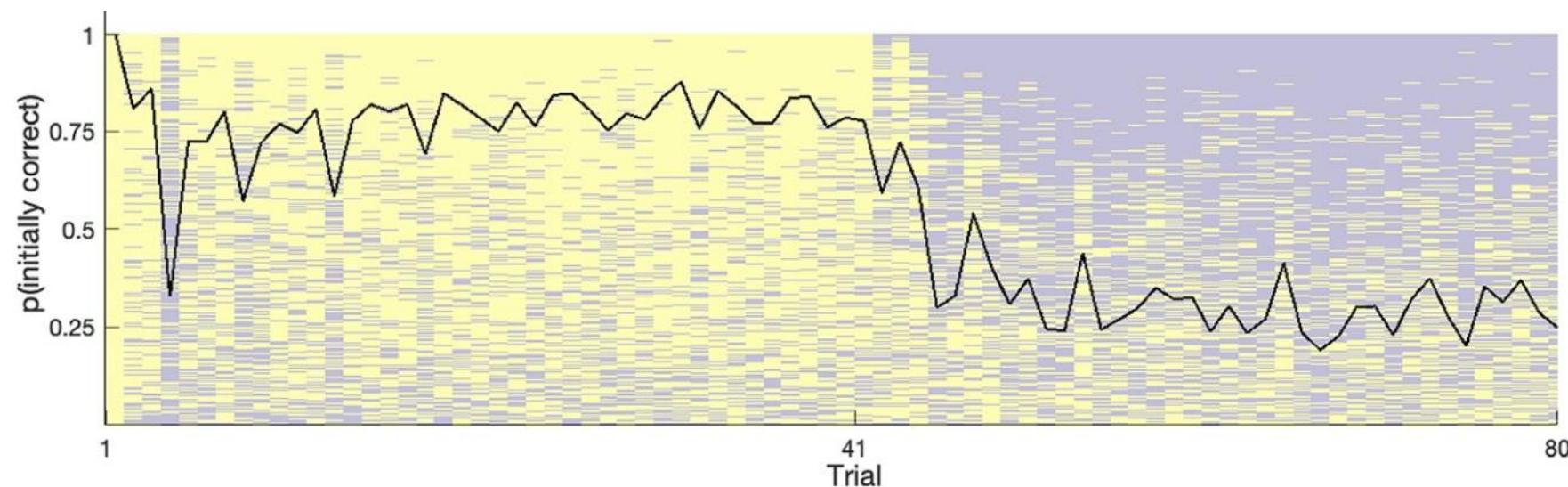
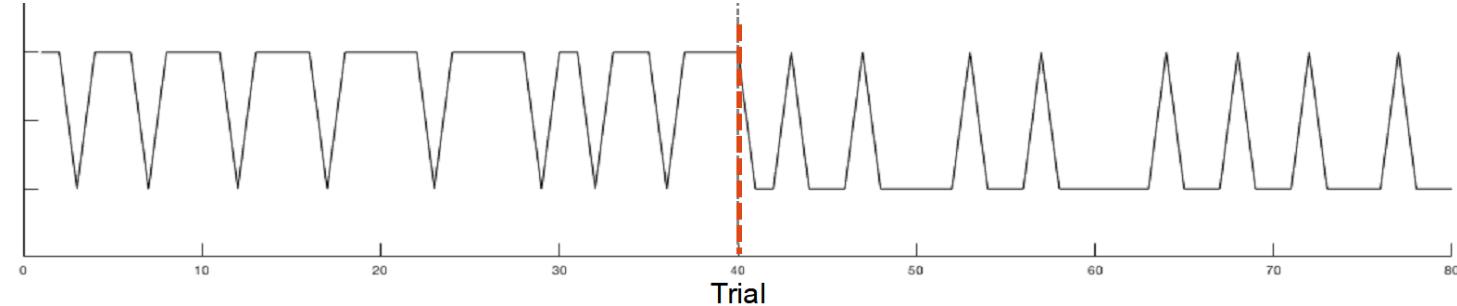
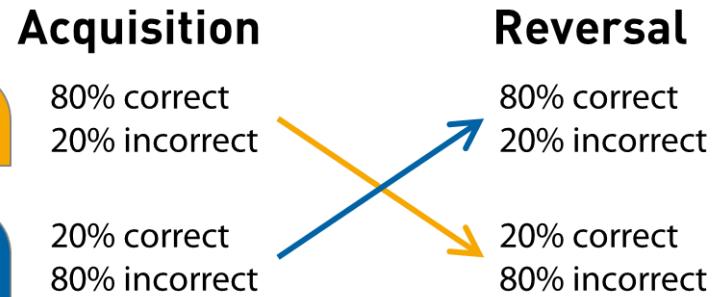


