What we talk about when we talk about Computational Psychiatry

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SCAN Unit

universität wien

Fakultät für Psychologie

Outline

- The birth 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

CellPress

Review

Special Issue: Cognition in Neuropsychiatric Disorders

Computational psychiatry

P. Read Montague [1, 2], Raymond J. Dolan [2], Karl J. Friston [2], Peter Dayan [3]

ELSEVIER

Neural Networks

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

2011 Special Issue

Are computational models of any use to psychiat

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 [a], Prof Klaas Enno Stephan PhD [a, b], Prof Read Montague PhD [a, c], Prof Raymond J Dolan FRS [a]

nature neuroscience

Published: 23 February 2016

Computational psychiatry as a
from neuroscience to clinical a

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

Neuron

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

CellPress

Perspective

Computational Psychiatry

Xiao-Jing Wang [1, 2, 3], John H. Krystal [3, 4, 5, 6]

Viewpoint

April 24, 2019

The Two Cultures of Computational Psychiatry

Daniel Bennett, PhD[1]; Steven M. Silverstein, PhD[2,3]; Yael Niv, PhD[1,4]

Author Affiliations | Article Information

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

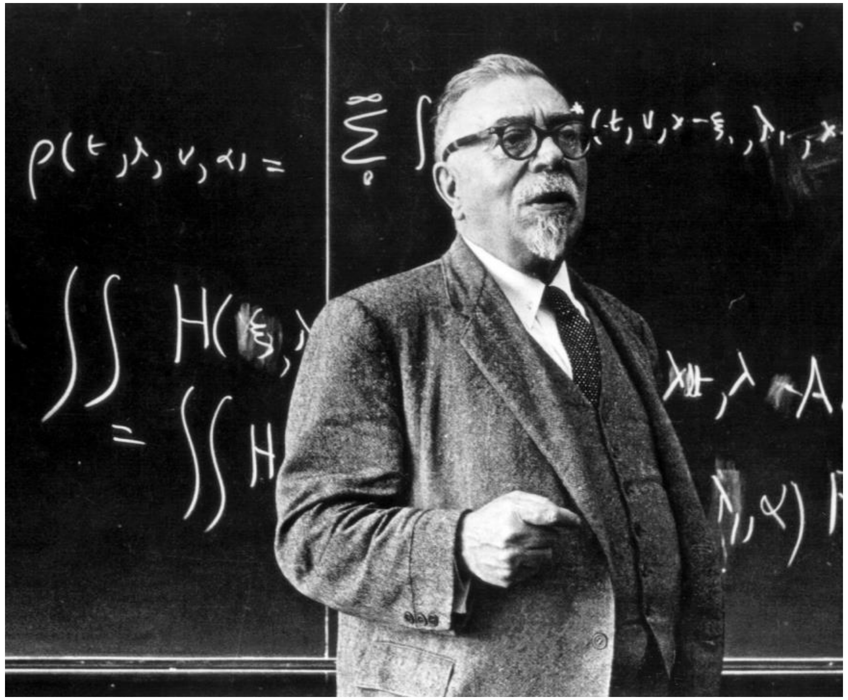
Molecular Psychiatry

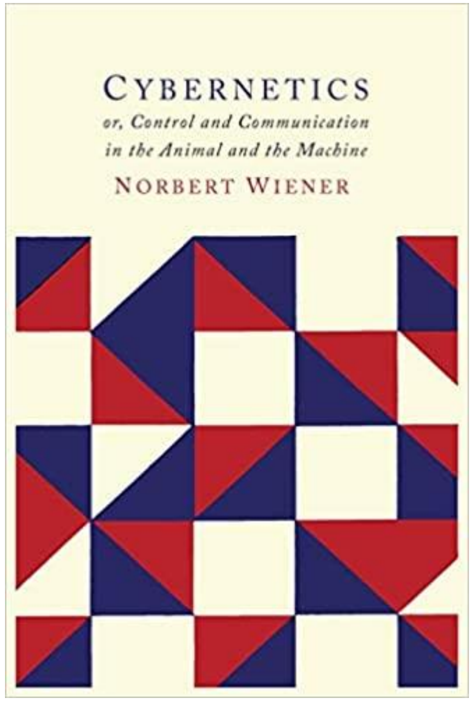
News | Open Access | Published: 27 April 2018

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."

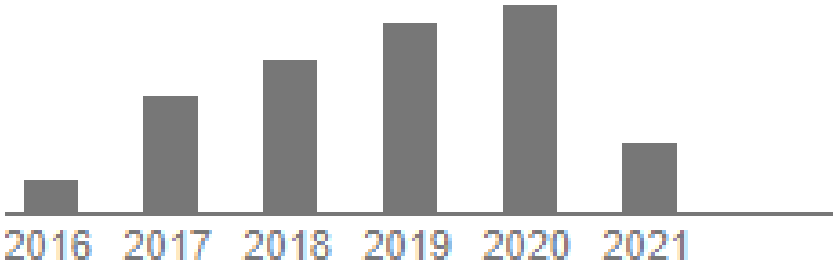
The rise of CP

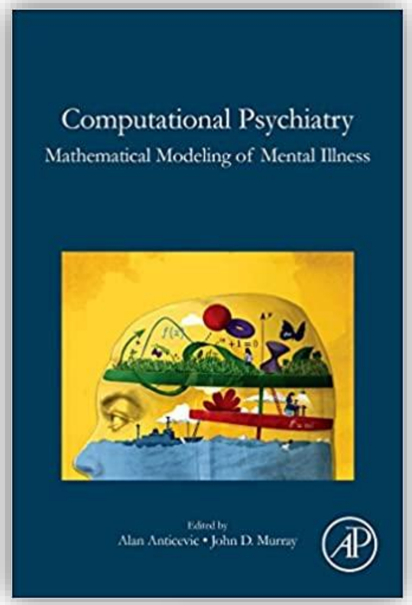
Published: 23 February 2016

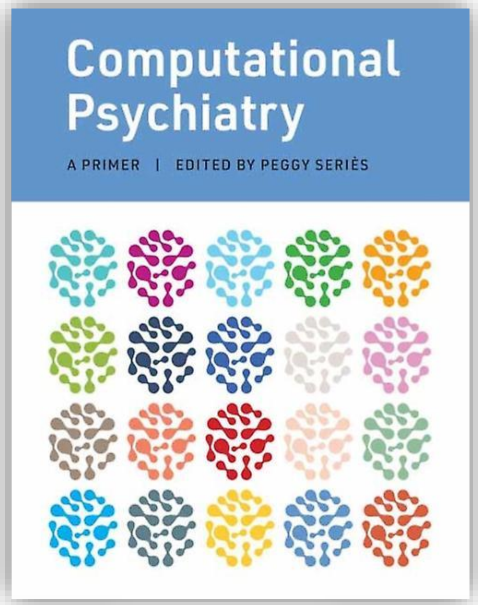
Computational psychiatry as a bridge from neuroscience to clinical applications

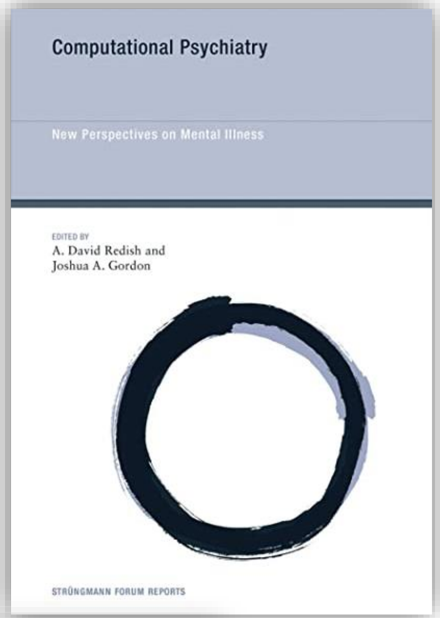
Quentin J M Huys, Tiago V Maia & Michael J Frank

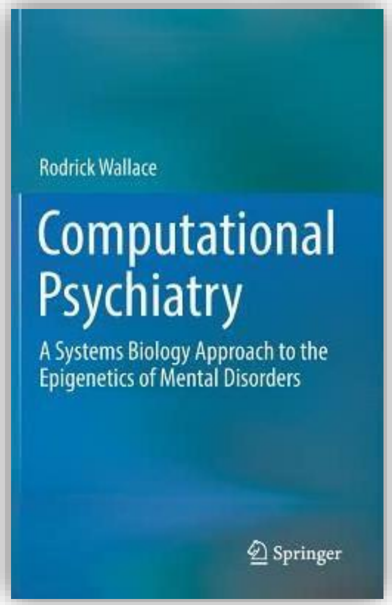
Nature Neuroscience **19**, 404–413(2016) | Cite this article

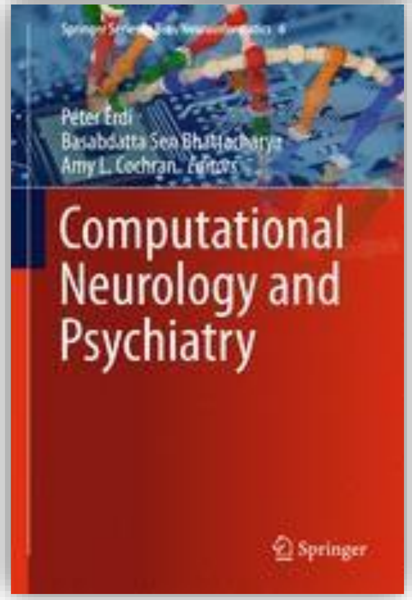












Huys et al., (2016)

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)

computational psychiatry

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.

ELSEVIER
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....

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

Replying 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

Replying to @EikoFried

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

Jon Roiser @jonroiser · Dec 5, 2017
Replying to @dan_marinazzo @EikoFried and 4 others
golden rule of CP: N reviews>N empirical papers!

Xiaosi Gu @xiaosigu · Dec 5, 2017
Replying 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[1]; Steven M. Silverstein, PhD[2,3]; Yael Niv, PhD[1,4]

