# Advanced Statistical Methodology and Psychological Flourishing

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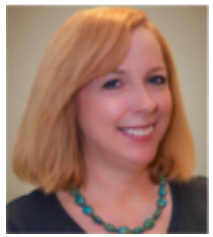
Nov 2019

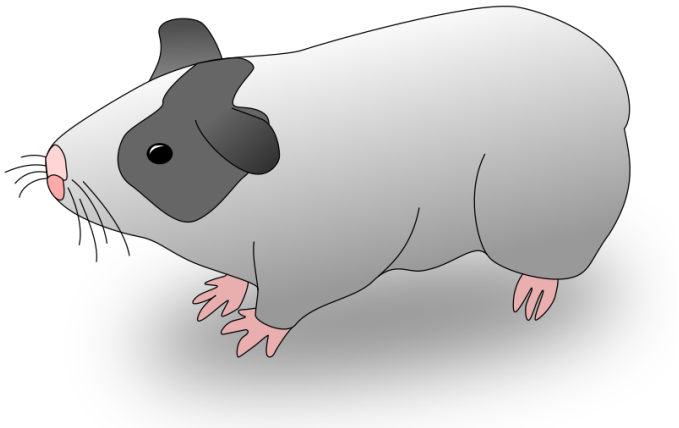
# Acknowledgment

Some mentors and collaborators

- Mike Neale
- Tim Brick (Penn State Univ)
- Steven Boker (Univ of Virginia)
- Karen Schmidt (Univ of Virginia)
- OpenMx development team



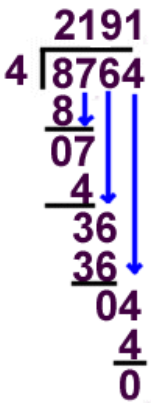





Funded in part by NIDA R25 DA-26119

# Number of estimated parameters

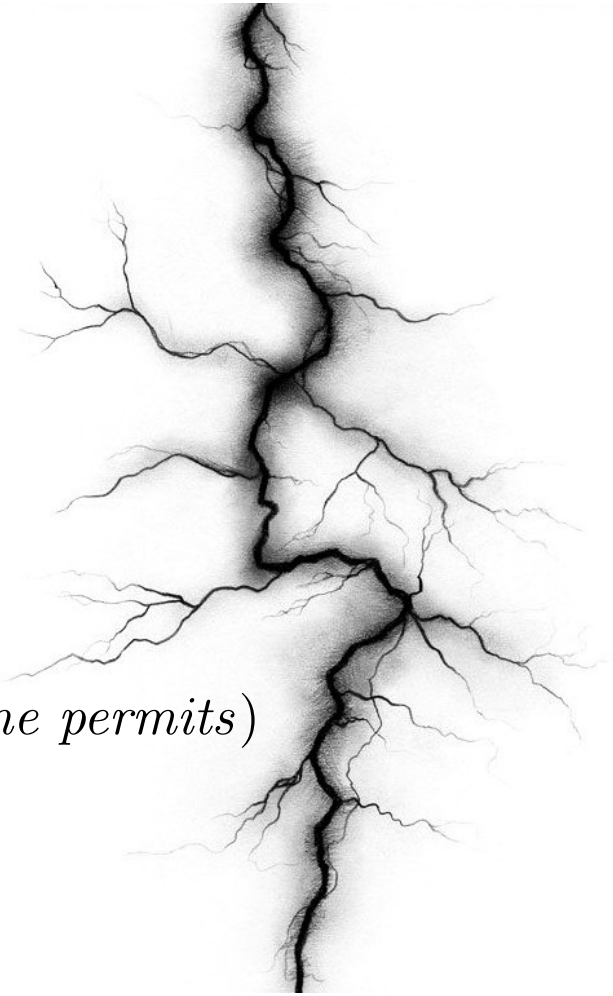
By hand Data science AI





Agenda

- OpenMx
- Heritability of cortical thickness
- Confidential analyses
- Psychological wellbeing
- Flow & physical activities
- Understanding human wellbeing (*if time permits*)



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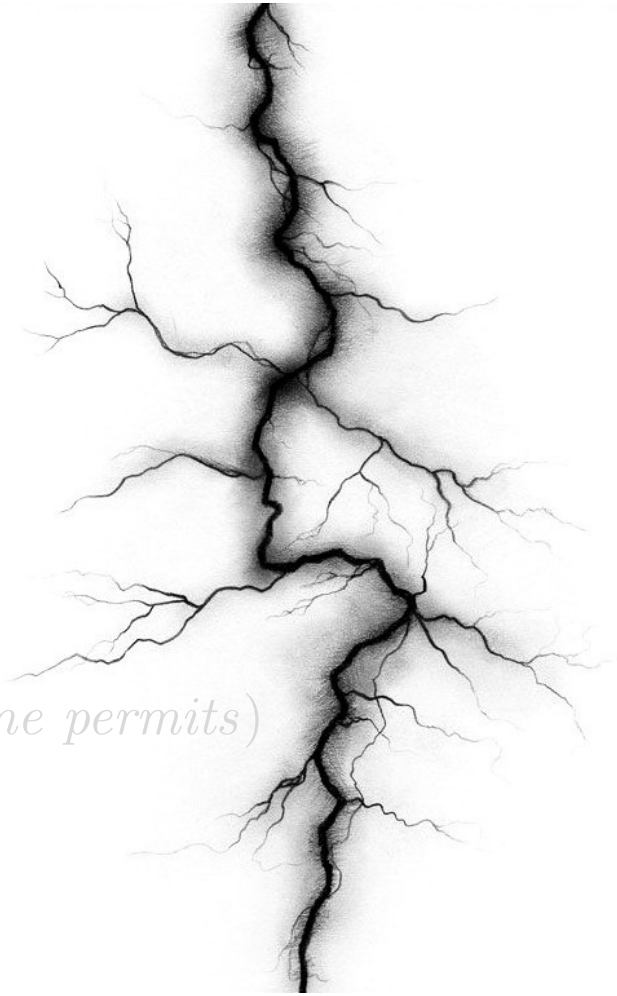


# OpenMx

Extended structural equation modelling[1]

Written in R & C++

Open source

11 authors over 12 years

Team meeting Friday 9am-11 (subject to change)

Comparable to lavaan, Mplus, EQS, LISREL, SPSS, etc. . .

[1] Neale et al. (2016)

# Some of my contributions

Modern test theory/Item response theory[2]

Many-level multilevel structural equation modeling[3]

Multivariate normal maximum likelihood with both ordinal and continuous variables, and data missing at random[4]

Likelihood-based confidence intervals for a parameter with an upper or lower bound[5]

## Main source of publications

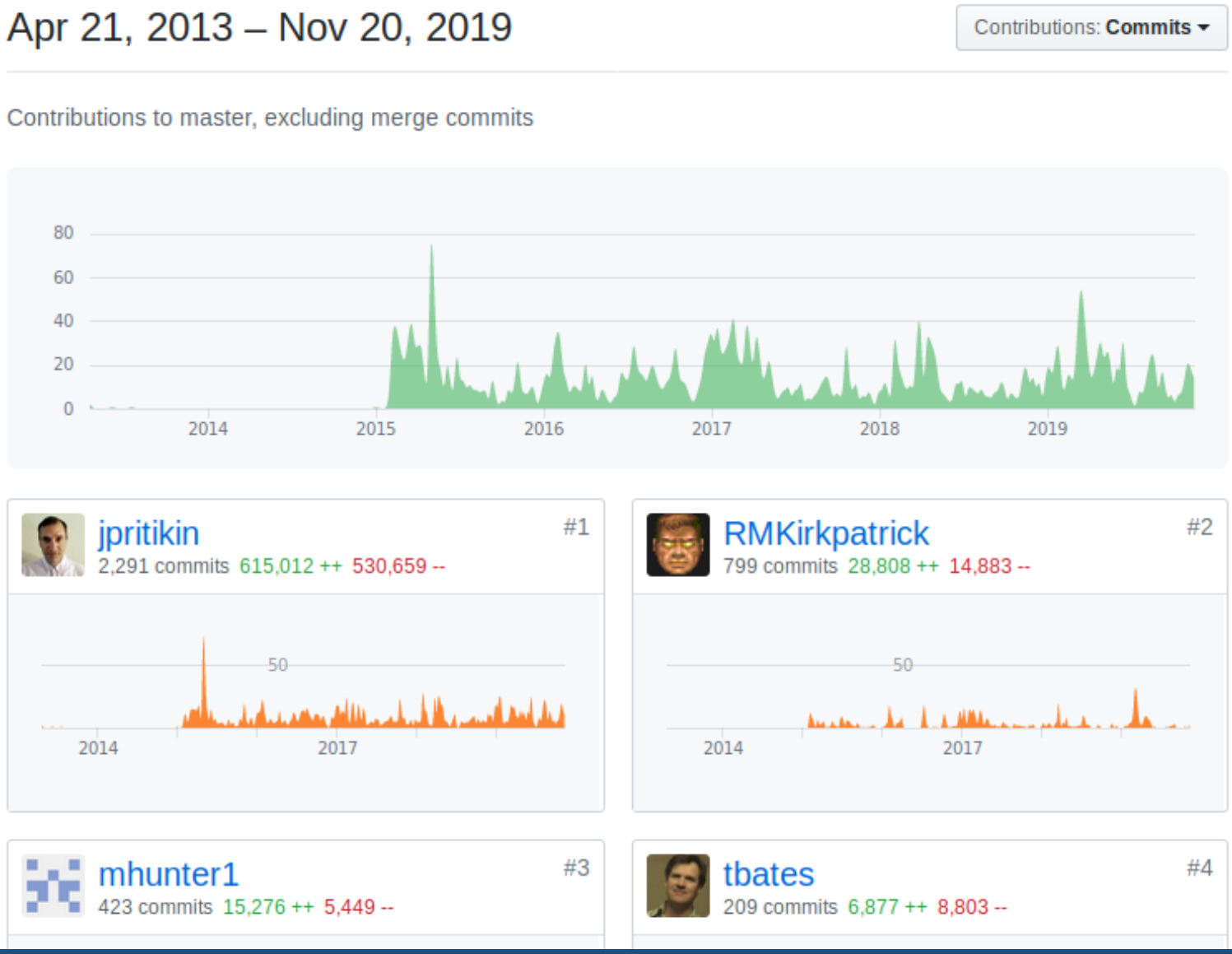
[2] Pritikin (2017a); Pritikin and Schmidt (2016); Pritikin, Hunter, and Boker (2015); Pritikin (2016)