Age group	Diagnosis		
	ASD	TD	Total
Children (6-11 years)	81	64	145
Adolescents (12-17 years)	114	90	204
Adults (18-30 years)	126	97	223
<b>Total</b>	<b>321</b>	<b>251</b>	<b>572</b>

- ASD = Autism spectrum disorder
- TD = Typical development

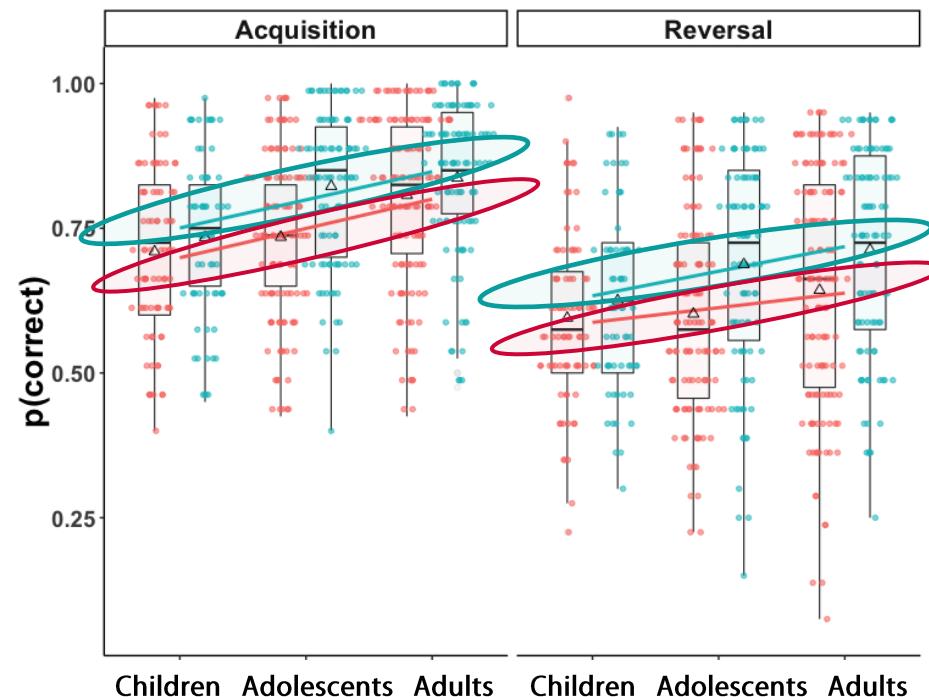


# Paradigm

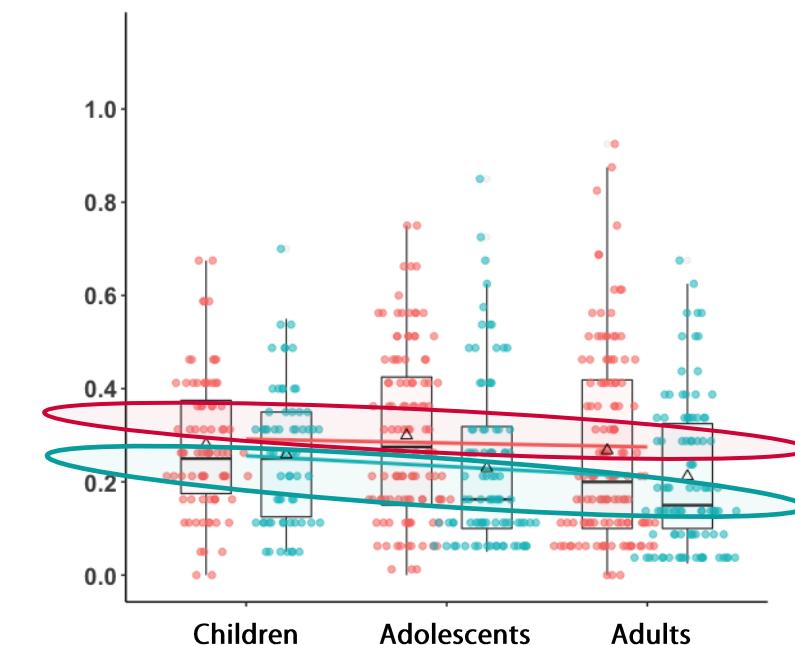


# Less optimal learning performance in ASD

## Choice accuracy

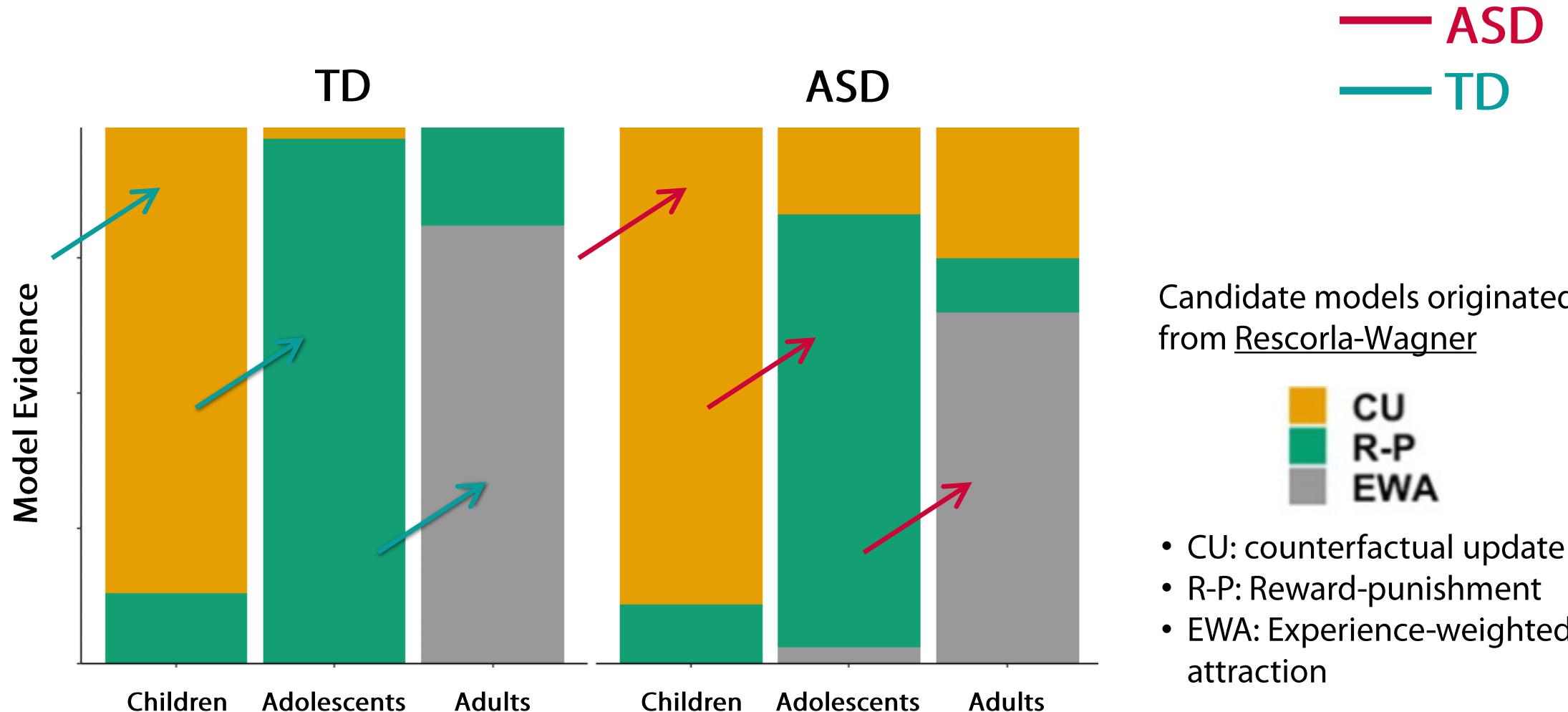


## Perseverative errors (after reversal)



— ASD  
— TD