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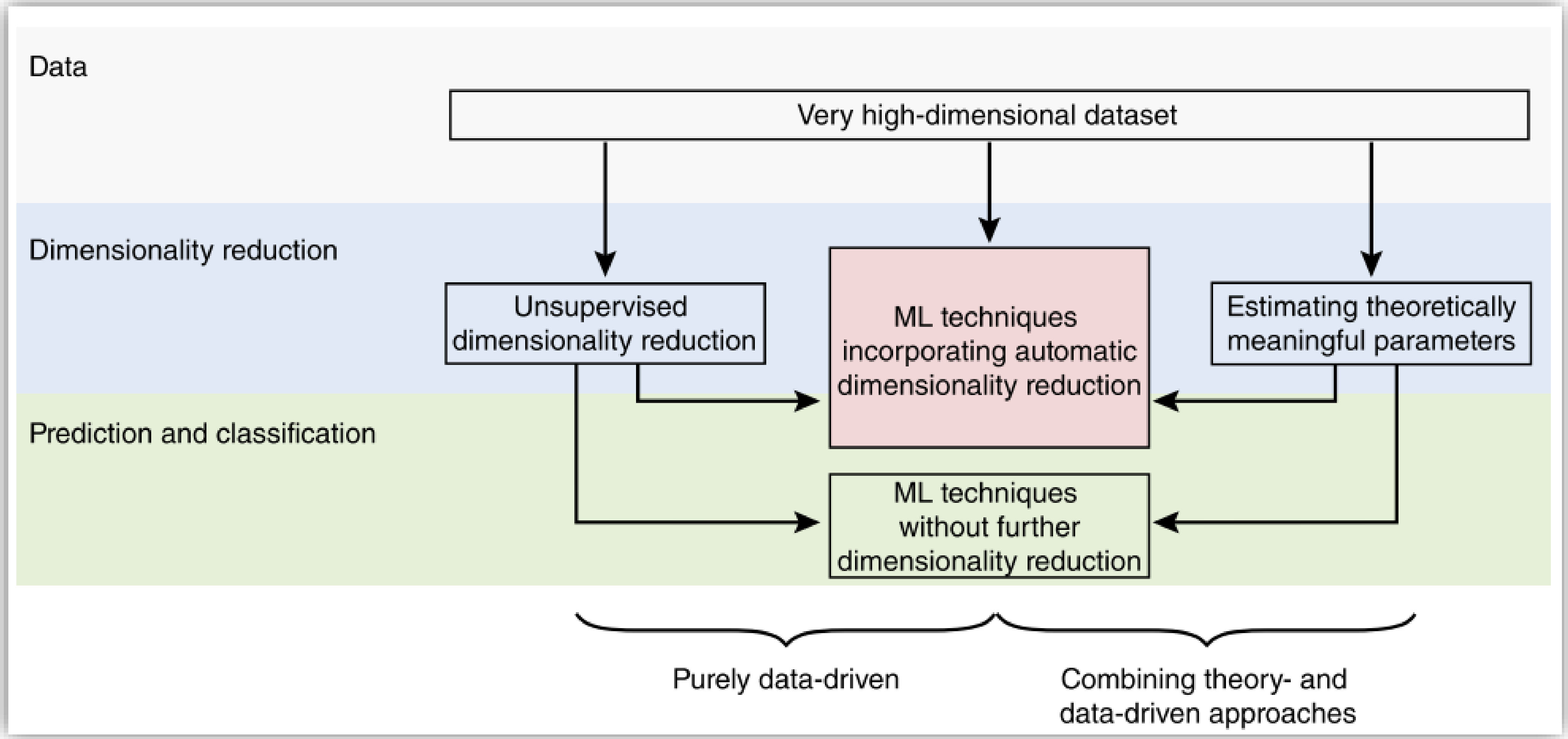


Bennett et al., (2019)

Three cultures of CP

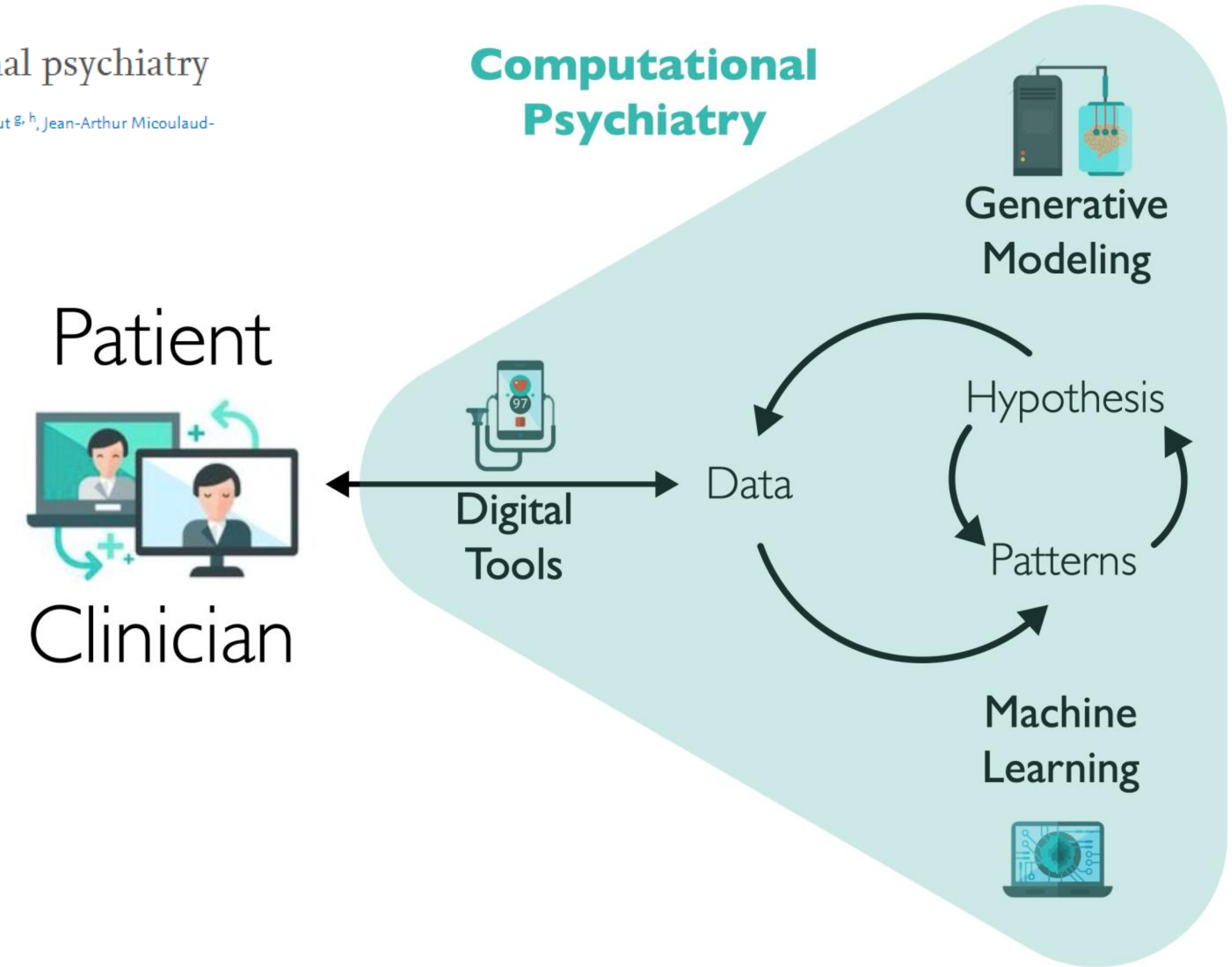
Communication

Les trois cultures de la psychiatrie computationnelle

The three cultures of computational psychiatry

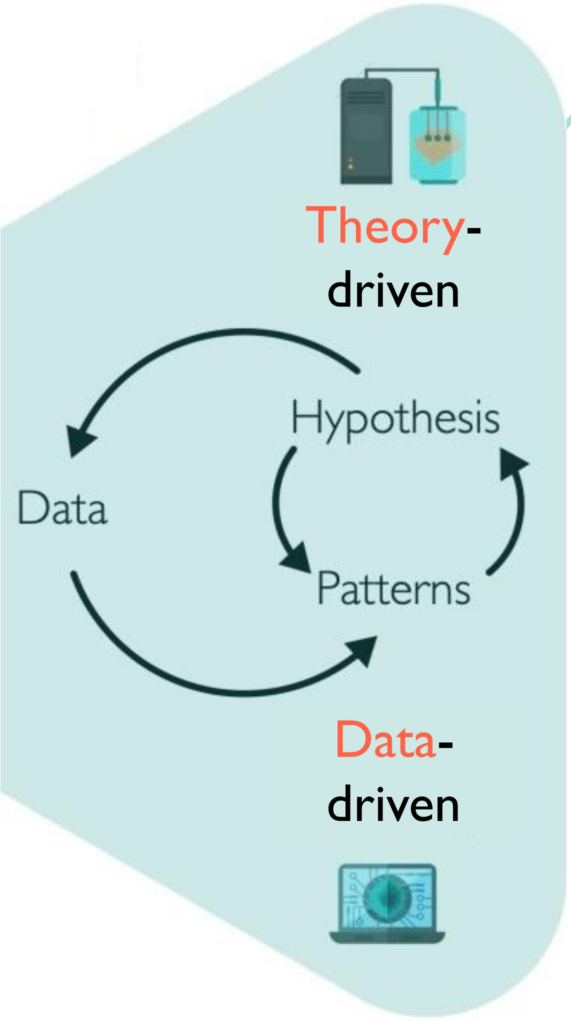
Christophe Gauld [a, b], Guillaume Dumas [c, d], Éric Fakra [e, f], Jérémie Mattout [g, h], Jean-Arthur Micoulaud-Franchi [i, j]

Show more



Gauld et al., (2021)

Theory-driven



Provide
mechanistic
explanation

Generate
prediction/
classification

Construct

RDoC
Research Domain Criteria Initiative

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

Computational modeling

On the role of theory and modeling in neuroscience

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

How Computational Modeling Can Force Theory Building in Psychological Science

Olivia Guest, Andrea E. Martin

Huys et al., (2016); Paulus, (2017); Bennett et al., (2019); Gauld et al., (2021)

Computational modeling

Cognition as information processing

Input

Output

$$y = f(x)$$

'Some math happens'

Computational modeling

Cognition as information processing

Behavior

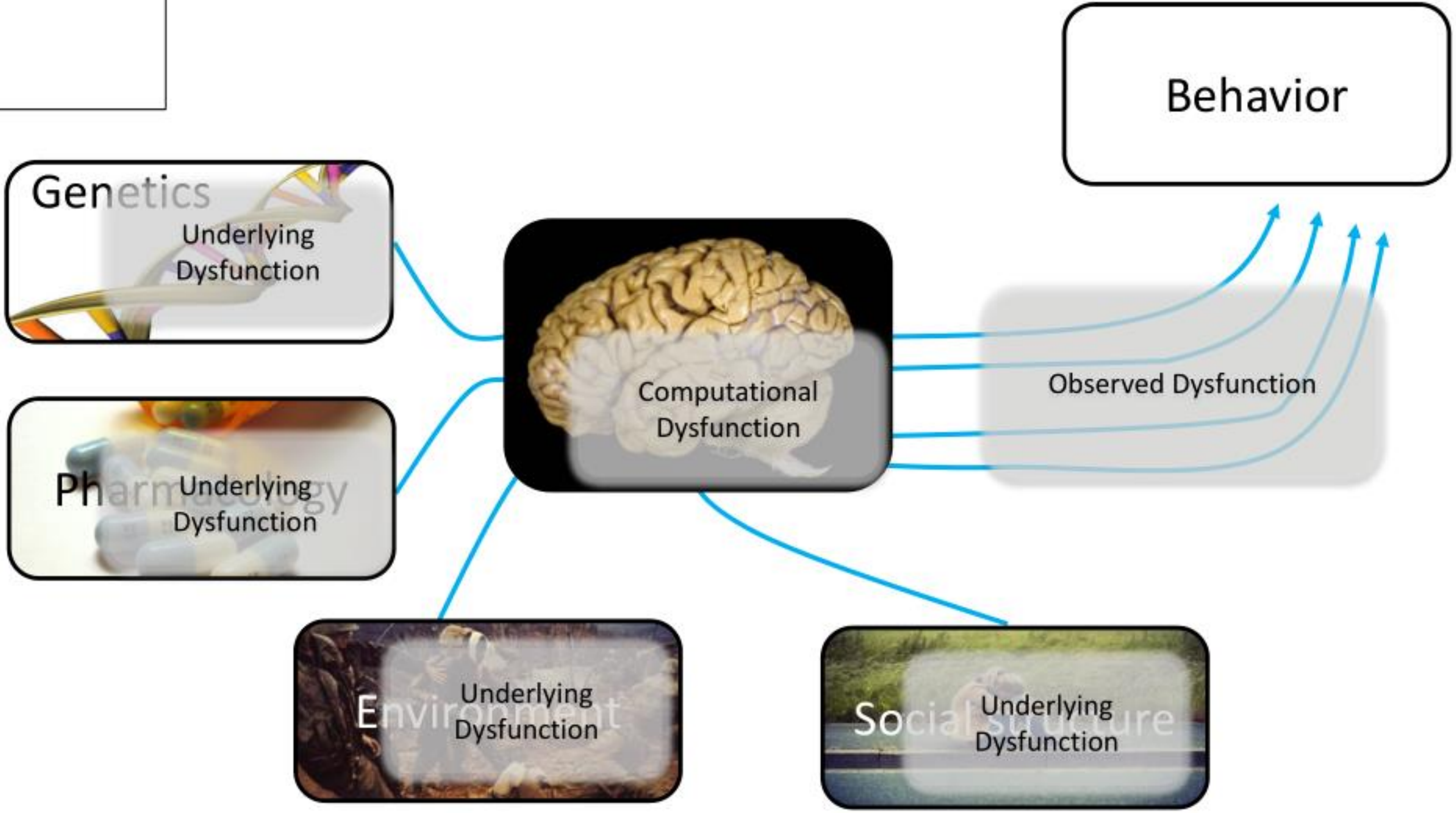
$$B = f(P, E)$$

Person   Environment

Kurt Lewin, (1936)