[3] Pritikin, Hunter, von Oertzen, Brick, and Boker (2017)

[4] Pritikin, Brick, and Neale (2018)

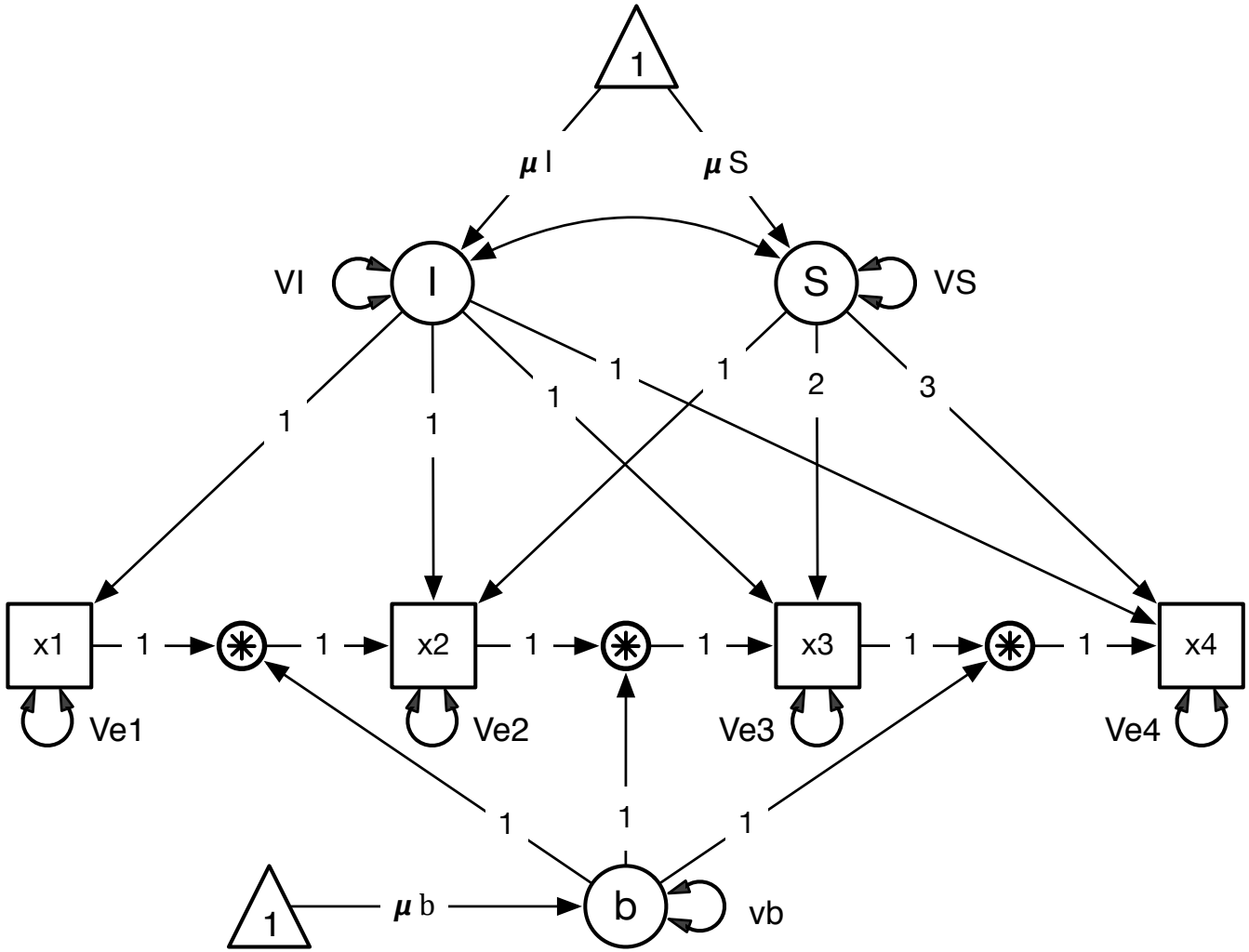
[5] Pritikin, Rappaport, and Neale (2017)

# 5 years, 500k lines of code

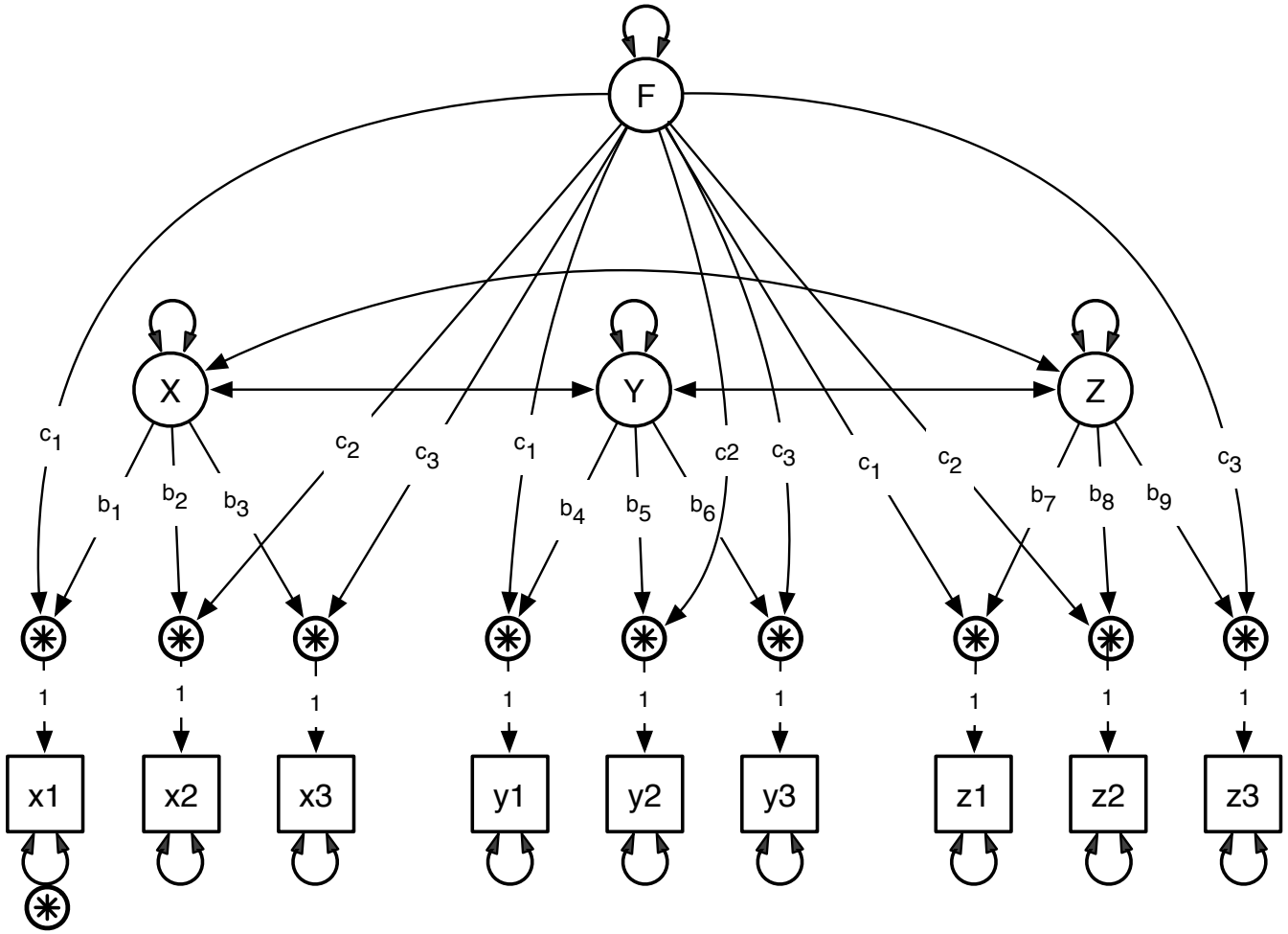



COMING
SOON

# Latent growth curve + autoregressive model



# Factor model, F scales loadings



# Potential student projects

Some ideas:

- Higher moments to fit product models
- Automatic conversion to Bayesian
- Copula for diverse link functions
- Analogue of quantile regression

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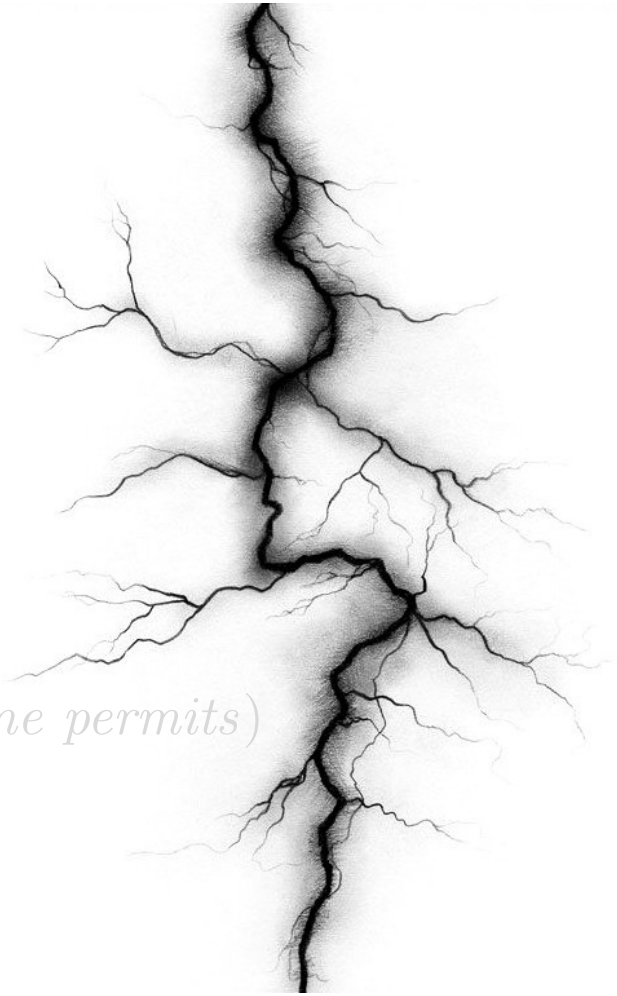