# Same computational model within age group

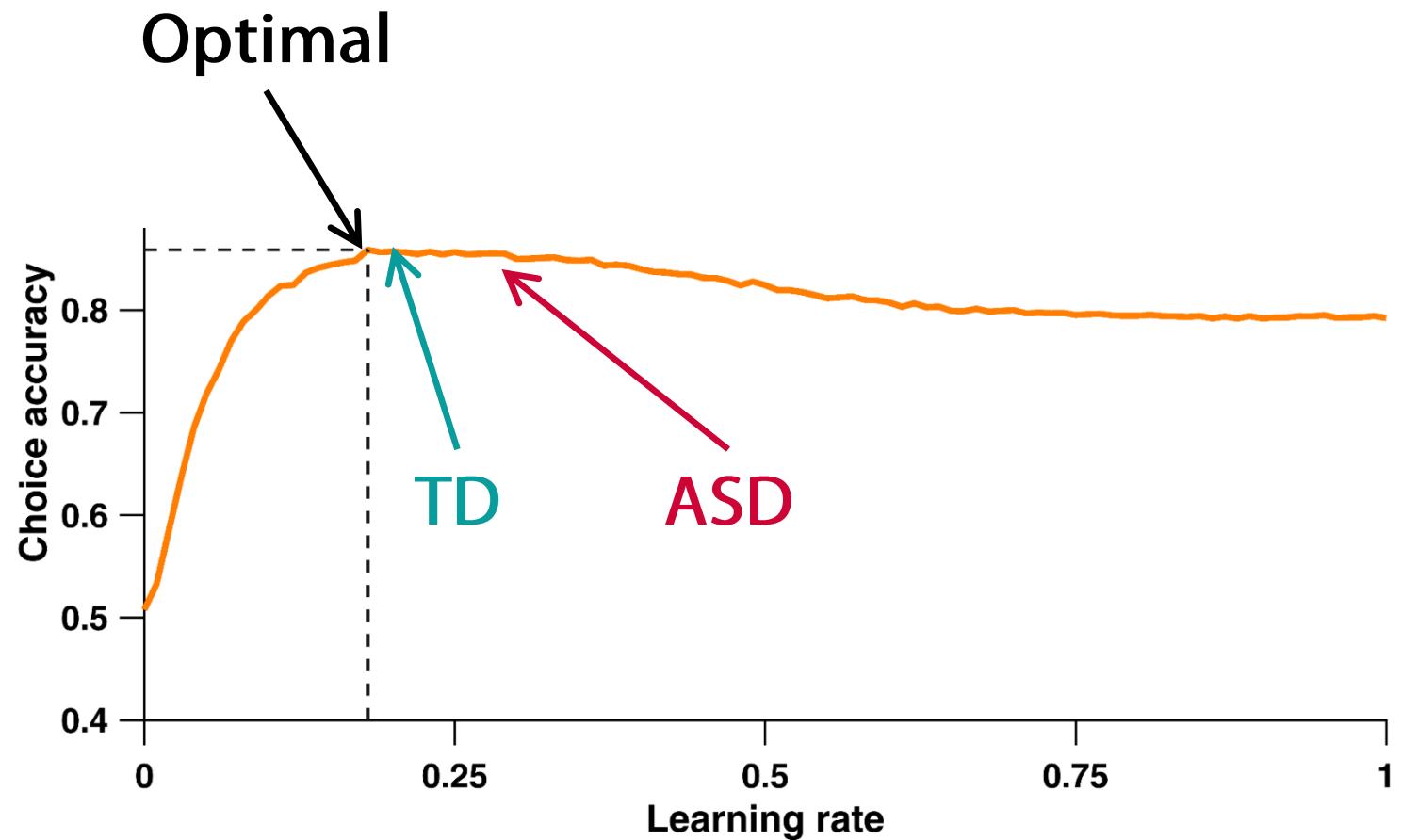
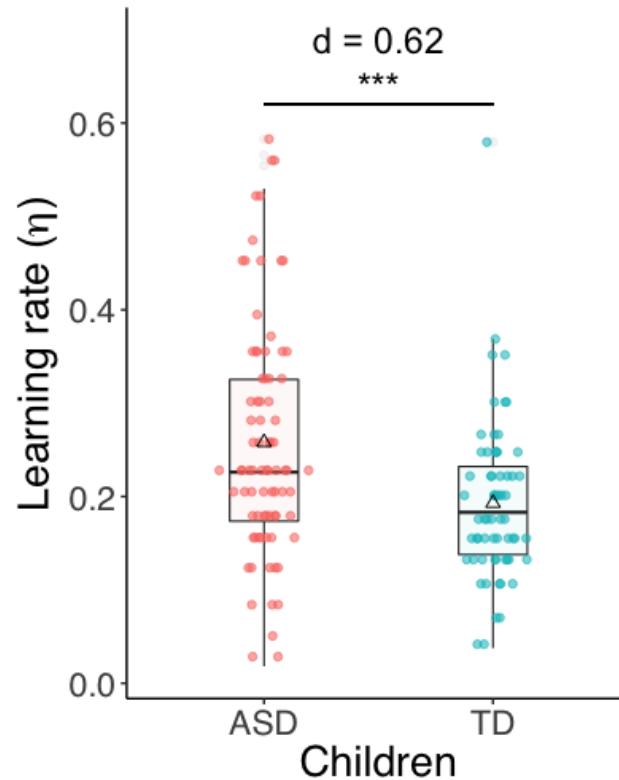


Candidate models originated from Rescorla-Wagner



- CU: counterfactual update
- R-P: Reward-punishment
- EWA: Experience-weighted attraction