Behavior depends on computation

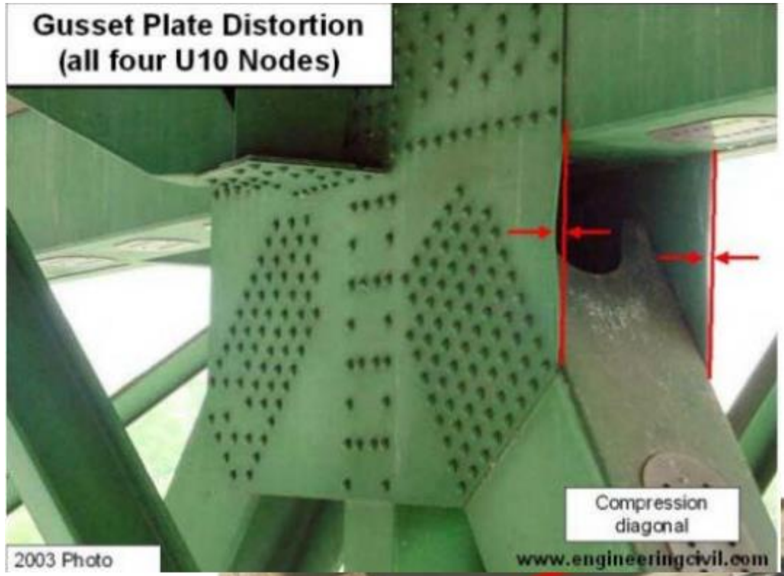
This suggests a new view of psychiatry as neurophysiological ***computational* dysfunctions**



Adapted from Redish (2020)

Failure modes

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

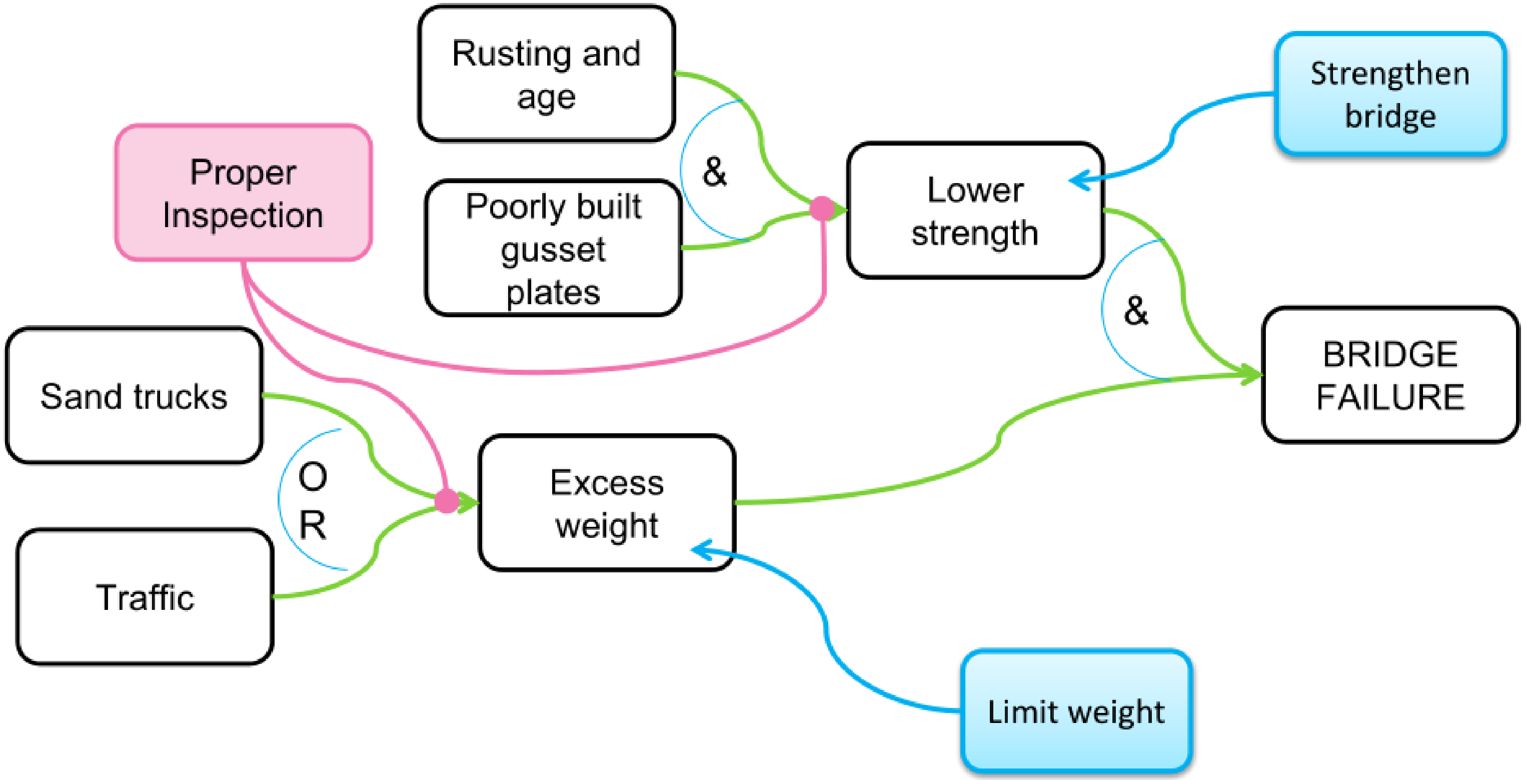


Adapted from Redish (2020)

Failure modes

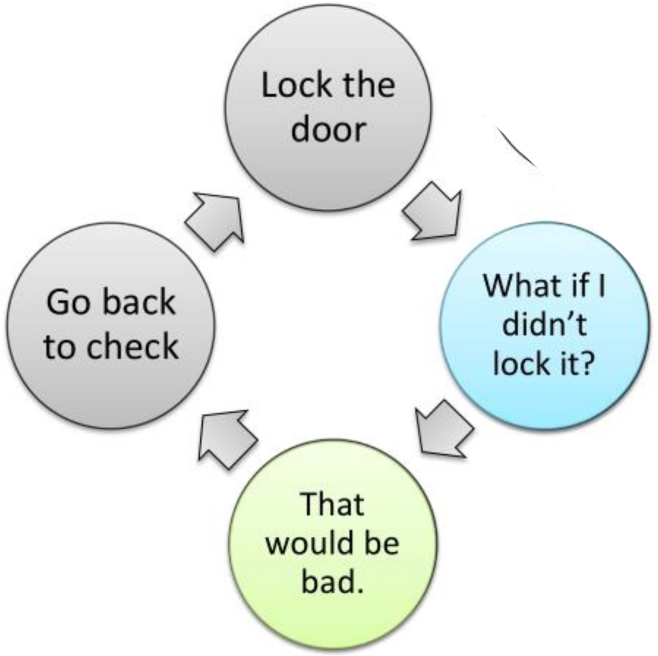
If we know the failure modes, we can guide treatment.

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



Adapted from Redish (2020)

Failure modes: OCD example



Adapted from Redish (2020)

All of these are **computational failure modes**

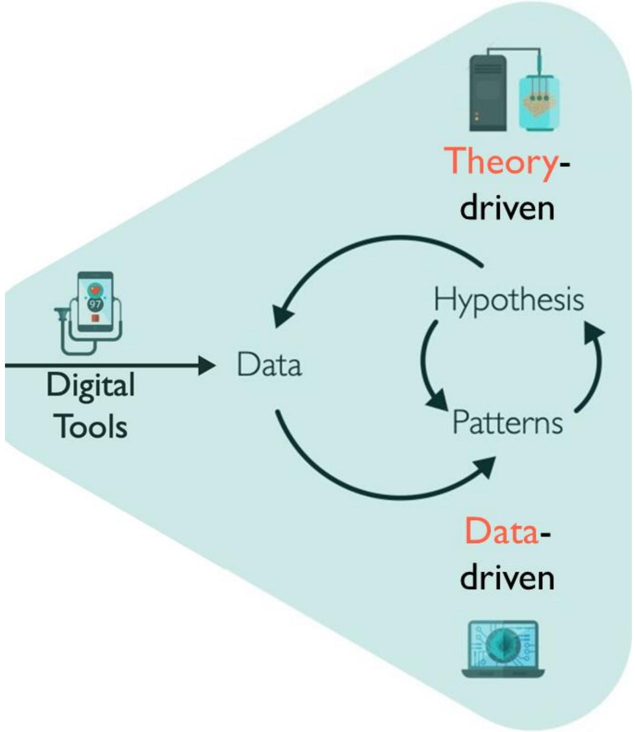
an imbalance between planning and habit modes,

