

*How to reveal neuro-  
computational mechanisms of  
reinforcement learning &  
decision-making?*

*It is easy to do with the hBayesDM package*

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# *Reinforcement Learning and Decision-Making (RLDM)*

## *Computational modeling*

- Individual differences
- Latent processes (& their time course)

*Special Issue: Cognition in Neuropsychiatric Disorders*

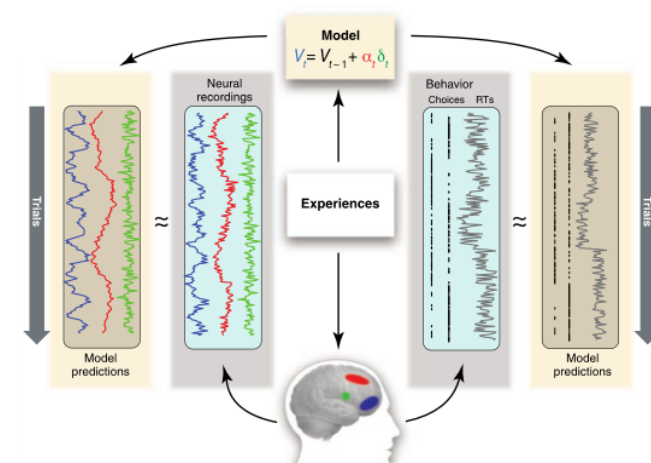
# Computational psychiatry

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

Montague et al (2012) Trends in Cog Sci

## *Model-based fMRI/EEG*

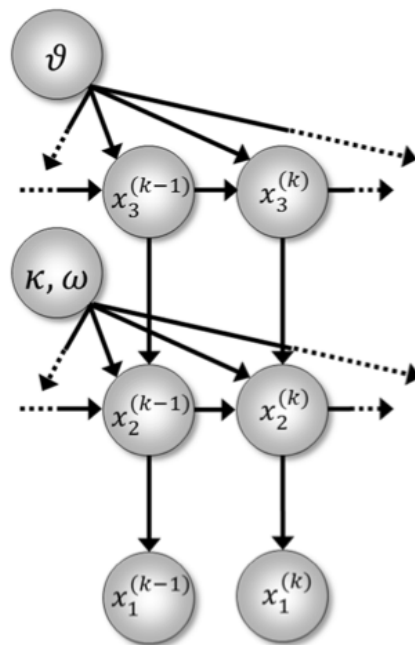
e.g., Forstmann & Wagenmakers (2015); O'Doherty et al (2007)