# Suboptimal learning parameters in ASD

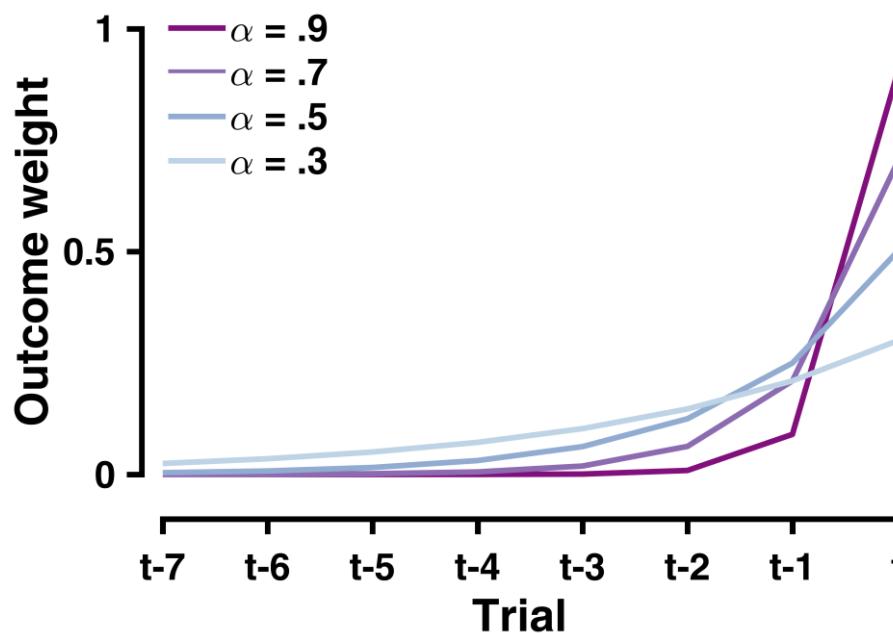


# Understand the learning rate

Value update:  $V_t = V_{t-1} + \alpha * \text{PE}_{t-1}$

Prediction error:  $\text{PE}_{t-1} = R_{t-1} - V_{t-1}$

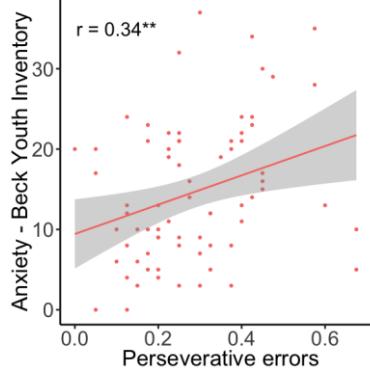
$$\begin{aligned}V_t &= (1 - \alpha) V_{t-1} + \alpha R_{t-1} \\&= (1 - \alpha)(V_{t-2} + \alpha(R_{t-2} - V_{t-2})) + \alpha R_{t-1} \\&= (1 - \alpha)^t V_0 + \sum_{i=1}^t (1 - \alpha)^{t-i} \alpha R_i\end{aligned}$$



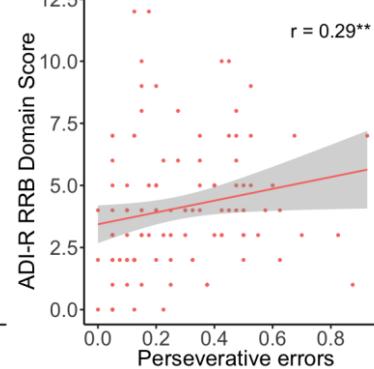
# Parameter ~ clinical scales

## Task behaviour

A. Children

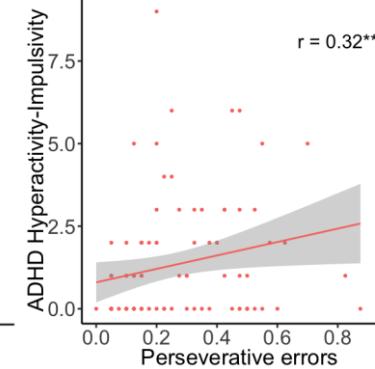


B.

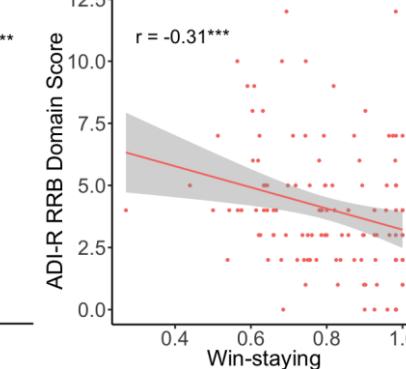


Adults

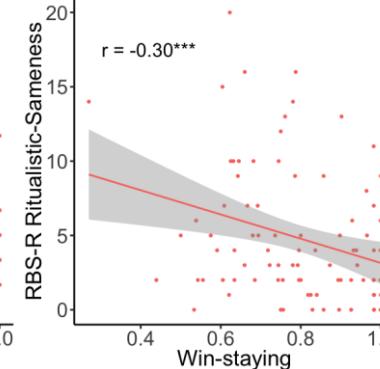
C.



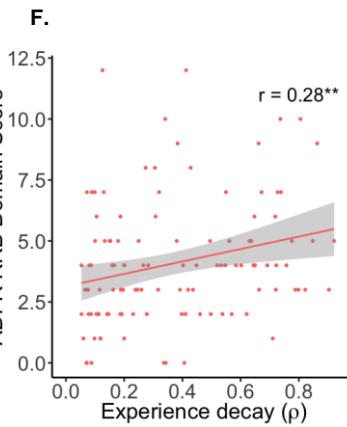
D.