perhaps via problems with *response inhibition*,

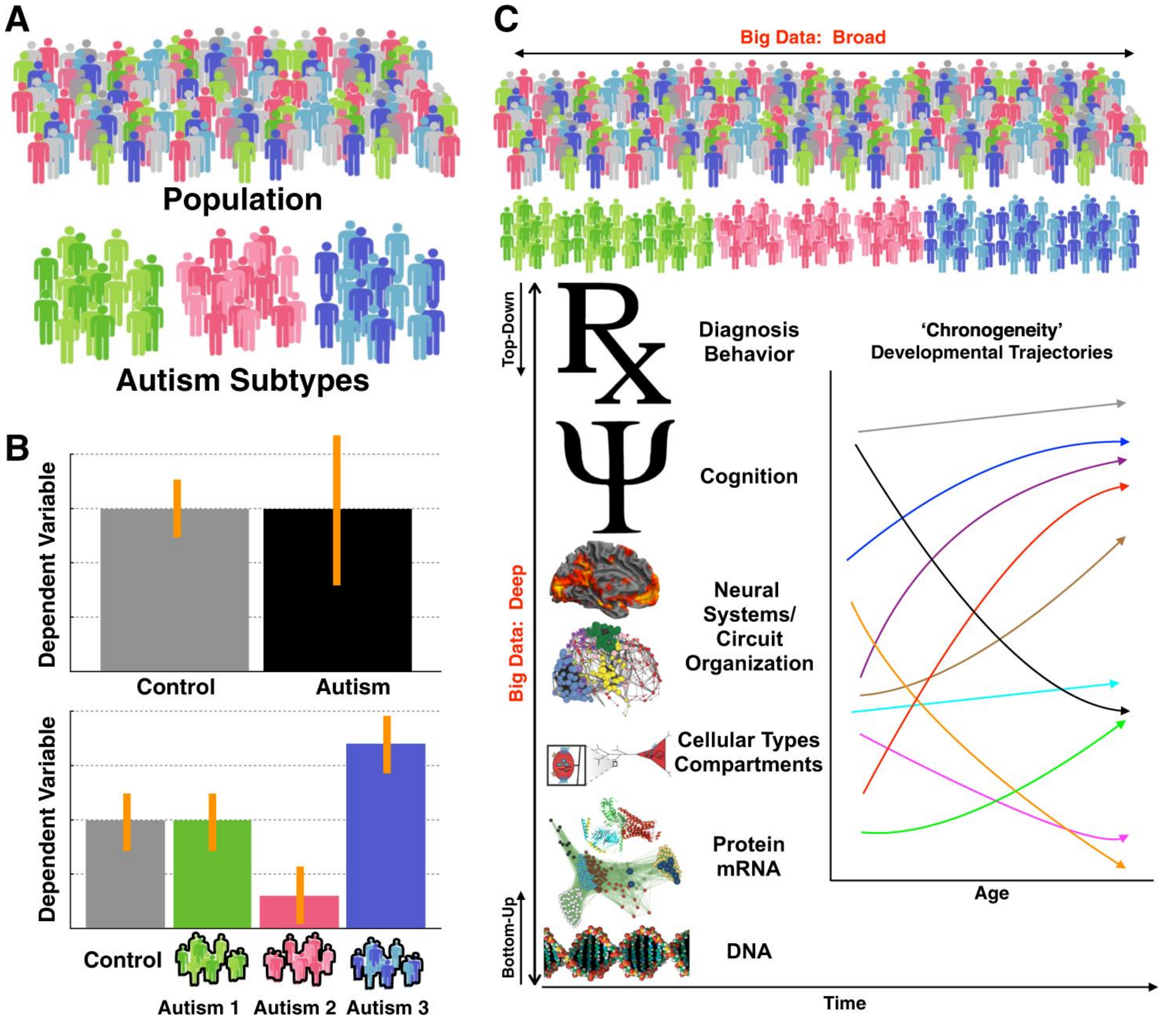
or an inability to recognize completion of a target,

or an over-intensity of anxiety predictions?

Data-Driven



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



Loth (2016); Lombardo et al. (2019)

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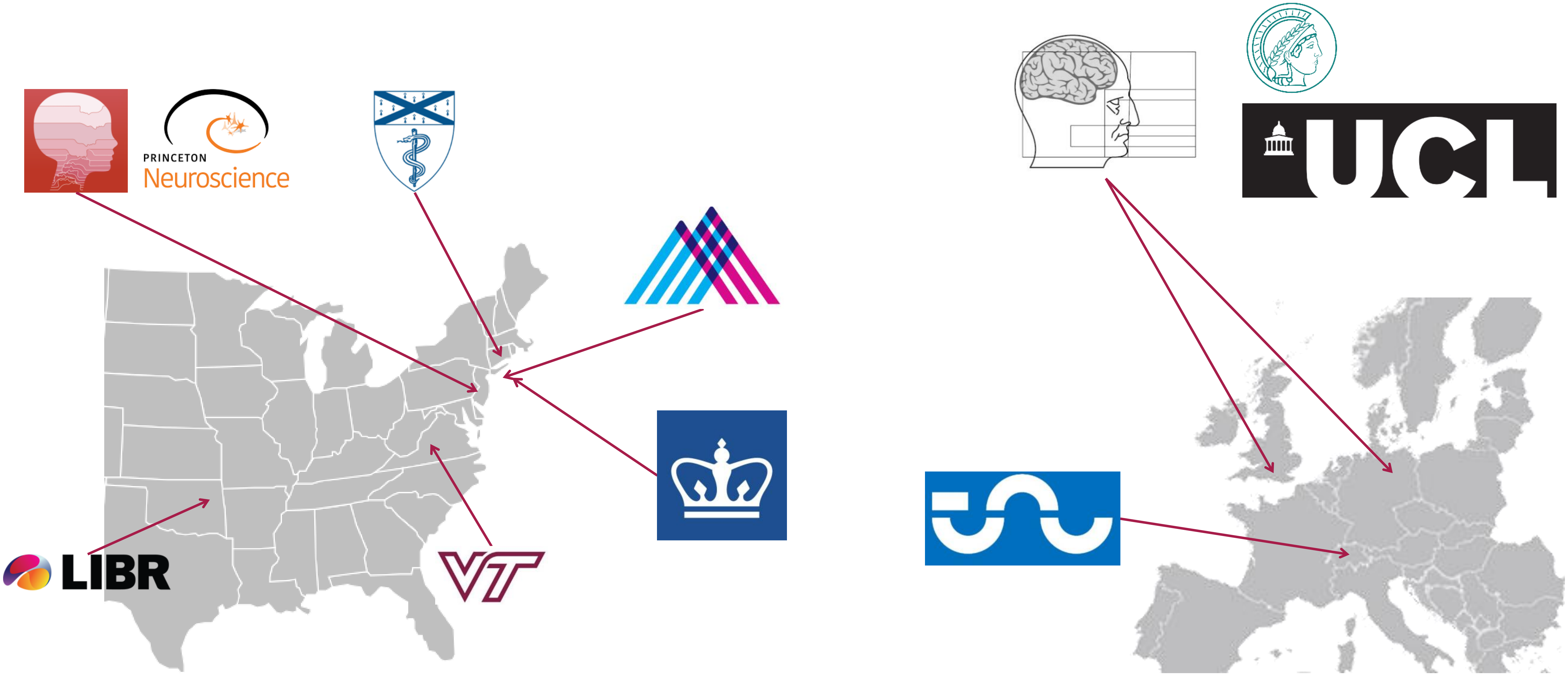
CP Landscape: institutions



CP Landscape: funding opportunities

NIH National Institute of Mental Health

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.

ERC-2020-STG

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

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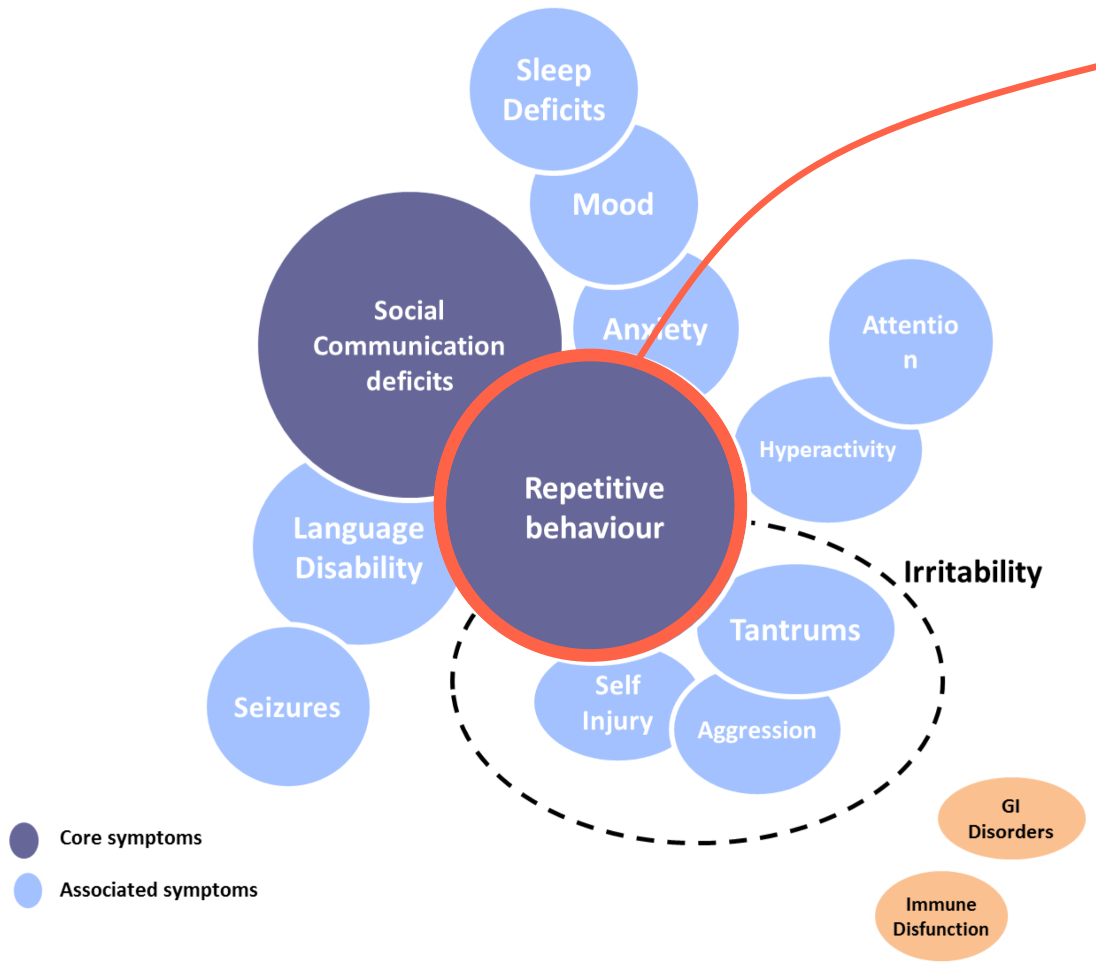
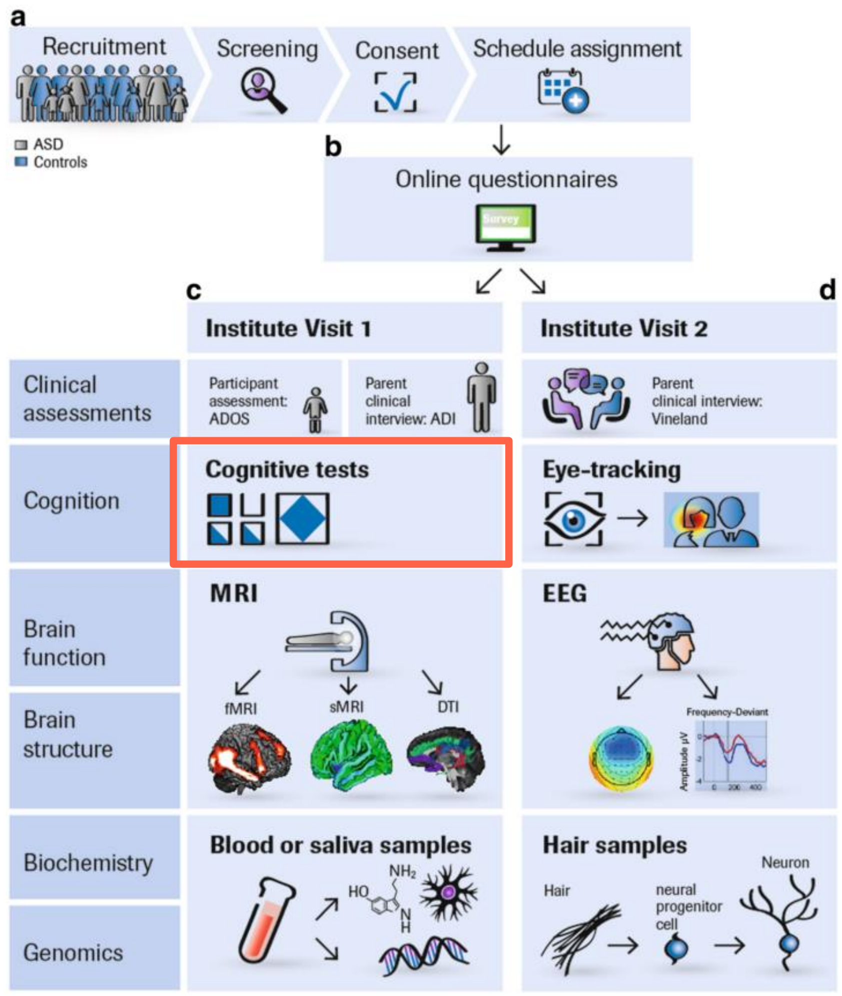
Impaired cognitive flexibility in Autism