# Corticol thickness[6]

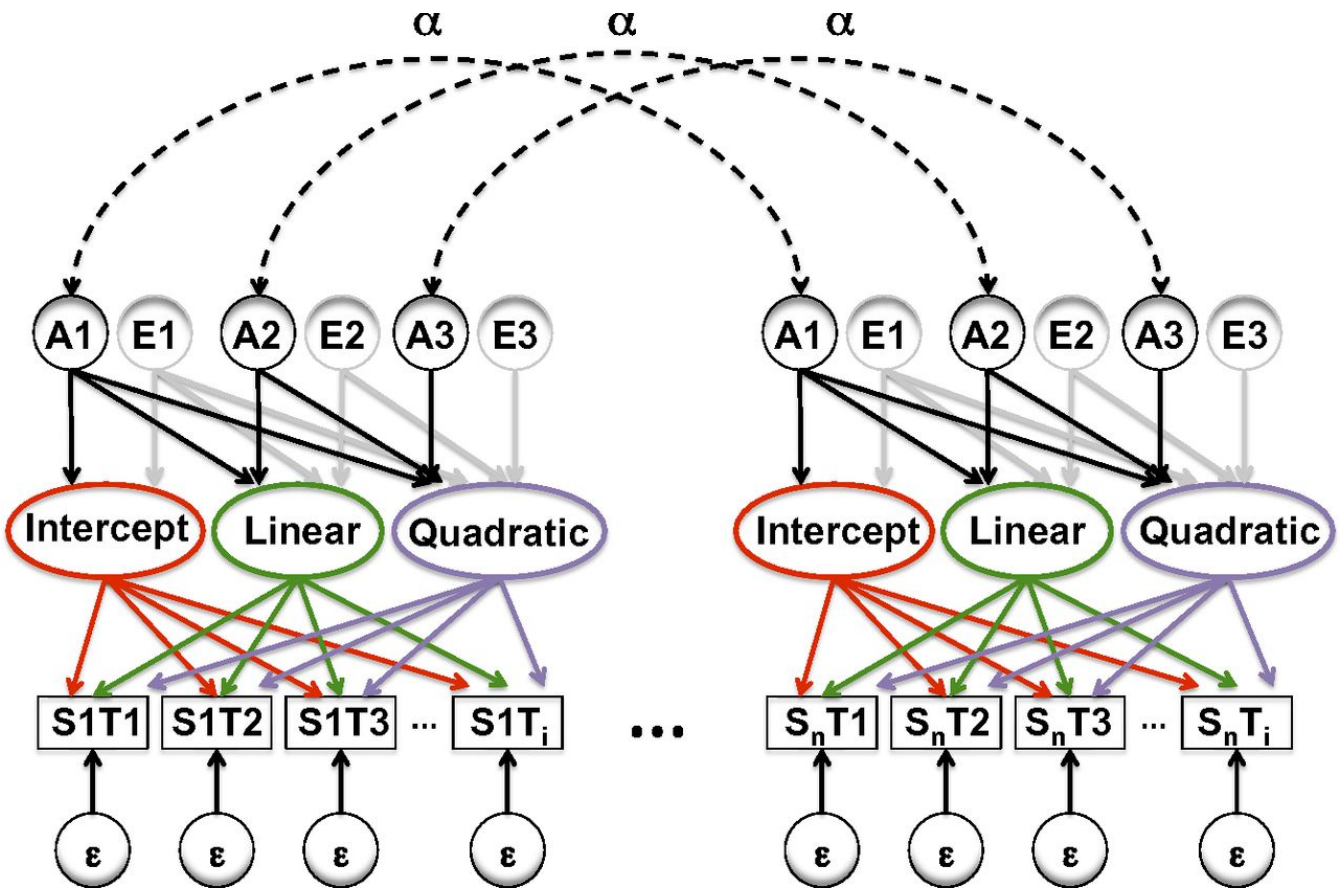
Application of OpenMx

Recently evolved phenotypes exhibits variability

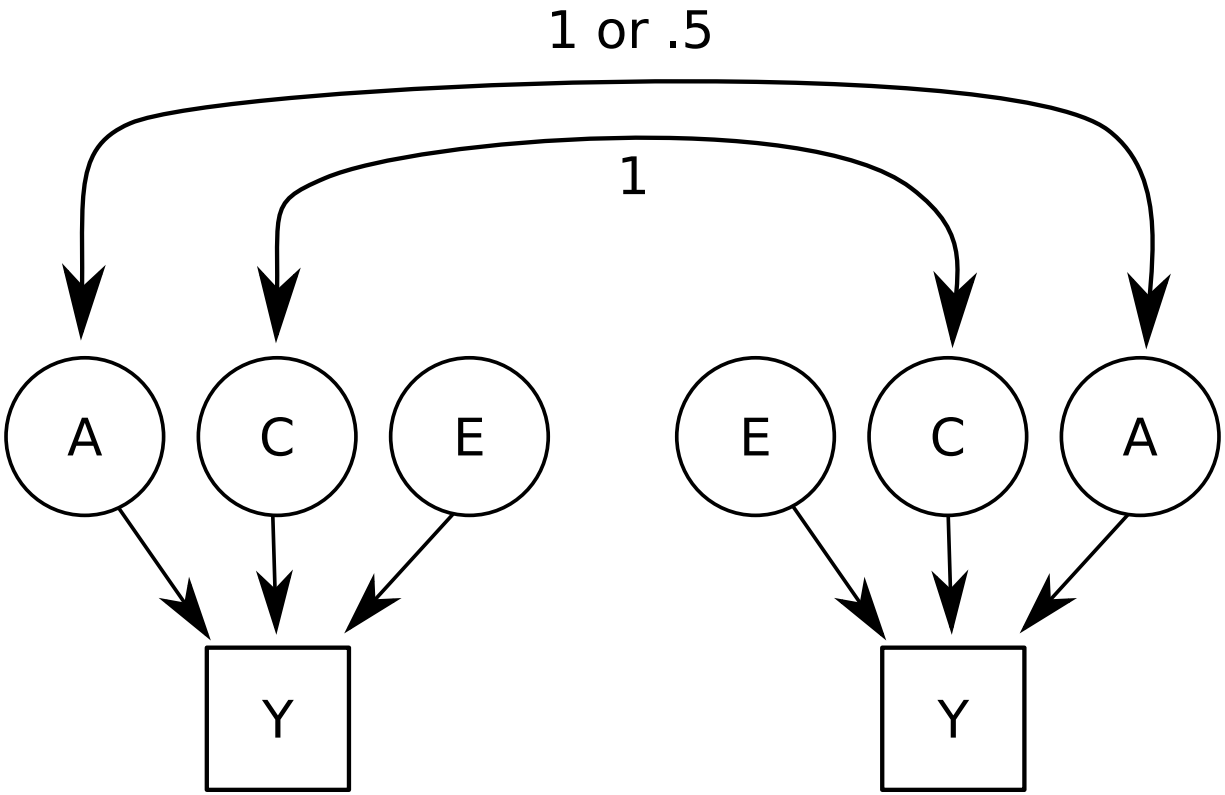
- 410 families
- 792 normally developing children, adolescents, and young adults
- Up to 8 MRI scans performed per individual
- Mean interval between scans was 2.4 yrs
- 1,748 MRI datasets acquired

[6] Schmitt et al. (2014)

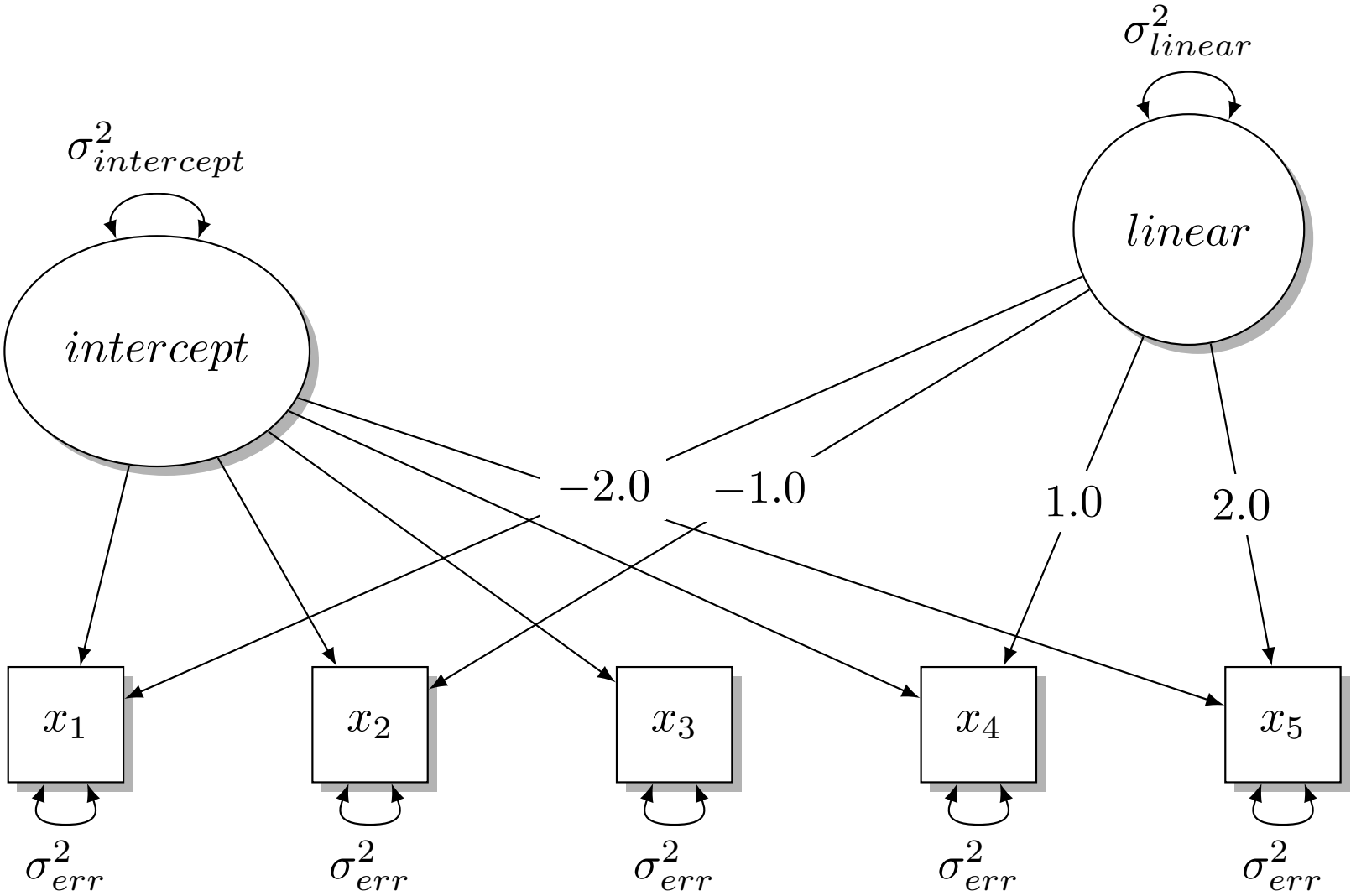
# Genetically informative latent growth curve model