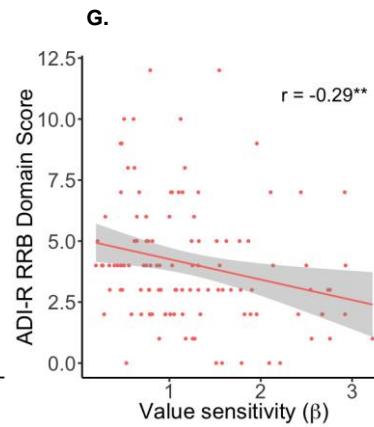
E.



## Model parameters

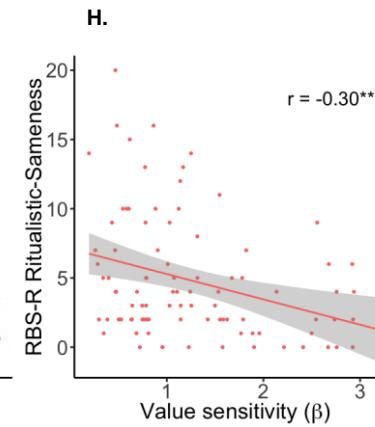


G.

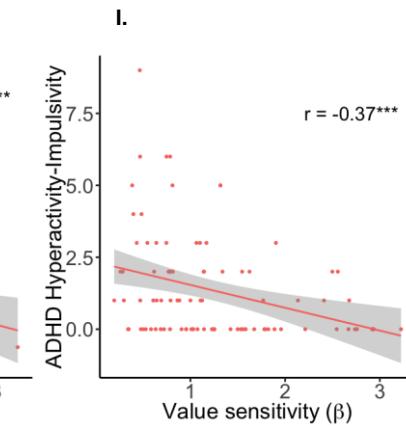


Adults

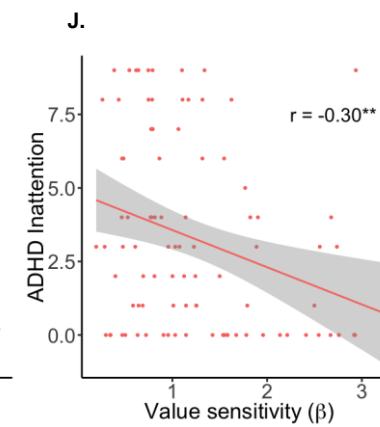
H.



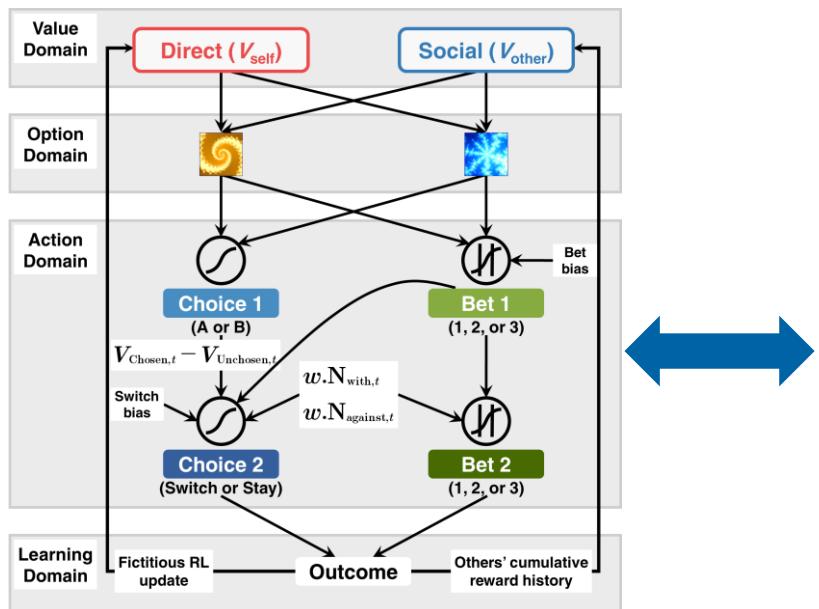
I.



J.