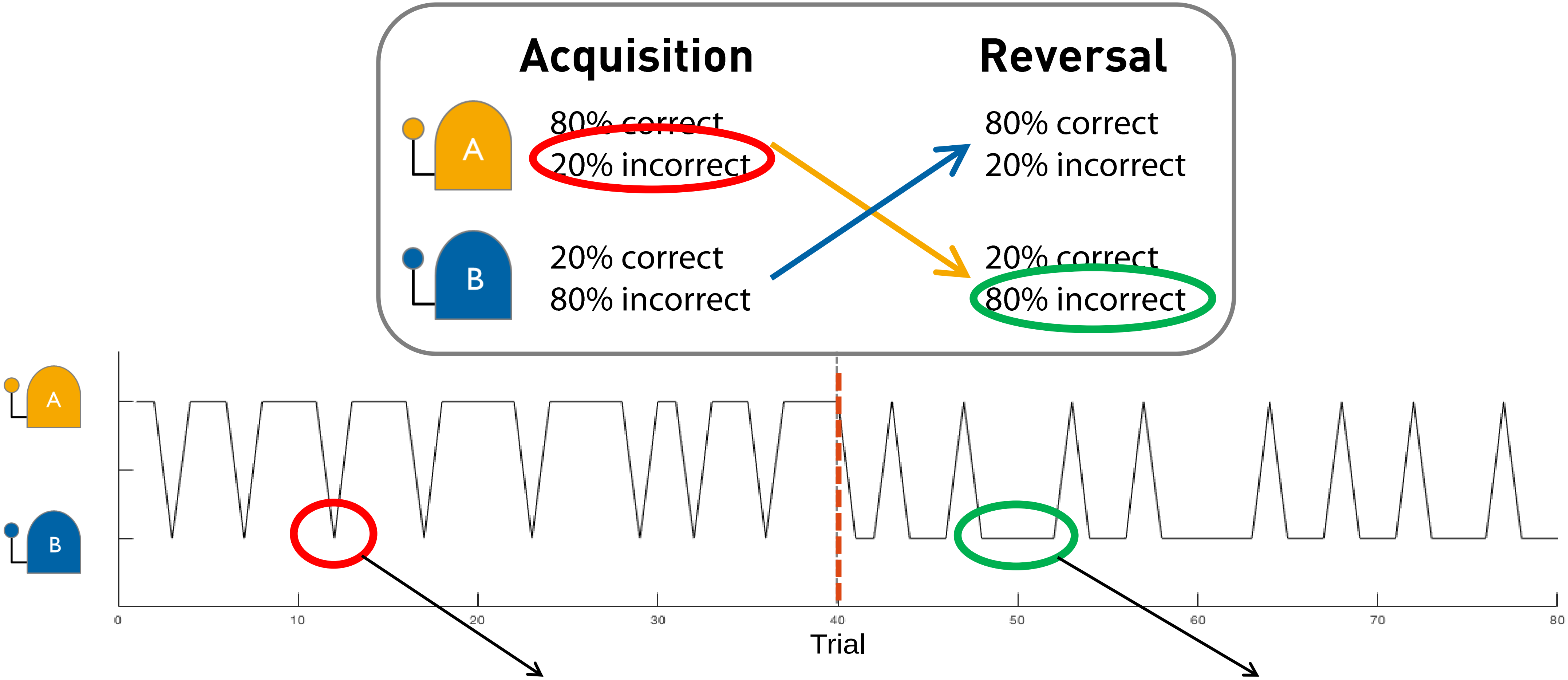
Behavioral rigidity is underpinned by cognitive (in)flexibility





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

Cognitive flexibility in reversal learning

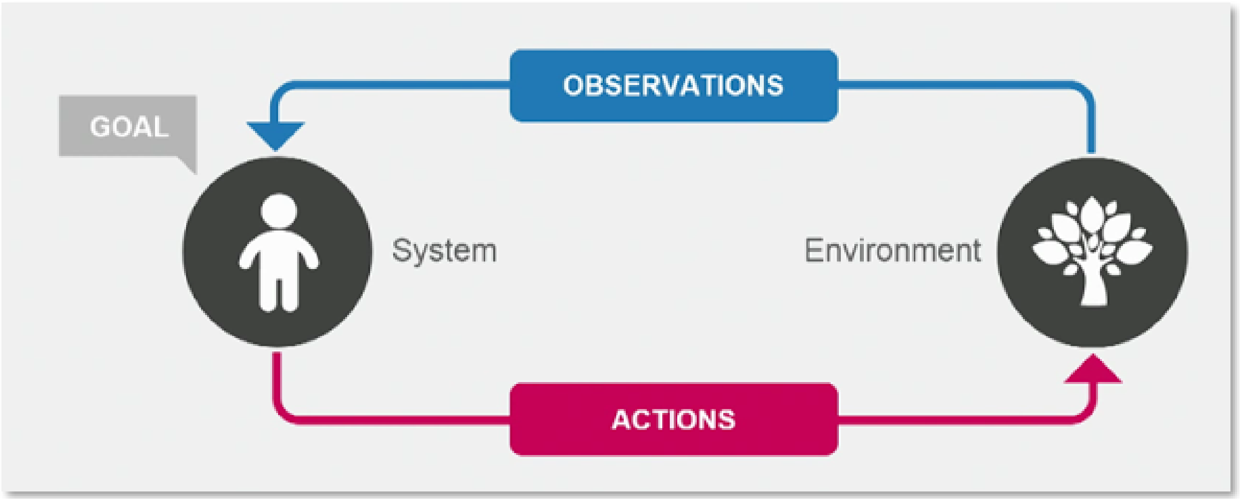


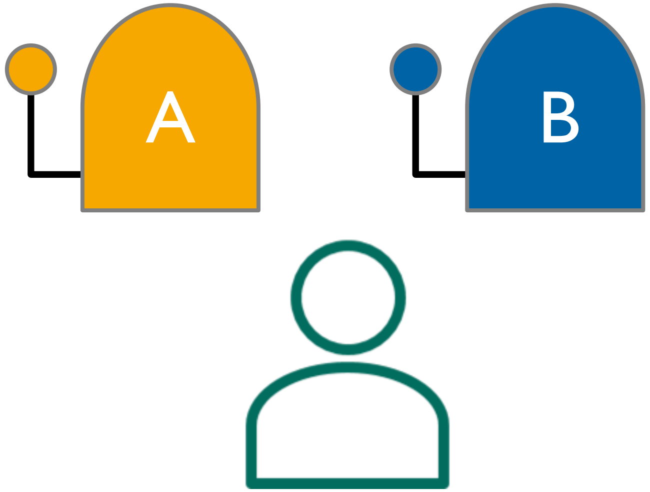
Rare outcome
needs to be ignored

Common outcome
needs to be learned

Cools et al., (2002); den Ouden et al., (2013); Izquierdo et al., (2017)

Computational focus





Reinforcement learning

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

Rescorla-Wagner Model

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

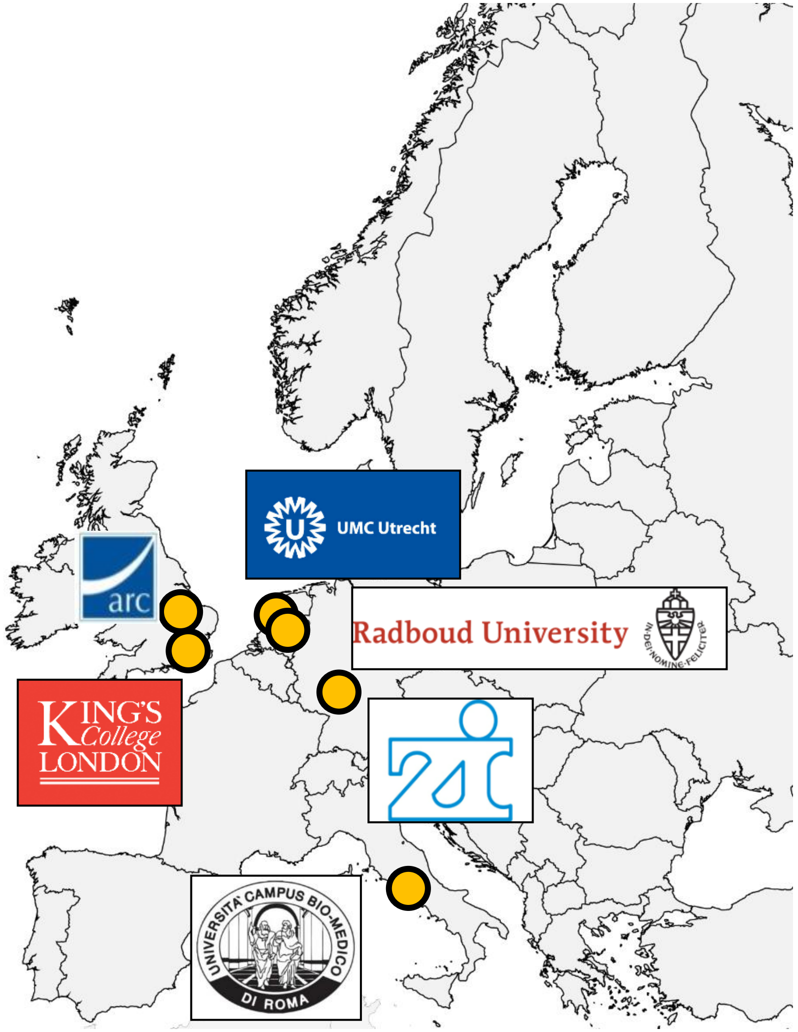
Prediction error: $\mathrm{PE}_{t-1} = R_{t-1} - V_{t-1}$

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

Sutton & Barto, (2018); Rescorla & Wagner, (1972)