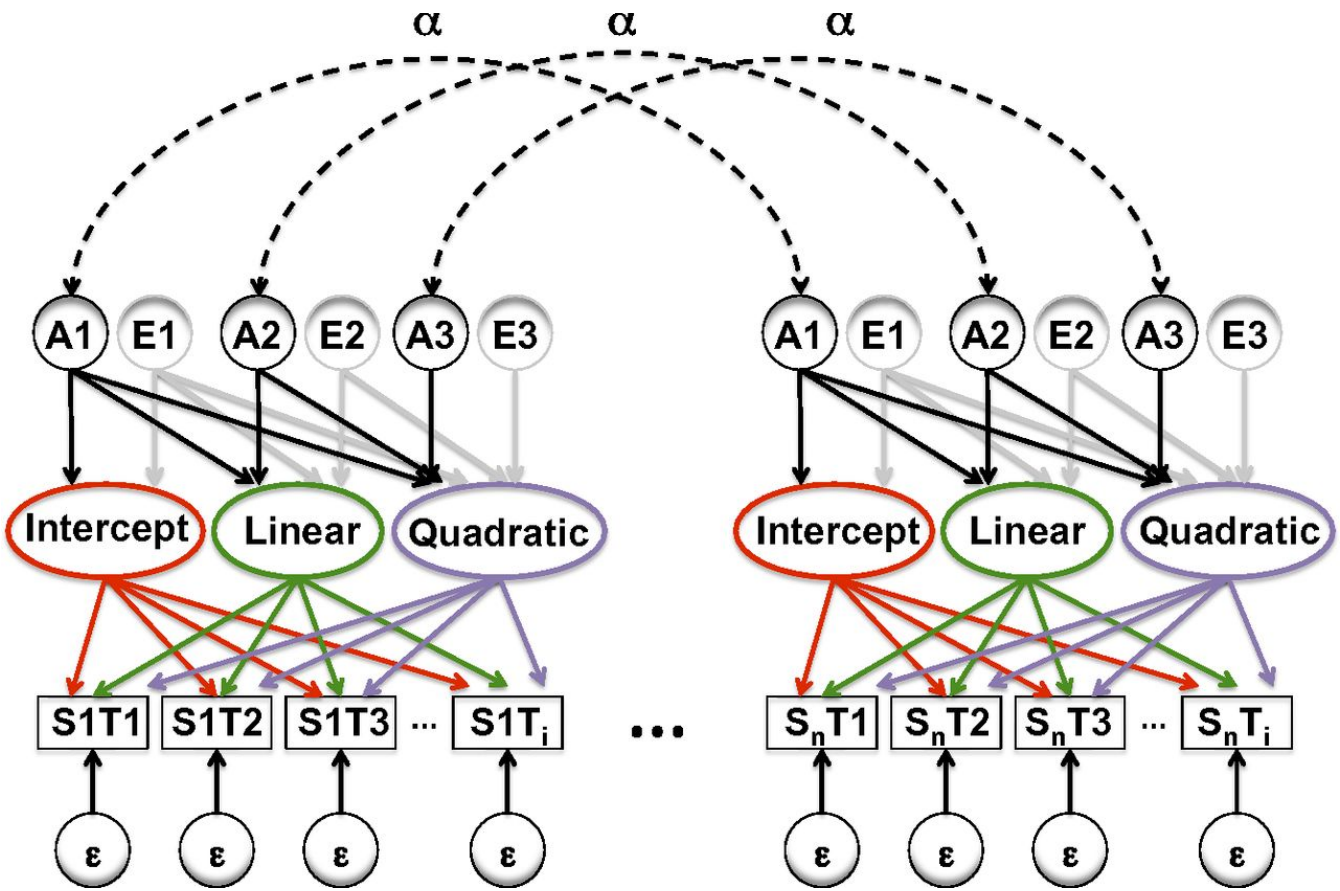
# Univariate twin model



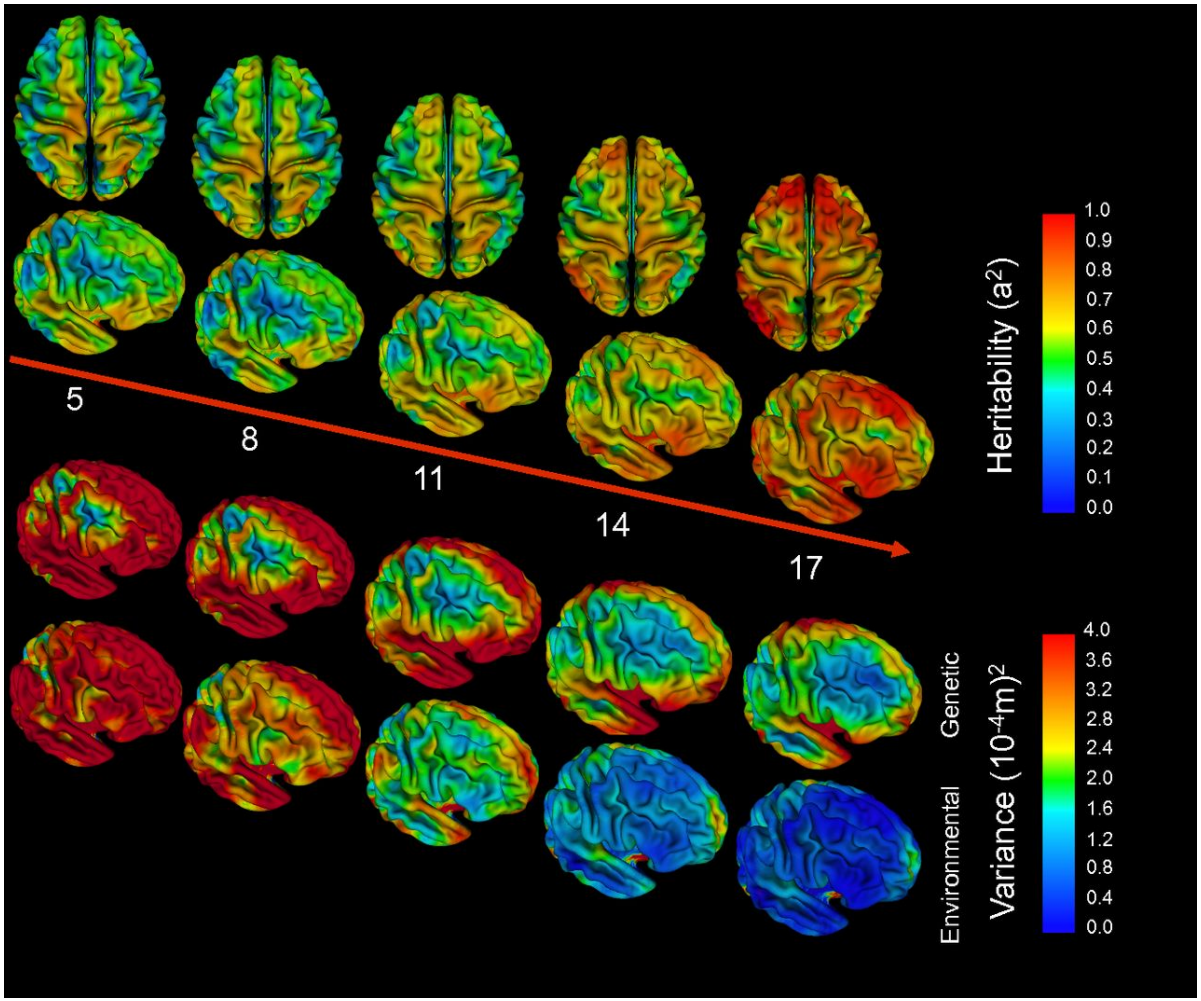

# Latent growth curve



# Genetically informative latent growth curve model



# Results


5
8
11
14
17
Heritability ($a^2$)
1.0
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0.0
Environmental
Genetic
Variance ($10^{-4}$m)$^2$
4.0
3.6
3.2
2.8
2.4
2.0
1.6
1.2
0.8
0.4
0.0

# Cloud computing

Original 2014 analyses[7]

- 3.7 GHz Quad Core Mac Pro Desktop computer
- 4 months of processing time

Reanalysis[8]

- Rented 1024 CPUs
- Kubernetes
- Done in 2 hr
- Identical results
- Cost: $200

Recently applied to new data[9]

[7] Schmitt et al. (2014)
[8] Pritikin, Schmitt, and Neale (2019)
[9] Schmitt, Neale, et al. (2019); Schmitt, Raznahan, et al. (2019)

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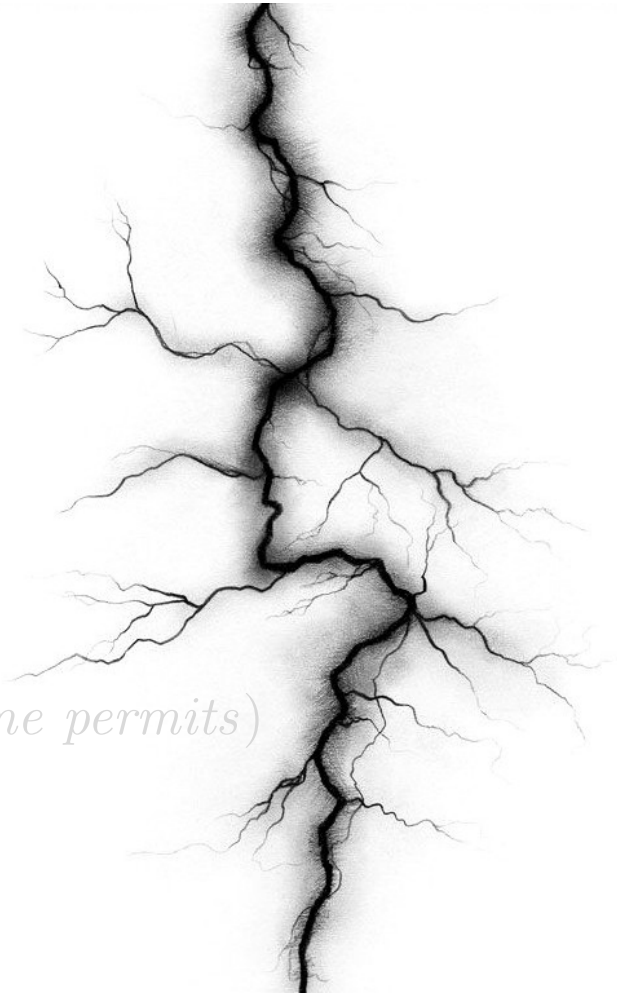


# Confidential analyses

What if we could keep participant data confidential,

never revealed to researchers,

and still fit statistical models to data and test hypotheses?