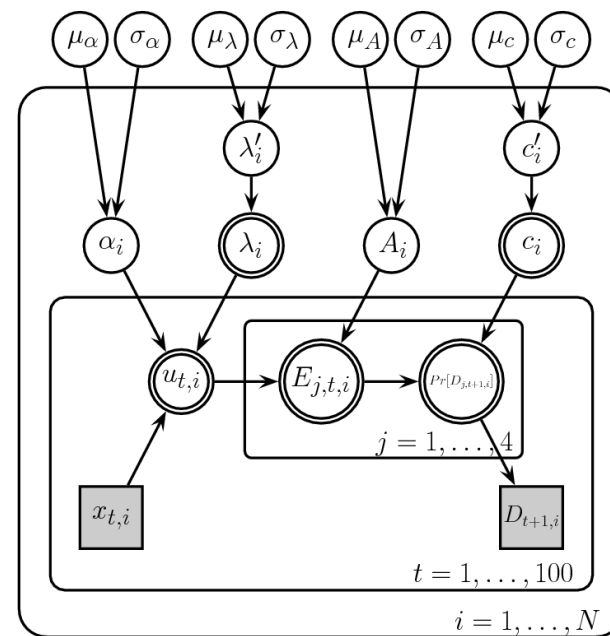
Behrens, Hunt, Rushworth (2009) Science

*I like the idea of modeling*

*But...*



Mathys et al (2011) Frontiers

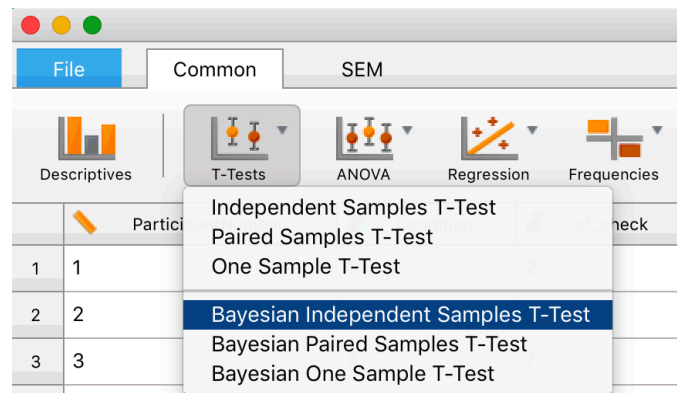


Ahn et al (2011) JNPE

# *Can we make it easy to do computational modeling?*

*Q) As easy as doing a T-test?*

JASP, SPSS



R

```
Console ~/Desktop/   
> t.test(group1, group2)
```

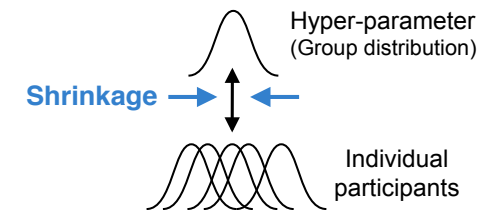
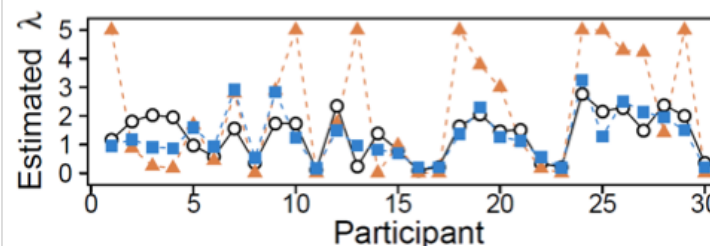
Several packages exist, but ...

Matze et al (2013) *Frontiers*; Wabersich & Vandekerckhove (2014); Wiecki et al (2013) *Frontiers*;  
Daunizeau et al (2014) *PLoS Comp Biol*

# ***hBayesDM*** (*hierarchical Bayesian modeling of Decision-Making tasks*) Package

- Models for 8 tasks/paradigms (next slide)
- Single-line of coding in R
  - Model fitting, visualization, model comparisons
- Based on the advanced Bayesian software, Stan (<https://mc-stan.org>).
- Hierarchical Bayesian modeling

**Simulation study**  
Hierarchical Bayesian ■  
Maximum likelihood ▲  
Actual values ○



Ahn et al (2011) JNPE

# *What tasks and models are available?*

Ahn & Busemeyer (2016) Curr Opin Behav Sci

- Delay Discounting (e.g., Mazur, 1987)
- *Iowa Gambling* (Bechara et al, 1994)
- (Orthogonalized) Go/Nogo (Guitart-Masip et al, 2012)
- Two-choice Bandit (Experience-based) including Reversal Learning (e.g., Erev et al, 2010)
- Two-choice Description-based (e.g., Sokol-Hessner et al, 2009; Tom et al, 2007)
- Ultimatum Game (e.g., Xiang et al, 2013)
- \*Two-Step (Daw et al, 2011)

*\*Version 2.3.0 or later*

# *How can I use it?*

Tutorials available at

<http://rpubs.com/CCSL/hBayesDM>

(you can find it by Googling 'hBayesDM')

Install it just like other R packages

```
install.packages("hBayesDM", dependencies=TRUE)
```

```
devtools::install_github("CCS-Lab/hBayesDM")
```



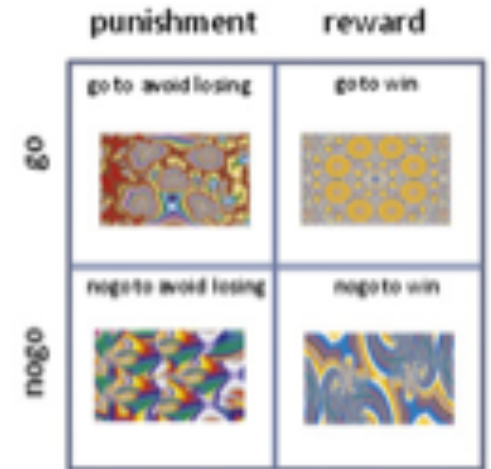
# *Brief step-by-step tutorials*

1. *Prepare raw (trial-by-trial) data*
2. *Fit candidate models*
3. *Plot (visualize) and inspect model parameters*
4. *Compare models (if there exist competing models)*