EU-AIMS LEAP

Longitudinal European Autism Project

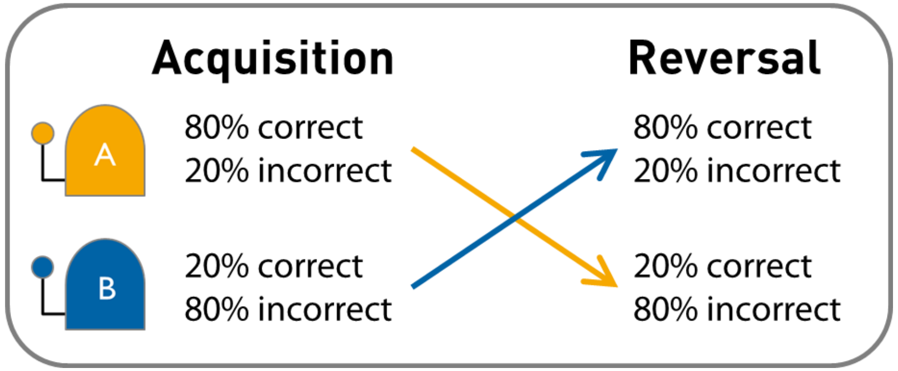


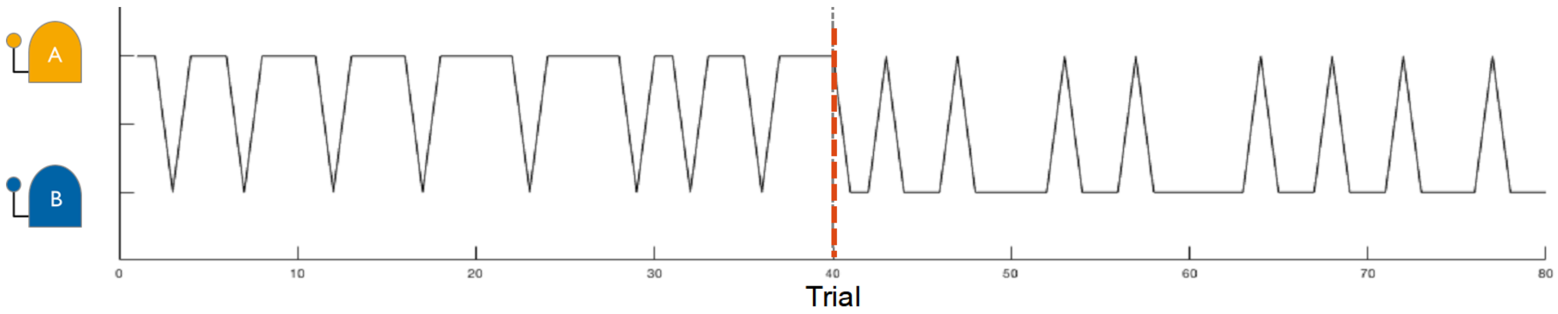
		Diagnosis		
		ASD	TD	Total
Age group	Children (6-11 years)	81	64	145
Age group	Adolescents (12-17 years)	114	90	204
Age group	Adults (18-30 years)	126	97	223
	Total	321	251	572

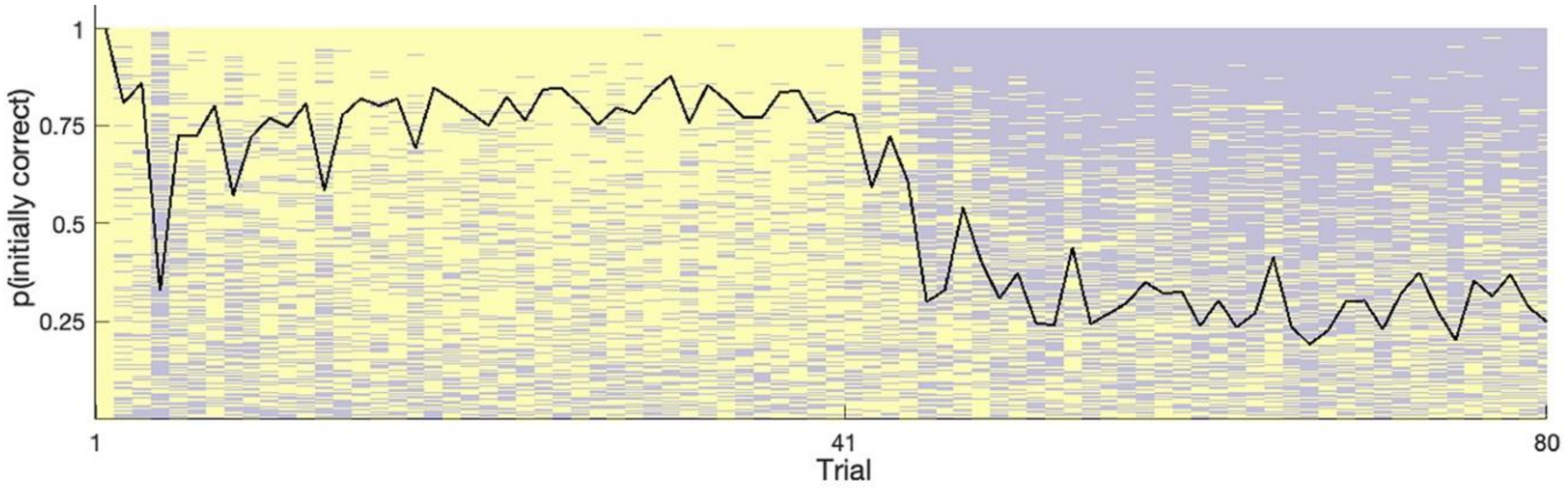
- ASD = Autism spectrum disorder
- TD = Typical development

Loth et al., (2017); Crawley* & Zhang* et al., *PLoS Biology*, (2020)

Paradigm

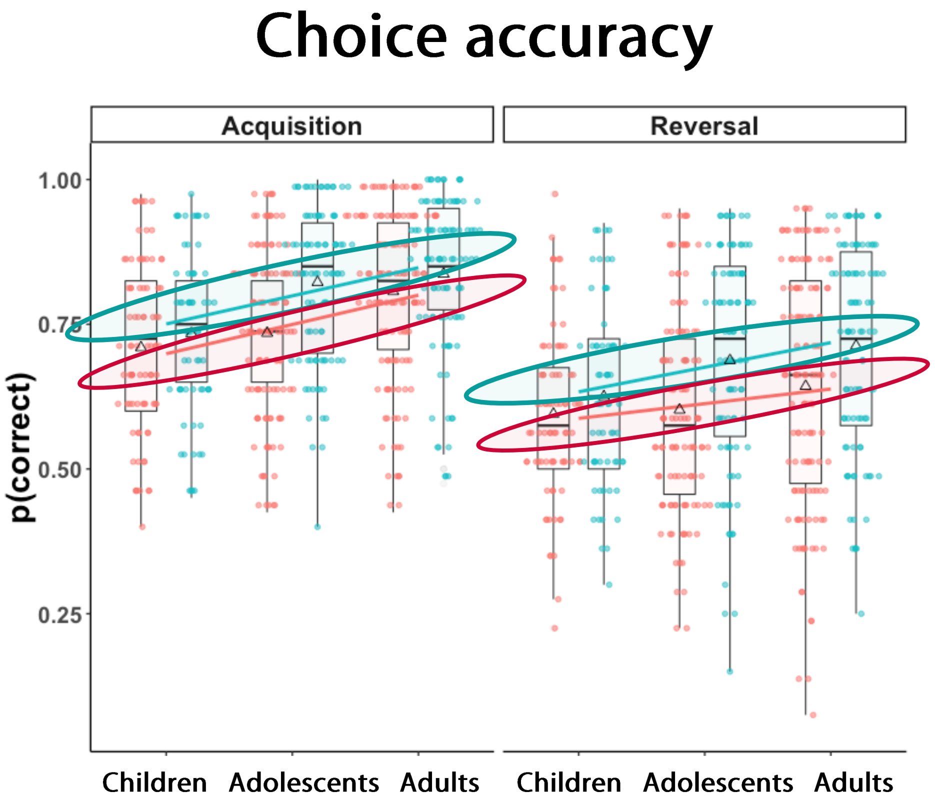


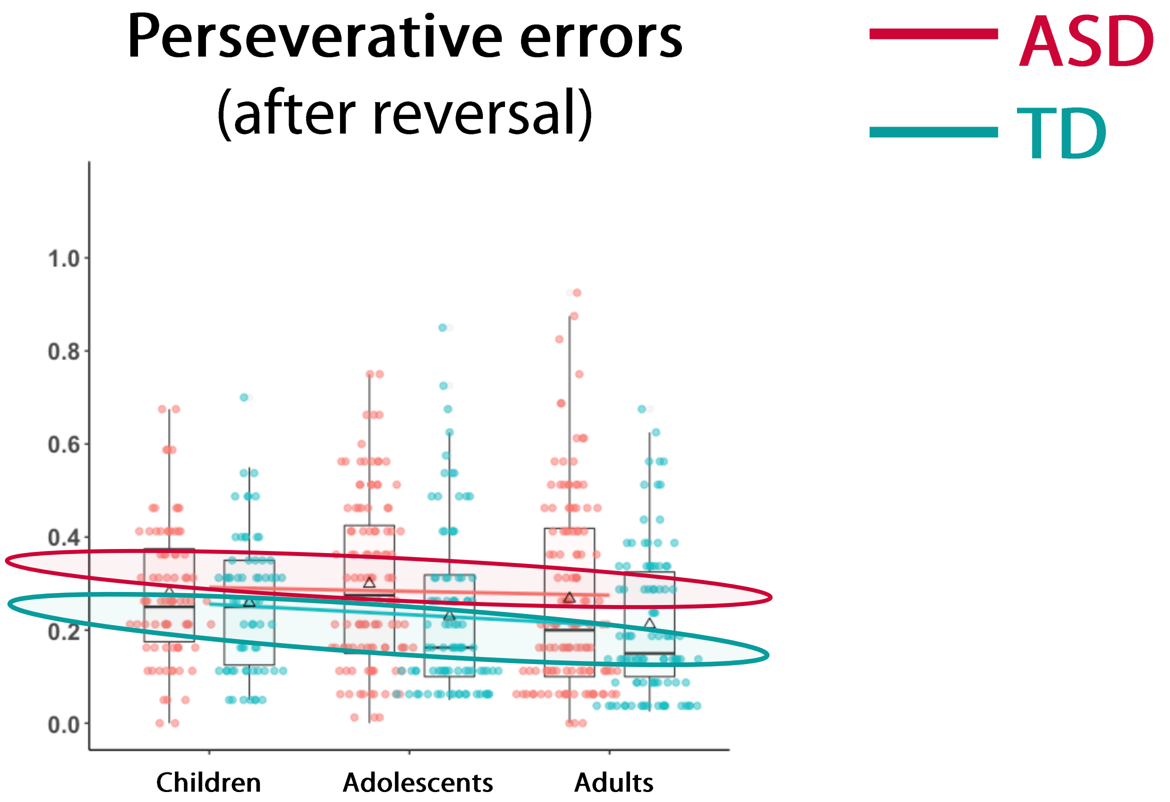




Crawley* & Zhang* et al., *PLoS Biology*, (2020)