# Statistical models

Given

$$x_i \quad \text{row } x \text{ of data from person } i \tag{1}$$
$$\theta \quad \text{parameter vector} \tag{2}$$

Full-information likelihood often has the form

$$\sum_{i=1}^{I} \log L(x_i|\theta) \tag{3}$$

and rows are assumed independent and identically distributed.

# Distributed likelihood evaluation (DLE)

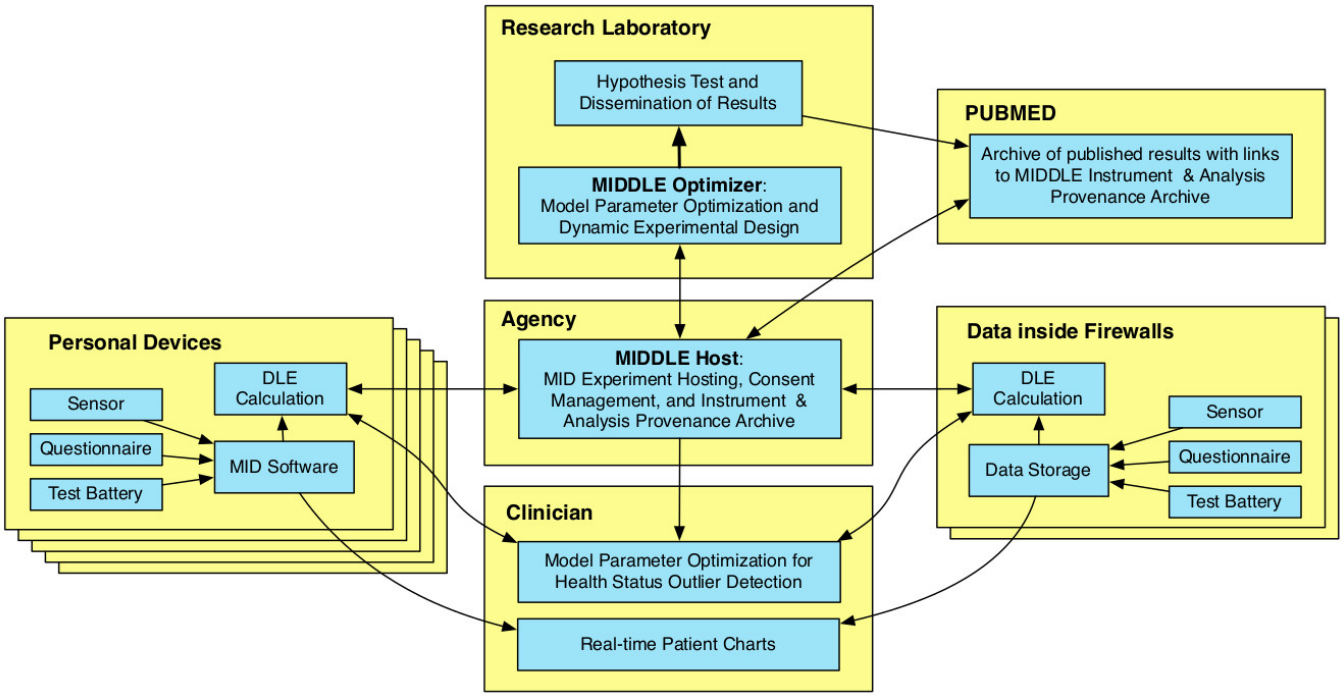
$$\begin{aligned}\sum_{i=1}^{I} \log L(x_i|\theta) = &\log L(x_1|\theta) \\ &\log L(x_2|\theta)+ \\ &\log L(x_3|\theta)+ \\ &\log L(x_4|\theta)+ \\ &\cdots + \\ &\log L(x_I|\theta) \end{aligned} \tag{4}$$

# Maintained individual data (MID)


Your personal $L(x_i|\theta)$ runs on your smartphone

- Data remain confidential
- Automatic data sharing across experiments
- Larger participant pool with more generalizable estimates

# Next steps




Proof-of-concept stage[10]

Apply to federal health agencies for funding

[10] Boker et al. (2015)

# Potential student projects

Some ideas:

- Delineate security and confidentiality trade-offs
- Investigate power and inference in the context of a continuously changing sample
- Recommend changes to informed consent and IRB processes

## Agenda

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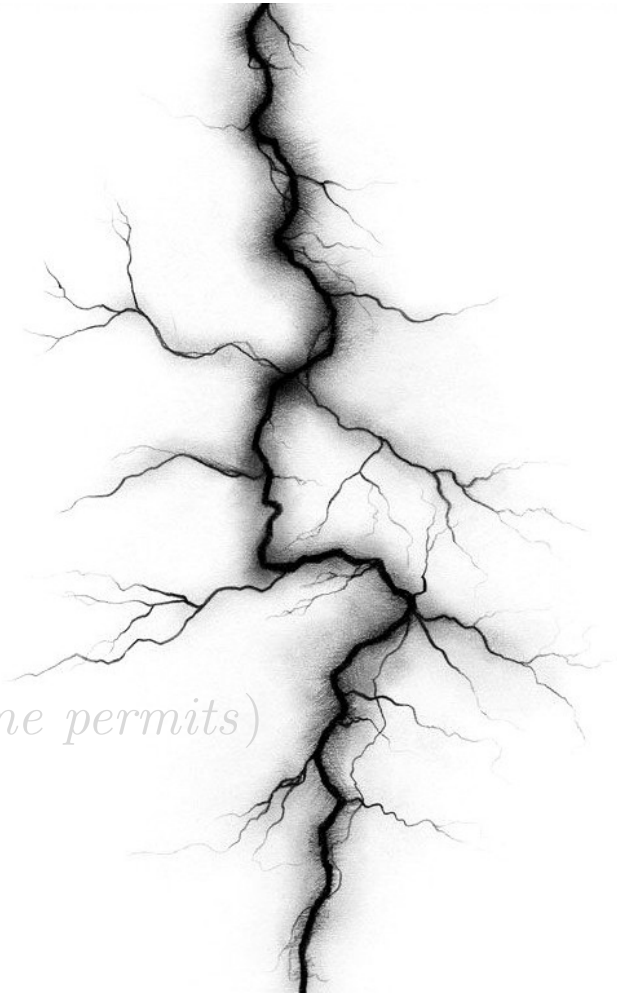
- Understanding human wellbeing (*if time permits*)

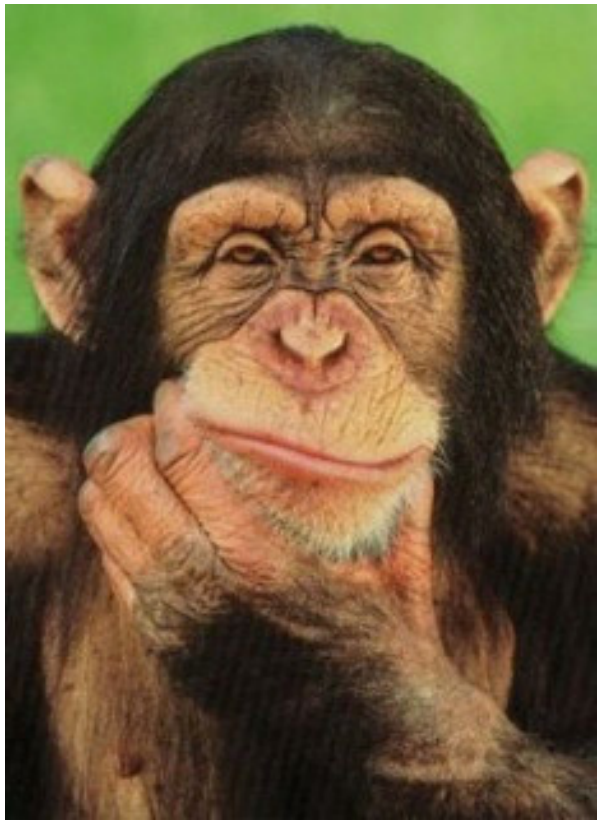


# History of sophisticated thinking

Not a study, but a research program (to be)

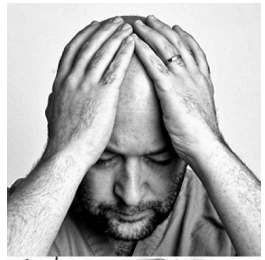
Recent evolution

- 1.8-1 MYO – Cooking[11]
- 200k-100k BCE – Homo sapiens
- 3400-3100 BCE – Written language
- 1500-200 BCE – Sophisticated thinking



[11] Wrangham (2009)

# Ouch

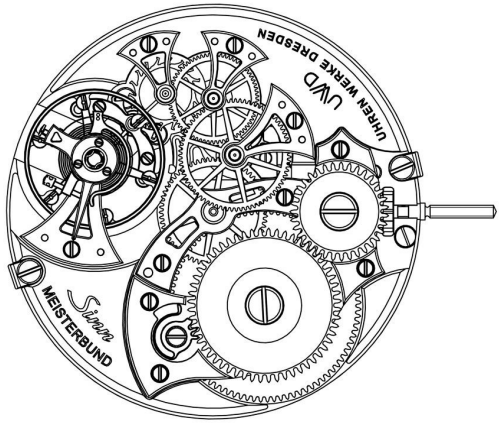



Conscious thinking has costs[12]

- maladaptive rumination
- jealousy, guilt
- anxiety, excessive planning

[12] Leary (2007)

# Solutions




Think better (e.g., cognitive behavioral therapy[13])

Temporarily cease thinking (to some extent)

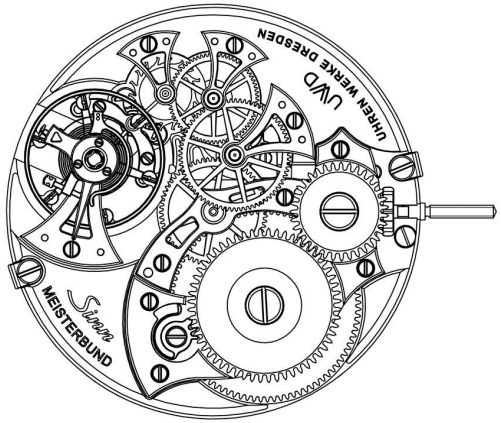
- Selflessness (i.e., dissolution of the self non-self boundary)
- Timelessness
- Effortlessness (i.e., spontaneous or involuntary)