# hBayesDM package



$$\begin{aligned}
 V_{self,t} &= [V_{self,t}(A), V_{self,t}(B)] \\
 V_{other,t} &= [V_{other,t}(A), V_{other,t}(B)] \\
 V_t &= \beta_{self} V_{self,t} + \beta_{other} V_{other,t} \\
 C1_t &\sim \text{Categorical}(\text{Softmax}(V_t)) \\
 U_{bet1,t} &= \beta_{bias} + \beta_{wifl(t)}(V_{Chosen,C1,t} - V_{Unchosen,C1,t}) \\
 B1_t &\sim \text{OrderedLogistic}(U_{bet1,t} | \theta) \\
 w.N_{spinet,t} &= \frac{\sum_{i=1}^K w_{i,t}}{\sum_{i=1}^K w_{i,t}}, K = 0, 1, \dots, 4 \\
 w.N_{with,t} &= \frac{\sum_{i=1}^{K_w} w_{i,t}}{\sum_{i=1}^K w_{i,t}} \\
 w.N_{against,t} &= \frac{\sum_{i=K_w+1}^K w_{i,t}}{\sum_{i=1}^K w_{i,t}} \\
 V_t(\text{switch}) &= \beta_{biasC2} + \beta_{wifl(t)}(V_{Chosen,C1,t} - V_{Unchosen,C1,t}) + \beta_{against} w.N_{spinet,t} \\
 C2 &\sim \text{Bernoulli}(V_t(\text{switch})) \\
 U_{bet2,t} &= \begin{cases} U_{bet1,t} + \beta_{with_{new}} w.N_{with,t} + \beta_{against_{new}} w.N_{against,t}, & \text{if } C1 = C2 \\ U_{bet1,t} + \beta_{with_{new}} w.N_{with,t} + \beta_{against_{new}} w.N_{against,t}, & \text{if } C1 \neq C2 \end{cases} \\
 B2_t &\sim \text{OrderedLogistic}(U_{bet2,t} | \theta) \\
 \Phi(x) &= \frac{1}{1+e^{-x}} \\
 \delta_{self,chosen,C2,t} &= R_{self,t} - V_{self,chosen,C2,t} \\
 \delta_{self,unchosen,C2,t} &= -R_{self,t} - V_{self,unchosen,C2,t} \\
 V_{self,chosen,C2,t+1} &= V_{self,chosen,C2,t} + \alpha \delta_{self,chosen,C2,t} \\
 V_{self,unchosen,C2,t+1} &= V_{self,unchosen,C2,t} + \alpha \delta_{self,unchosen,C2,t}
 \end{aligned}$$



$$P(A|B) = \frac{P(B|A)P(A)}{P(B)}$$

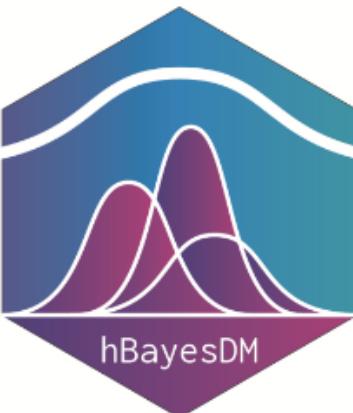
# hBayesDM package

## hBayesDM

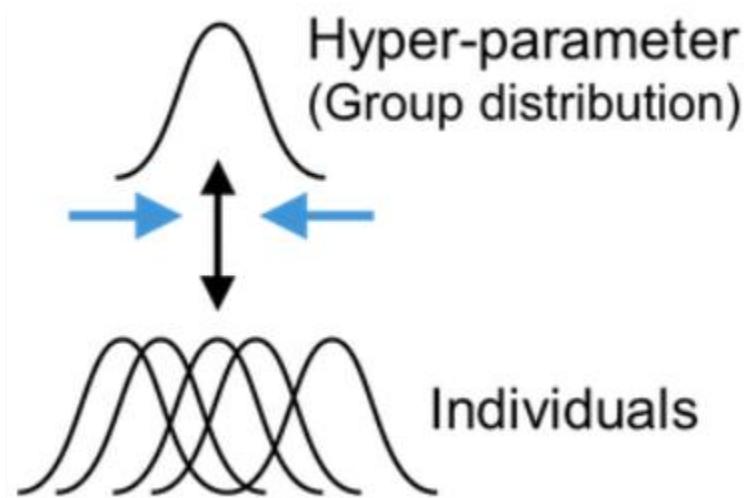
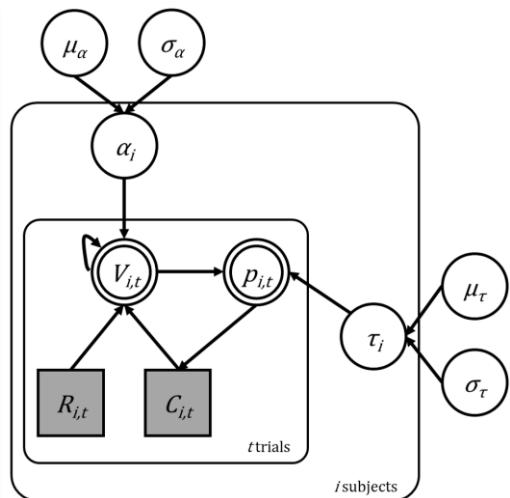
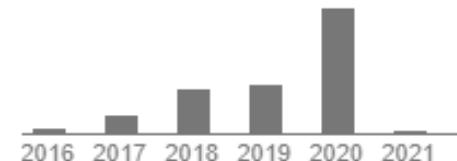
repo status Active build passing CRAN 1.0.2 – 2019-11-13 downloads 33K

DOI 10.1162/CPSY\_a\_00002

hBayesDM (hierarchical Bayesian modeling of Decision-Making tasks) is a user-friendly package that offers hierarchical Bayesian analysis of various computational models on an array of decision-making tasks. hBayesDM uses Stan for Bayesian inference.