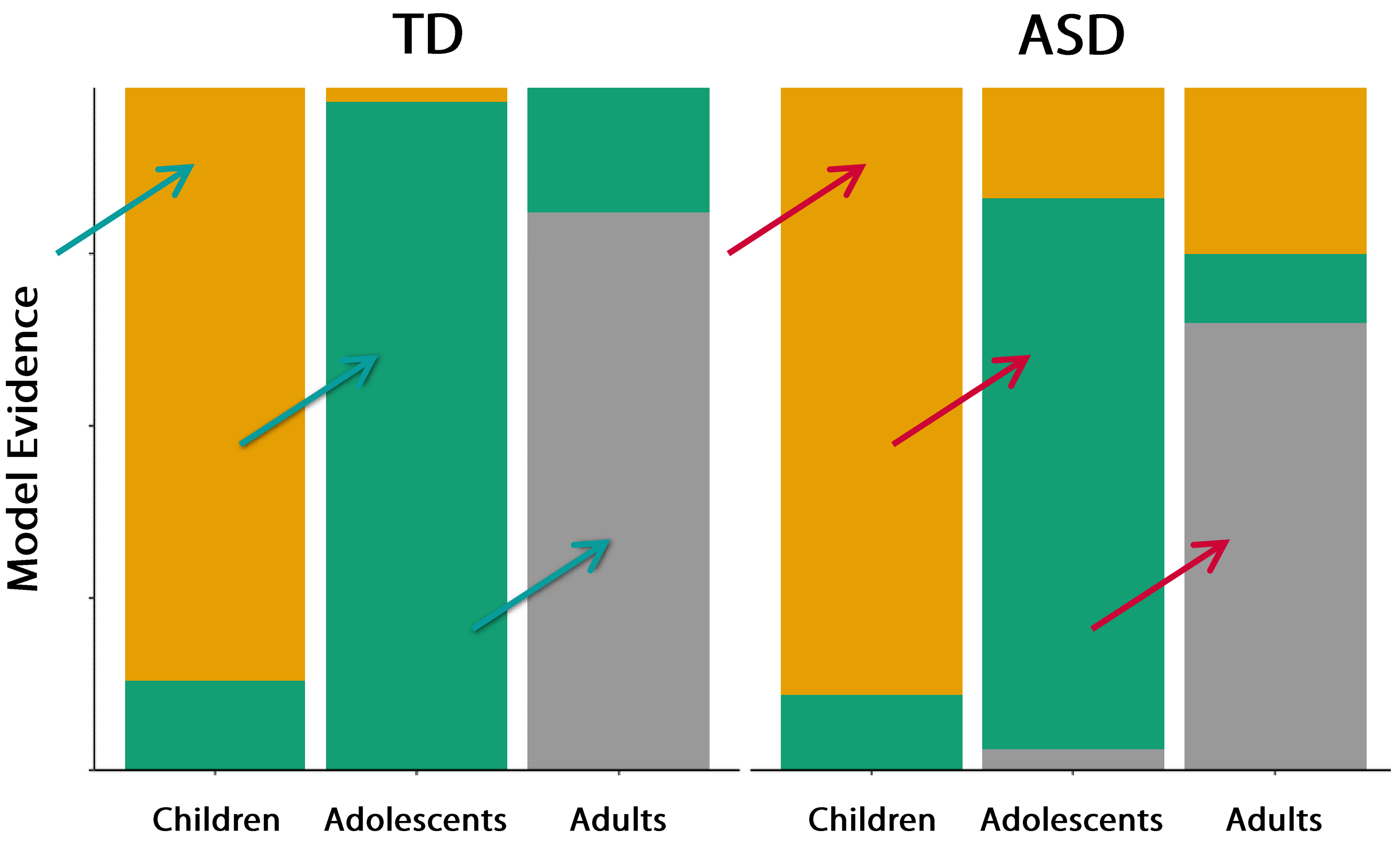
Less optimal learning performance in ASD



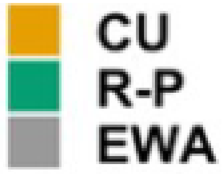


Crawley* & Zhang* et al., *PLoS Biology*, (2020)

Same computational model within age group



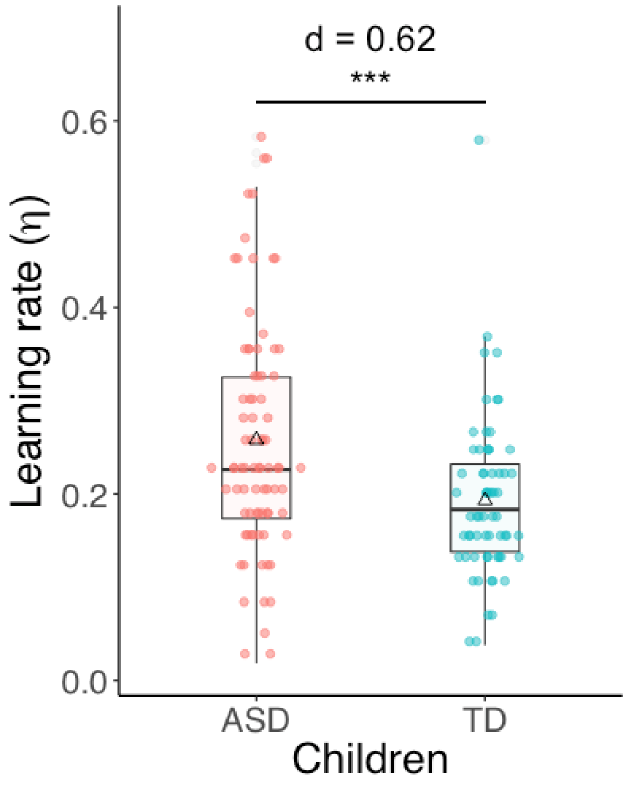
Candidate models originated from Rescorla-Wagner

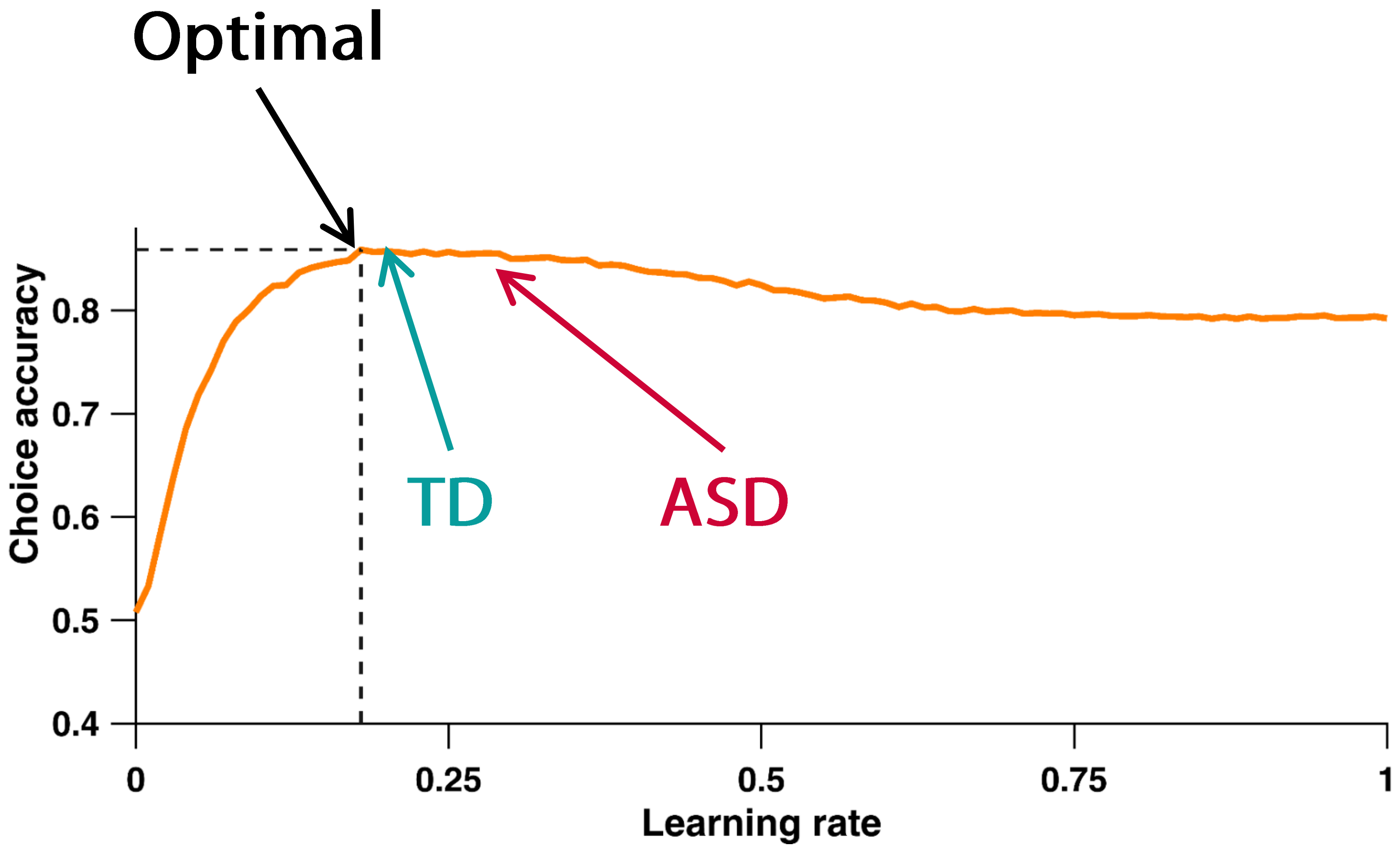


- CU: counterfactual update
- R-P: Reward-punishment
- EWA: Experience-weighted attraction

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

Suboptimal learning parameters in ASD





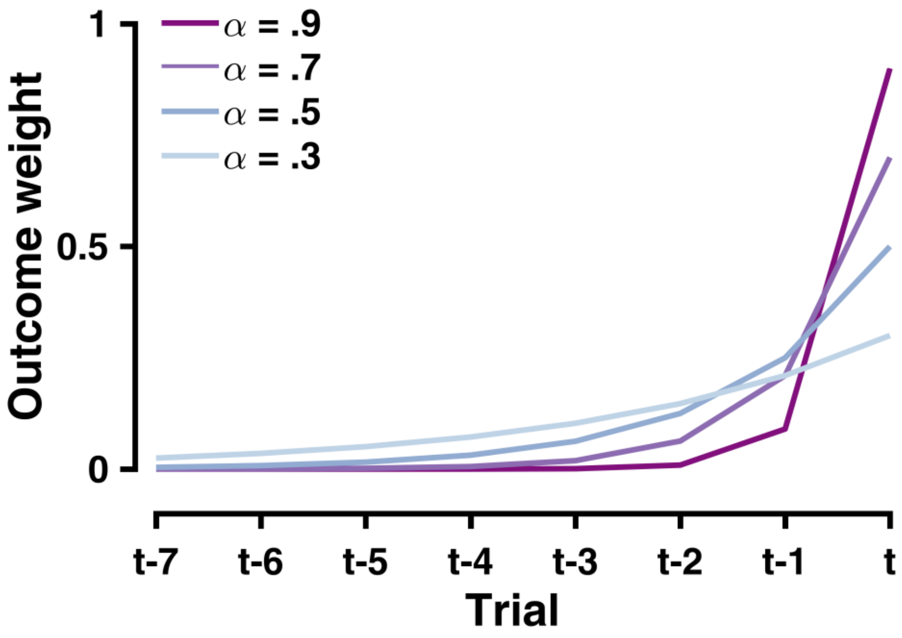
Crawley* & Zhang* et al., *PLoS Biology*, (2020)