## *The Orthogonalized Go/Nogo task*

- gng\_m1
- gng\_m2
- gng\_m3
- gng\_m4

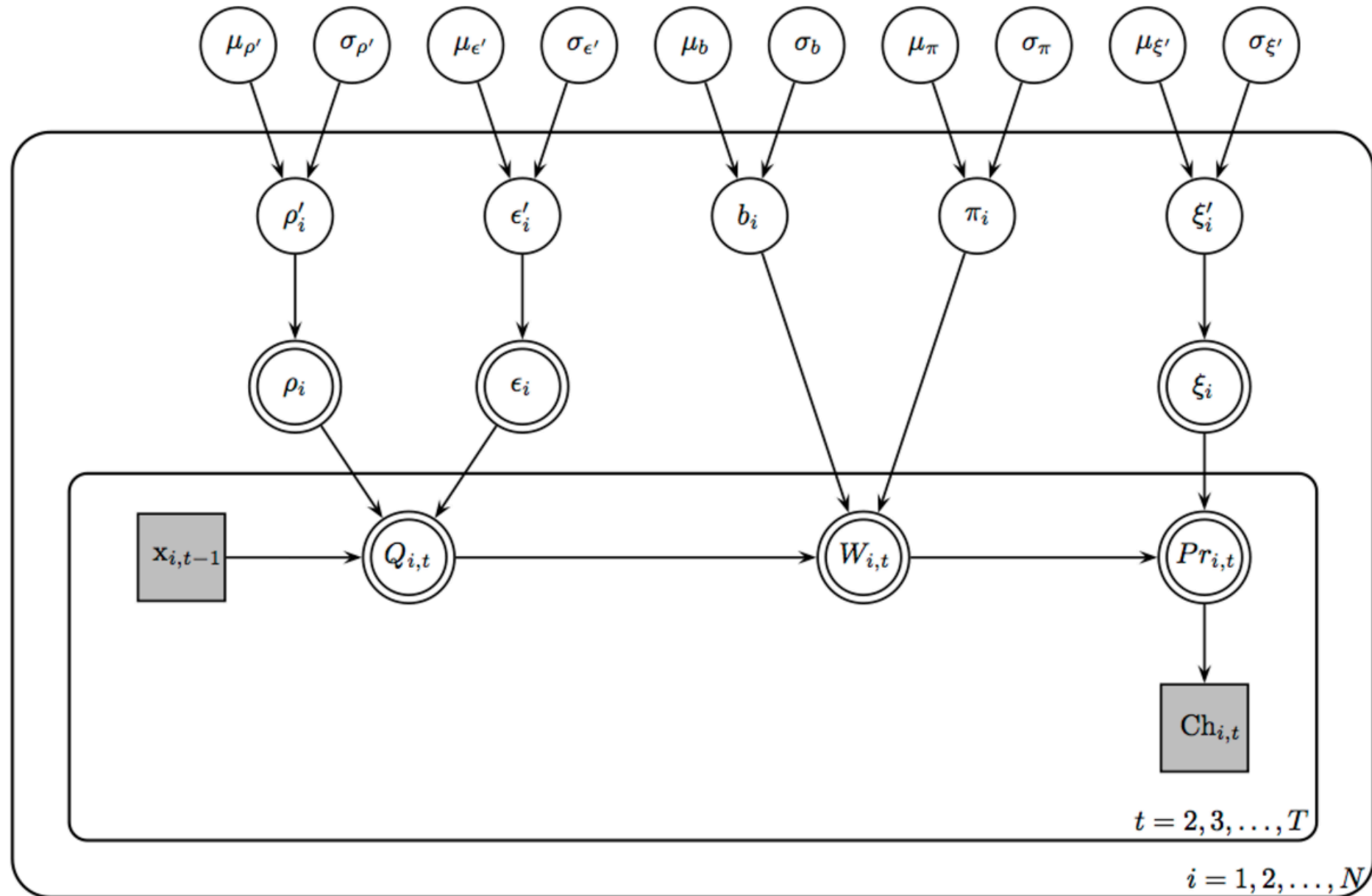
Guitart-Masip et al, 2012 Neuroimage  
Cavanagh et al, 2013 J Neuro