In part due to hypofrontality[14]

[13] Butler, Chapman, Forman, and Beck (2006)

[14] Dietrich (2003)

# Solutions

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In part due to hypofrontality[14]

[13] Butler et al. (2006)
[14] Dietrich (2003)

# Substantive research focus

Non-ordinary states of consciousness that support

- psychological well-being
- optimal functioning
- mental and physical health
- fulfillment

Includes: flow, meditation, mindfulness, psychedelic drugs[15]

Excludes: dreaming, daydreaming, hypnosis

[15] Pollan (2018)

# Big challenges

Tricky to induce in the lab

Ephemeral

Prior work has often underestimated the difficulty[16]

[16] E.g., Goyal et al. (2014)

# Big challenges

. . . and it's gone

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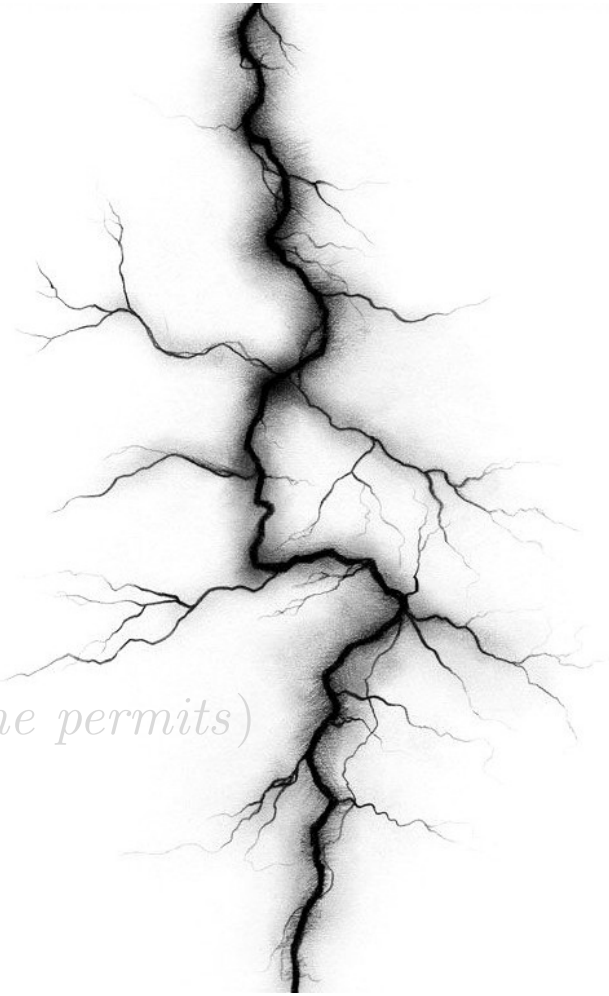


# Exploratory survey

Personal factors

- Psychological[17]
- Physiological[18]
- Neurological[19]

What about situational factors?

[17] E.g., Jackson, Ford, Kimiecik, and Marsh (1998)
[18] E.g., de Manzano, Theorell, Harmat, and Ullén (2010)
[19] E.g., Limb and Braun (2008)

# Optimal performance

Flow involves[20]

- Complete immersion without reflective self-consciousness but with a deep sense of control
- Preconditions: skills-demands compatibility, clear goals, and immediate feedback

Contexts:

- Running[21]
- Jazz improvisation[22]
- Etc. . .

[20] Keller and Landhäußer (2012)
[21] Csikszentmihalyi, Latter, and Duranso (2017)
[22] Limb and Braun (2008)

# Sample item (template)

Participant picks: [A], [B]

How predictable is the action?

- [B] is much more predictable than [A].
- [B] is somewhat more predictable than [A].
- Both offer roughly equal predictability.
- [A] is somewhat more predictable than [B].
- [A] is much more predictable than [B].

# Sample item

Participant picks: running, golf

How predictable is the action?

- golf is much more predictable than running.
- golf is somewhat more predictable than running.
- Both offer roughly equal predictability.
- running is somewhat more predictable than golf.
- running is much more predictable than golf.

20 items inspired by prior research on flow[23]

[23] Kotler (2014); Sawyer (2007); Wegner (2002)

# Birnbaum's dichotomous response model[24]

$$\pi(1|\alpha, c, \theta) = \frac{1}{1 + \exp(-(\alpha\theta + c))} \tag{5}$$

$$\pi(0|\alpha, c, \theta) = 1 - \pi(1|\alpha, c, \theta) \tag{6}$$

where

- $\alpha$ is the discrimination parameter
- $c$ is the intercept
- $\theta$ is the latent ability

[24] Birnbaum (1968)

# Build your understanding

Open your laptop and run `R`

- `install.packages(c('ifaTools', 'pcFactorStan'))`
- `library(ifaTools)`
- `ifaTools::itemModelExplorer()`
- `https://www.youtube.com/watch?v=KlnSiarkoOg`

# Adjust for paired comparisons

$$\pi(1|\alpha, c, \theta) = \frac{1}{1 + \exp(-(\alpha\theta + c))} \tag{7}$$

$$\pi(0|\alpha, c, \theta) = 1 - \pi(1|\alpha, c, \theta) \tag{8}$$

where

- $\alpha$ is the discrimination parameter
- $c$ is the intercept
- $\theta$ is the latent ability

# Adjusted for paired comparisons

$$\pi(1|\alpha, c, \theta_i, \theta_j) = \frac{1}{1 + \exp(-(\alpha(\theta_j - \theta_i) + c))} \tag{9}$$

$$\pi(0|\alpha, c, \theta_i, \theta_j) = 1 - \pi(1|\alpha, c, \theta_i, \theta_j) \tag{10}$$

where

- $\alpha$ is the discrimination parameter
- $c$ is the intercept
- $\theta_{i,j}$ are two latent worths

# What about symmetry?

Given,

$$\pi(1|\alpha, c, \theta_i, \theta_j) = \frac{1}{1 + \exp(-(\alpha(\theta_j - \theta_i) + c))} \tag{11}$$

If

$$\pi(1|\alpha, c, \theta_1, \theta_2) = 1 - \pi(1|\alpha, c, \theta_2, \theta_1) \tag{12}$$

then

$$c = 0. \tag{13}$$

# Paired comparison response function[25]

$$\pi(1|\alpha, \theta_i, \theta_j) = \frac{1}{1 + \exp(-\alpha(\theta_j - \theta_i))} \tag{14}$$

$$\pi(0|\alpha, \theta_i, \theta_j) = 1 - \pi(1|\alpha, \theta_i, \theta_j) \tag{15}$$

where

- $\alpha$ is the discrimination parameter
- $\theta_{i,j}$ are two latent worths

[25] Bradley and Terry (1952)

# Build your understanding

In R,

- `library(pcFactorStan)`
- `pcFactorStan::itemModelExplorer()`
- `https://www.youtube.com/watch?v=6Q311PByM4Q`

# Some differences

Dichotomous response model

- Sum score
- Judge differences (latent ability)

Paired comparison model

- No sum score
- Judge differences regarded as measurement error

# Item 1/10: Predictability

Participant picks: running, golf

How predictable is the action?

- golf is much more predictable than running.
- golf is somewhat more predictable than running.
- Both offer roughly equal predictability.
- running is somewhat more predictable than golf.
- running is much more predictable than golf.

# Item 2/10: Skill

Participant picks: running, golf

How much skill is required?

- running requires much more skill than golf.
- running requires somewhat more skill than golf.
- Both require roughly equal skill.
- golf requires somewhat more skill than running.
- golf requires much more skill than running.

# Item 3/10: Creativity

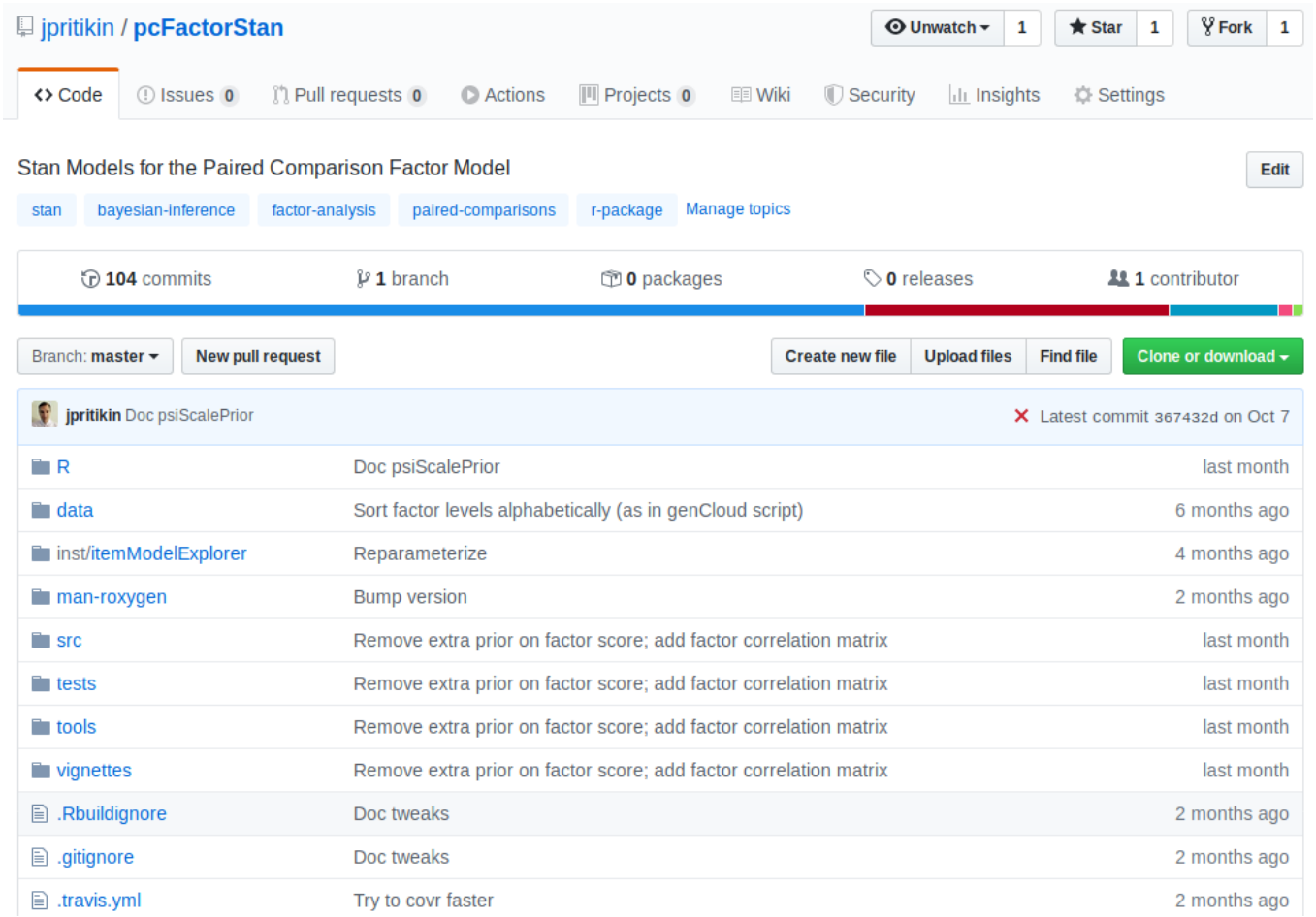
Participant picks: running, golf

To what extent are there opportunities to express creativity during the activity?