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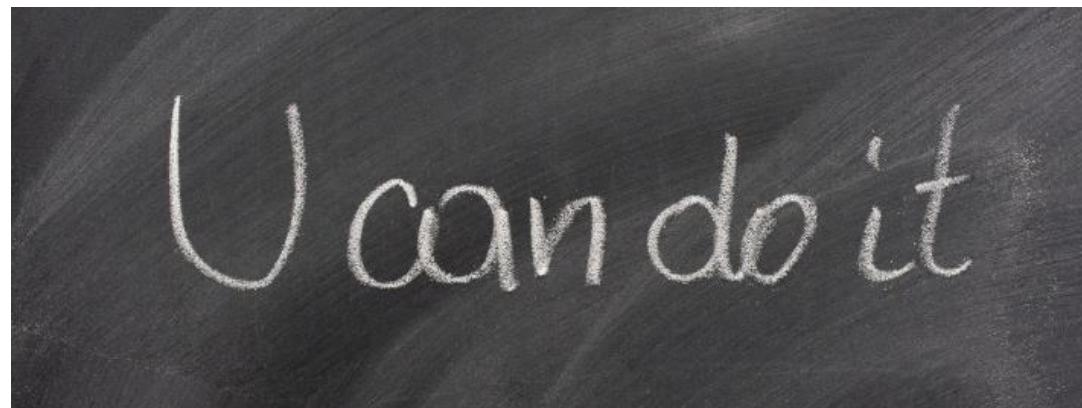


# Outline

- The born and the rise of Computational Psychiatry (CP)
- Three cultures of CP
- Current landscape of CP: institutions and funding opportunities
- A case study: flexible choice behavior in Autism
- **Summary**

# Summary

- CP is newly emerging and rapidly growing → embrace the opportunity!
- Computational modeling is never new → don't let it fear you!
- Read classic works → improve theoretical thinking
- Learn in pairs; no one can do everything → seek for cooperation!
- Learn to seek external help → existing packages! e.g., hBayesDM
- Be open minded, be aware of research landscape → use Twitter!



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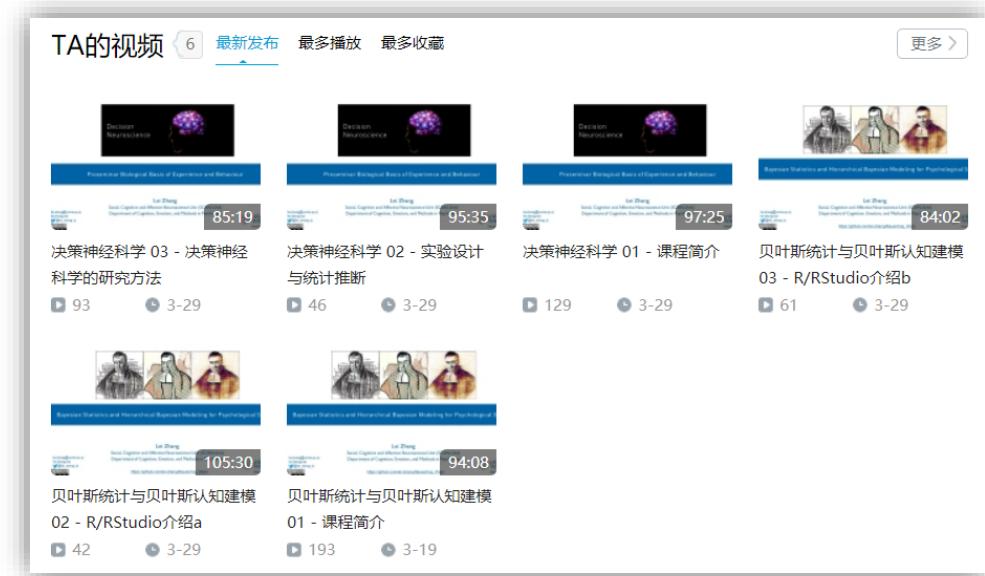
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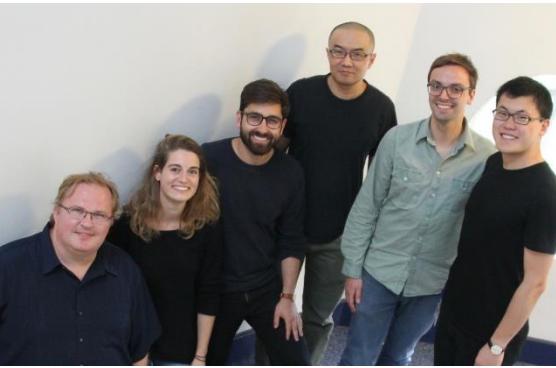


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# Thank you!



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ANY  
QUESTIONS  
?

Happy Computing!