# 1. *Prepare raw (trial-by-trial) data as a single text file*

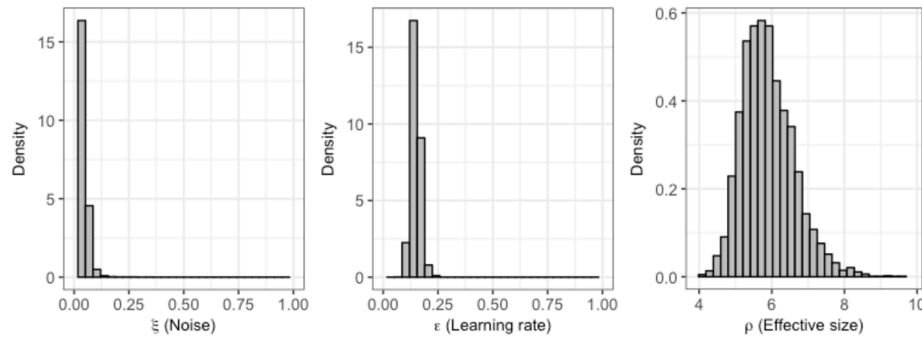
	A	B	C	D	E	F	G
1	trialNum	cue	keyPressed	success	congruentOutcome	outcome	subjID
2	1	1	1	1	2	0	1
3	2	2	0	1	1	1	1
4	3	4	0	1	1	0	1
5	4	4	1	0	1	-1	1
6	5	4	0	1	1	0	1
7	6	1	1	1	1	1	1
8	7	3	0	0	1	-1	1
9	8	1	1	1	1	1	1
10	9	3	1	1	1	0	1
11	10	3	0	0	1	-1	1
12	11	4	0	1	1	0	1
13	12	4	0	1	1	0	1
14	13	4	0	1	1	0	1

## 2. Fit candidate models



### 3. Plot (visualize) and inspect model parameters

```
plot(output1)
```

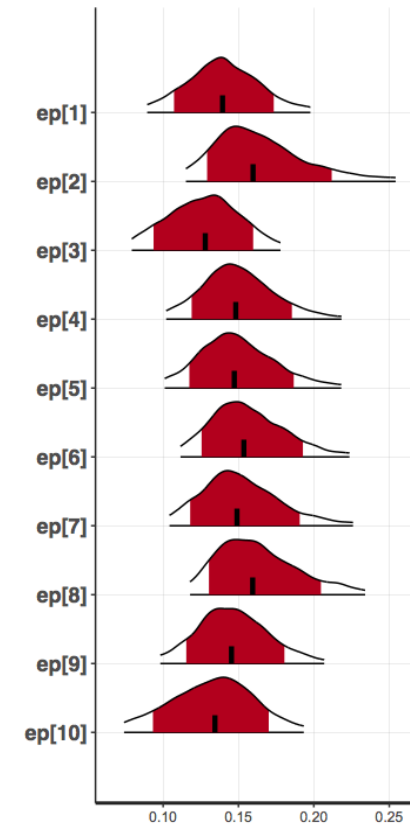


```
plotInd(output1, "ep")
```

```
> output1$allIndPars
```

	xi	ep	rho	subjID
1	0.03688558	0.1397615	5.902901	1
2	0.02934812	0.1653435	6.066120	2
3	0.04467025	0.1268796	5.898099	3
4	0.02103926	0.1499842	6.185020	4
5	0.02620808	0.1498962	6.081908	5

...



## 4. Bayesian model comparisons

Vehtari et al. (2016)

*Leave-One-Out Information Criterion (LOOIC) - default*

*Widely Applicable Information Criterion (WAIC)*

```
> printFit(output1, output2, output3, output4)
  Model    LOOIC
1 gng_m1 1588.843
2 gng_m2 1571.129
3 gng_m3 1573.872
4 gng_m4 1543.335
```

Model #4 is the best model  
(in terms of LOOIC)

# *More features!*

- Bayesian group comparisons
- \*Model-based regressors (e.g., trial-by-trial prediction errors) for model-based fMRI/EEG
- More tasks / models!

*I don't have much quantitative background,  
can I still do computational modeling?*

*Yes! Please check our tutorials/poster available  
@ <http://rpubs.com/CCSL/hBayesDM>*

GitHub: <https://github.com/CCS-Lab/hBayesDM>

*Can I add more models? Can you add more features? Can I contribute?*

*Yes! hBayesDM is also for experts. It is a work in progress. Please let us know if you have needs or cool models!*



# *Thank you!*



*Nate Haines*  
*The Ohio State University*



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Hamburg, Germany

Ahn, W.-Y., Haines, N., & Zhang, L. (2016). Revealing neuro-computational mechanisms of reinforcement learning and decision-making with the hBayesDM package. bioRxiv. <http://doi.org/10.1101/064287>

Extra slides

# Plan for model-based fMRI with hierarchical Bayesian estimation