- golf admits much more creativity than running.
- golf admits somewhat more creativity than running.
- Both admit roughly the same amount of creativity.
- running admits somewhat more creativity than golf.
- running admits much more creativity than golf.

# Factor model

# Manuscript under review



jpritikin / pcFactorStan

Unwatch 1 | Star 1 | Fork 1

Code | Issues 0 | Pull requests 0 | Actions | Projects 0 | Wiki | Security | Insights | Settings

Stan Models for the Paired Comparison Factor Model

Edit

stan | bayesian-inference | factor-analysis | paired-comparisons | r-package | Manage topics

104 commits | 1 branch | 0 packages | 0 releases | 1 contributor

Branch: master | New pull request | Create new file | Upload files | Find file | Clone or download

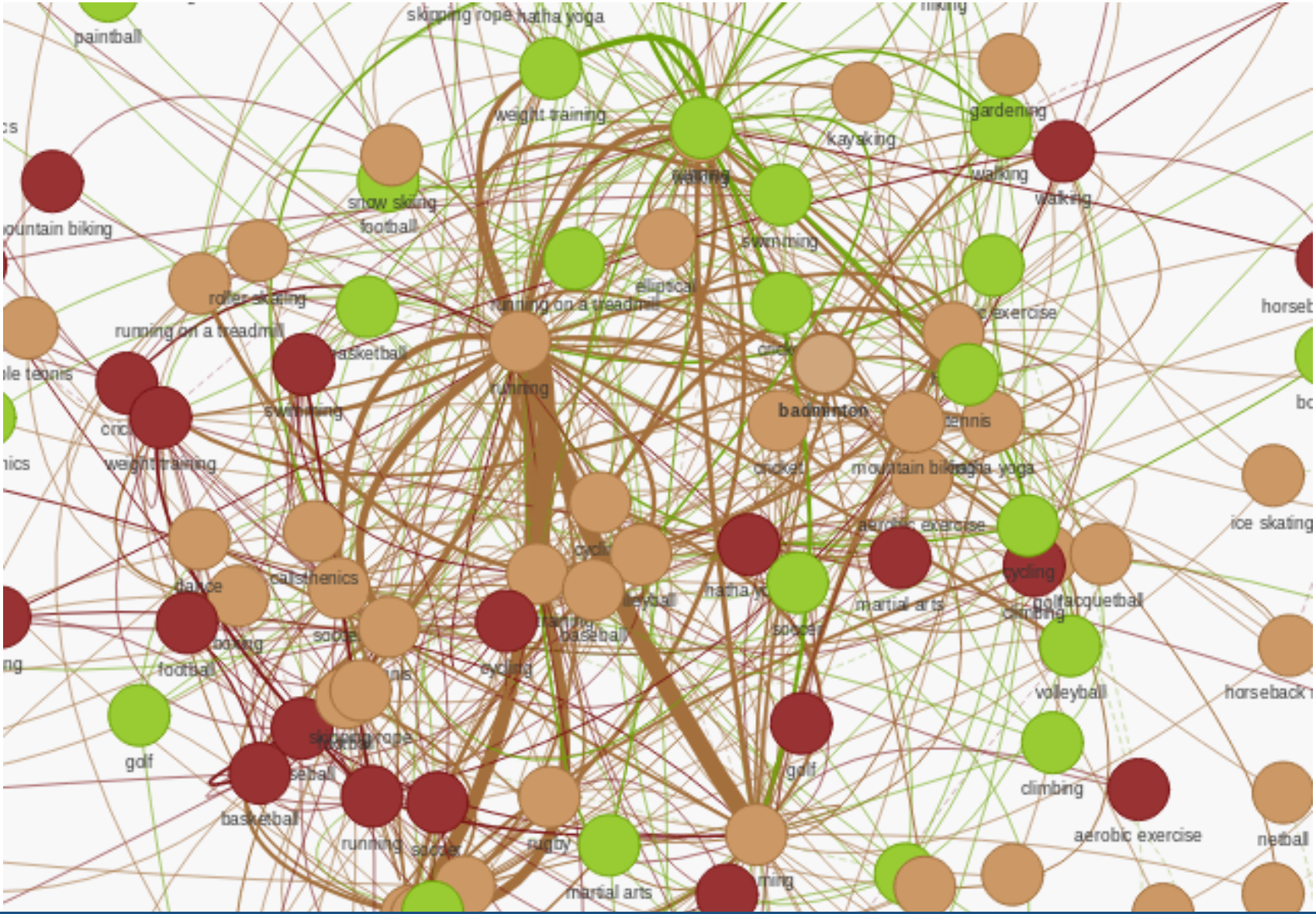
jpritikin Doc psiScalePrior — Latest commit 367432d on Oct 7

| | | |
|---|---|---|
| R | Doc psiScalePrior | last month |
| data | Sort factor levels alphabetically (as in genCloud script) | 6 months ago |
| inst/itemModelExplorer | Reparameterize | 4 months ago |
| man-roxygen | Bump version | 2 months ago |
| src | Remove extra prior on factor score; add factor correlation matrix | last month |
| tests | Remove extra prior on factor score; add factor correlation matrix | last month |
| tools | Remove extra prior on factor score; add factor correlation matrix | last month |
| vignettes | Remove extra prior on factor score; add factor correlation matrix | last month |
| .Rbuildignore | Doc tweaks | 2 months ago |
| .gitignore | Doc tweaks | 2 months ago |
| .travis.yml | Try to covr faster | 2 months ago |

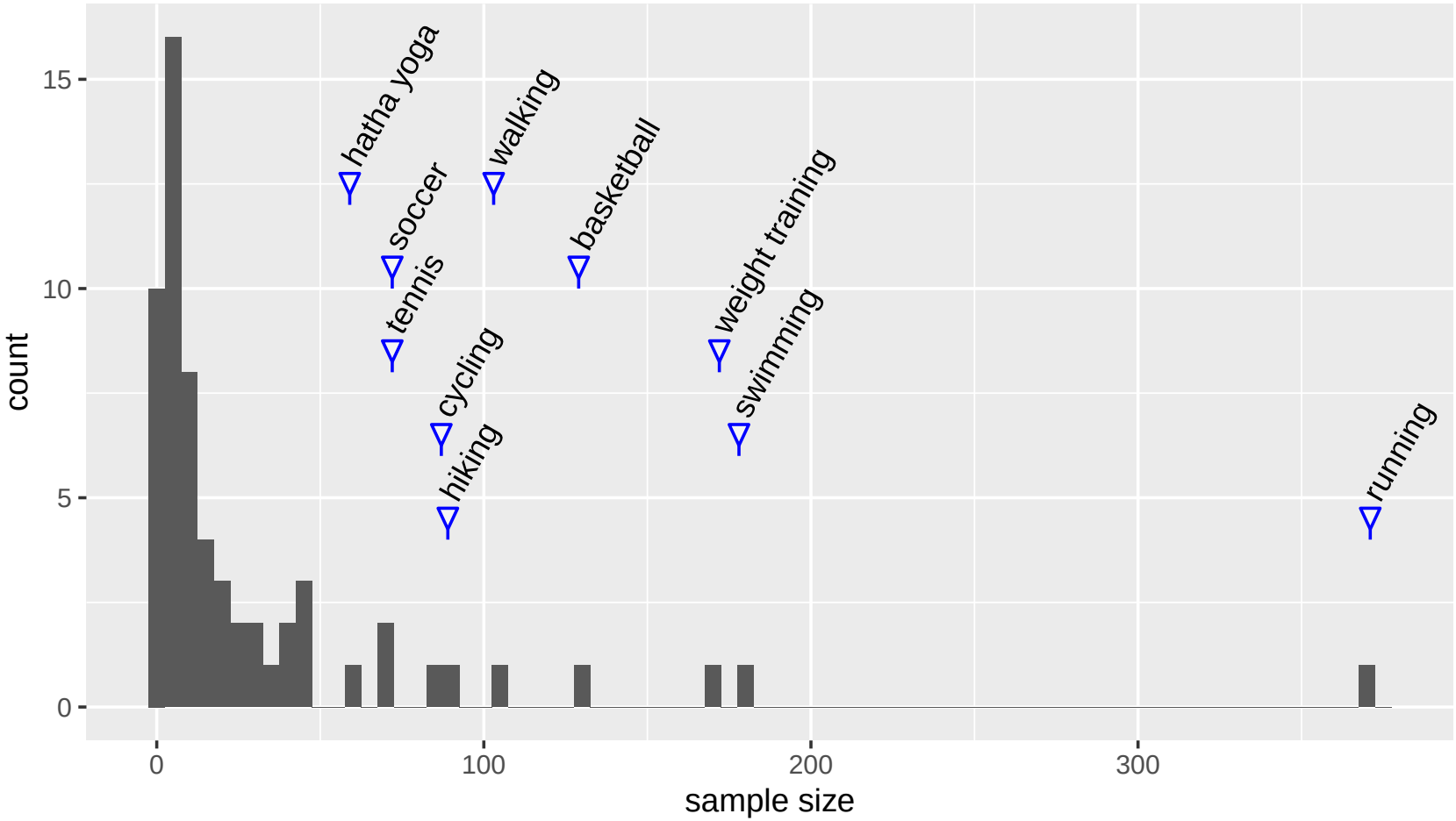
# Demographics, sex & country

| | source | |
|---|---|---|
| | public n = 230 | MTurk n = 757 |
| sex | | |
| female | 150 (65%) | 299 (39%) |
| male | 75 (33%) | 456 (60%) |
| *missing* | 5 (2%) | 2 (0%) |
| country | | |
| Austria | 4 (2%) | 0 (0%) |
| Canada | 6 (3%) | 9 (1%) |
| Germany | 16 (7%) | 0 (0%) |
| India | 1 (0%) | 79 (10%) |
| United Kingdom | 30 (13%) | 0 (0%) |
| USA | 147 (64%) | 641 (85%) |
| other | 16 (7%) | 13 (2%) |
| *missing* | 10 (4%) | 15 (2%) |