Understand the learning rate

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

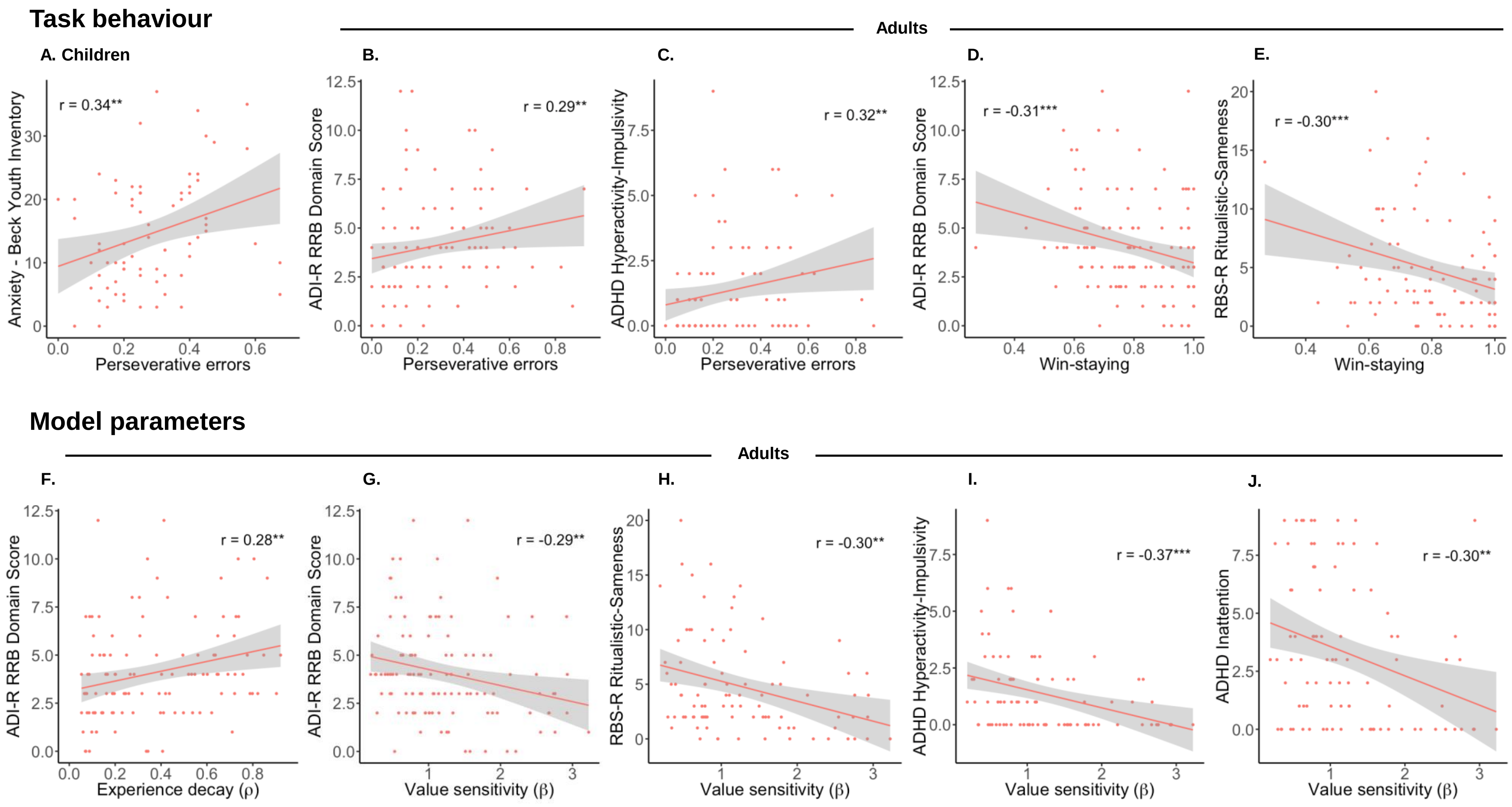
Prediction error: $\mathrm{PE}_{t-1} = R_{t-1} - V_{t-1}$

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



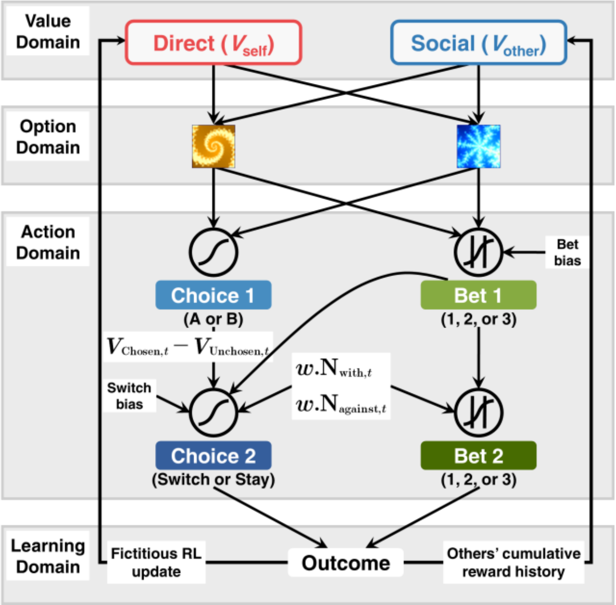
Crawley* & Zhang* et al., *PLoS Biology*, (2020); Zhang et al., *SCAN*, (2020)

Parameter ~ clinical scales



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

hBayesDM package



$$
\begin{aligned}
\mathbb{V}_{self,t} &= [V_{self,t}(\mathrm{A}), V_{self,t}(\mathrm{B})] \\
\mathbb{V}_{other,t} &= [V_{other,t}(\mathrm{A}), V_{other,t}(\mathrm{B})] \\
\mathbb{V}_{t} &= \beta_{vself}\,\mathbb{V}_{self,t} + \beta_{vother}\,\mathbb{V}_{other,t} \\
C1_t &\sim Categorical(Softmax(\mathbb{V}_t)) \\
U_{bet1,t} &= \beta_{bias_{c1}} + \beta_{vdiff_{c1}}(V_{chosen,C1,t} - V_{unchosen,C1,t}) \\
B1_t &\sim OrderedLogistic(U_{bet1,t} \mid \theta) \\
w.\mathrm{N}_{against,t} &= \frac{\sum_{s=1}^{K} w_{s,t}}{\sum_{s=1}^{4} w_{s,t}}, K = 0, 1, \ldots, 4 \\
w.\mathrm{N}_{with,t} &= \frac{\sum_{s=1}^{4-K} w_{s,t}}{\sum_{s=1}^{4} w_{s,t}} \\
V_t(\mathrm{switch}) &= \beta_{bias_{c2}} + \beta_{vdiff_{c2}}(V_{chosen,C1,t} - V_{unchosen,C1,t}) + \beta_{against}\,w.\mathrm{N}_{against,t} \\
C2 &\sim Bernoulli(V_t(\mathrm{switch})) \\
U_{bet2,t} &= \begin{cases} U_{bet1,t} + \beta_{with_{agr}}\,w.\mathrm{N}_{with,t} + \beta_{against_{agr}}\,w.\mathrm{N}_{against,t} &, \text{if } C1 = C2 \\ U_{bet1,t} + \beta_{with_{disagr}}\,w.\mathrm{N}_{with,t} + \beta_{against_{disagr}}\,w.\mathrm{N}_{against,t}, & \text{if } C1 \neq C2 \end{cases} \\
B2_t &\sim OrderedLogistic(U_{bet2,t} \mid \theta) \\
\Phi(x) &= \frac{1}{1+e^{-x}} \\
\delta_{self,chosen,C2,t} &= R_{self,t} - V_{self,chosen,C2,t} \\
\delta_{self,unchosen,C2,t} &= -R_{self,t} - V_{self,unchosen,C2,t} \\
V_{self,chosen,C2,t+1} &= V_{self,chosen,C2,t} + \alpha\delta_{self,chosen,C2,t} \\
V_{self,unchosen,C2,t+1} &= V_{self,unchosen,C2,t} + \alpha\delta_{self,unchosen,C2,t}
\end{aligned}
$$

Stan

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

Ahn, Haines, Zhang, *Computational Psychiatry*, (2017); Zhang & Gläscher, *Science Advances*, (2020)

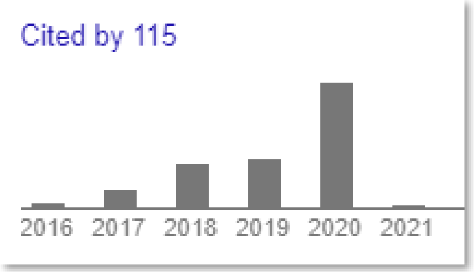
hBayesDM package

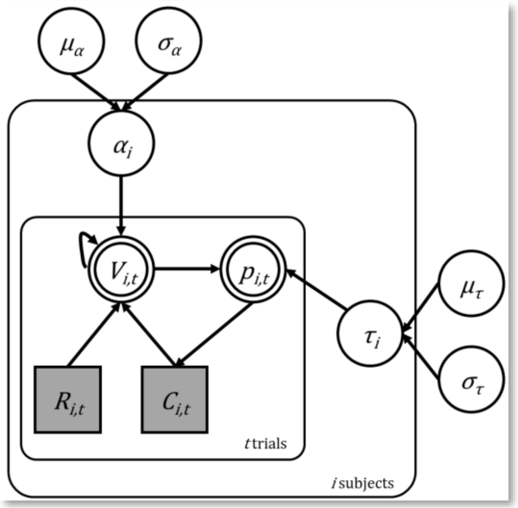
hBayesDM

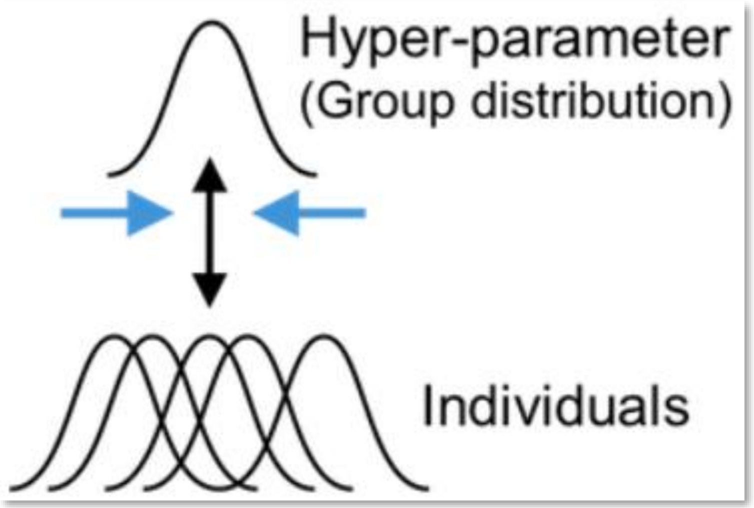
repo status Active | build passing | CRAN 1.0.2 – 2019-11-13 | downloads 33K

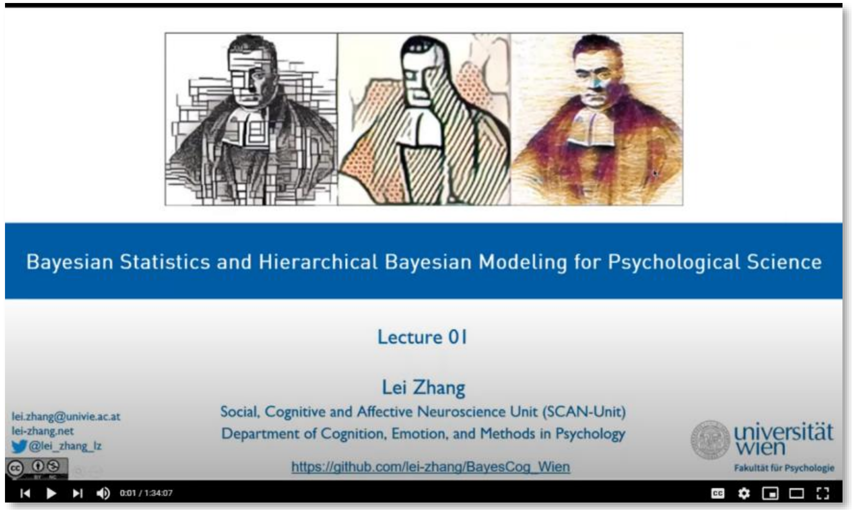
DOI 10.1162/CPSY_a_00002

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.









Ahn, Haines, Zhang, *Computational Psychiatry*, (2017)

Outline

- The birth 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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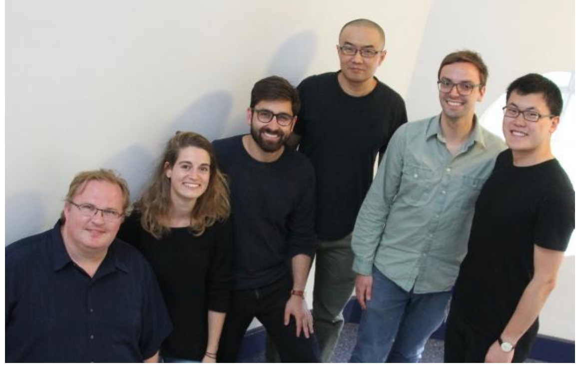

Thank you!

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ANY
QUESTIONS
?

Happy Computing!