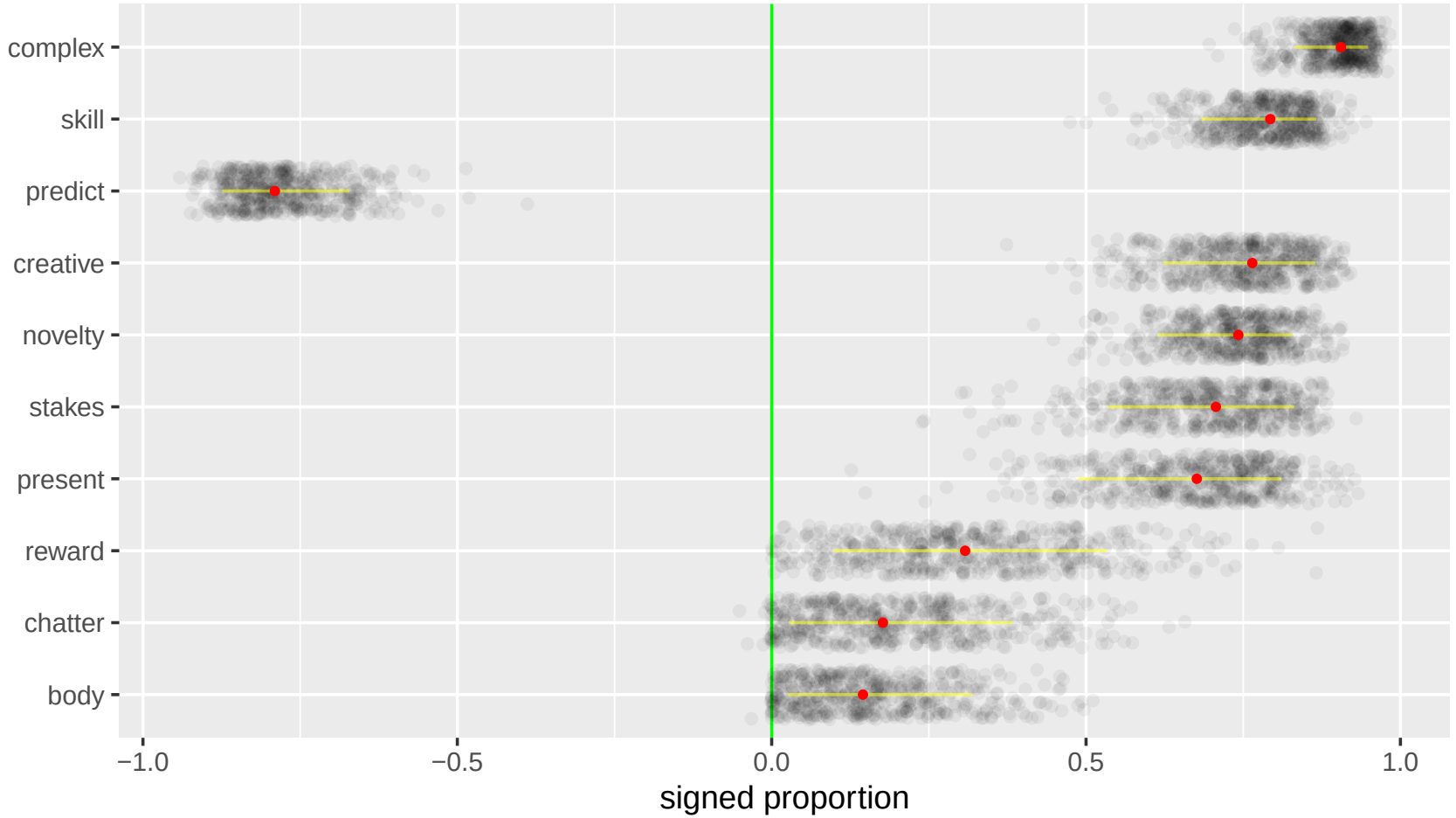
# Incomplete design



# Sample size distribution

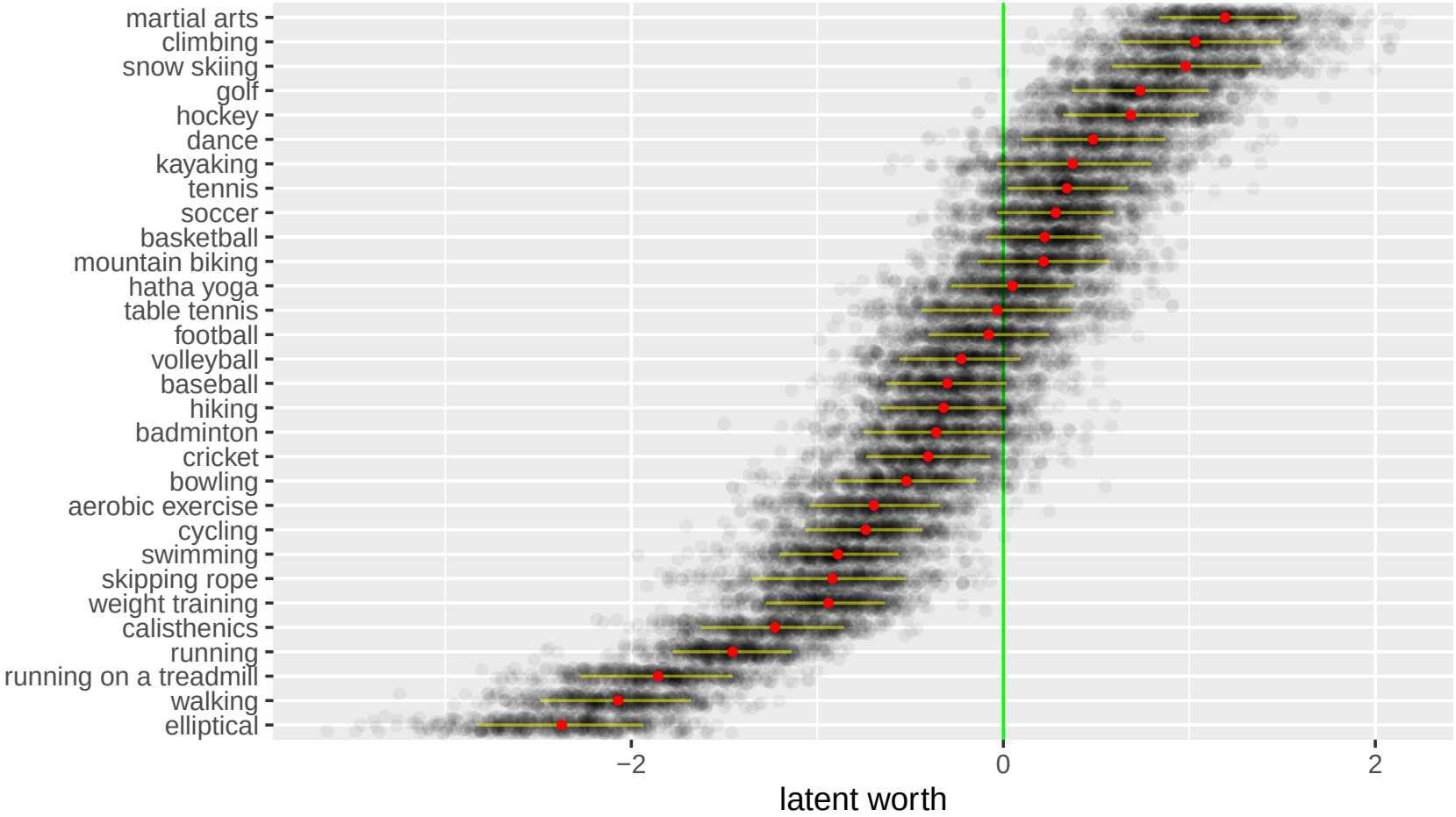


# Posterior item loadings



# Posterior flow propensity scores

## For activities with a sample size $\geq 11$



# Possible student projects

Some ideas:

- Confirmatory factor analysis
- Structural equation modeling
- Get more data on high flow propensity areas (e.g., martial arts)
- Investigate measurement invariance in a new sample

# Questions?

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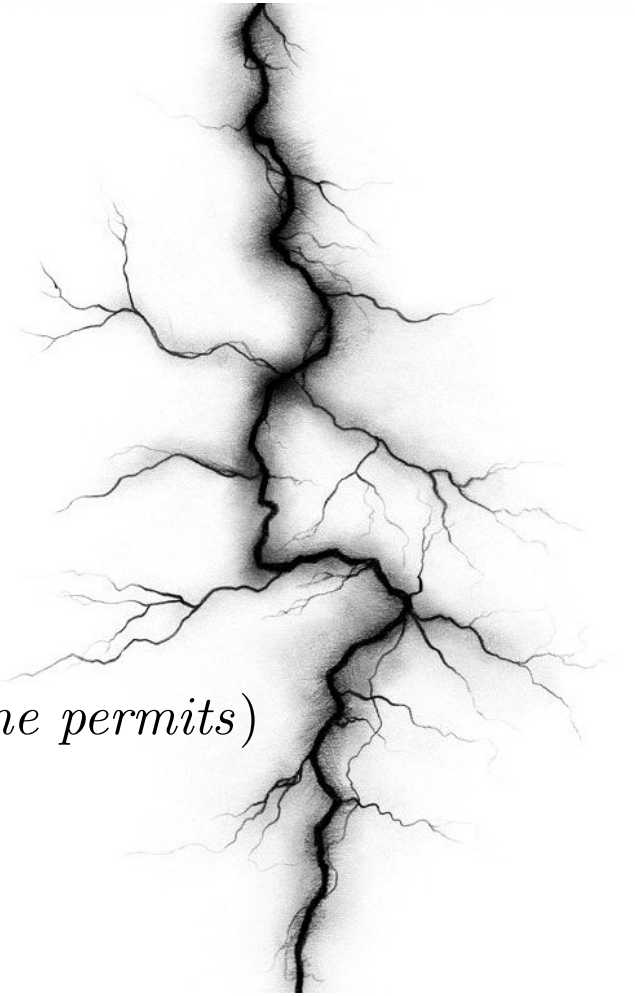
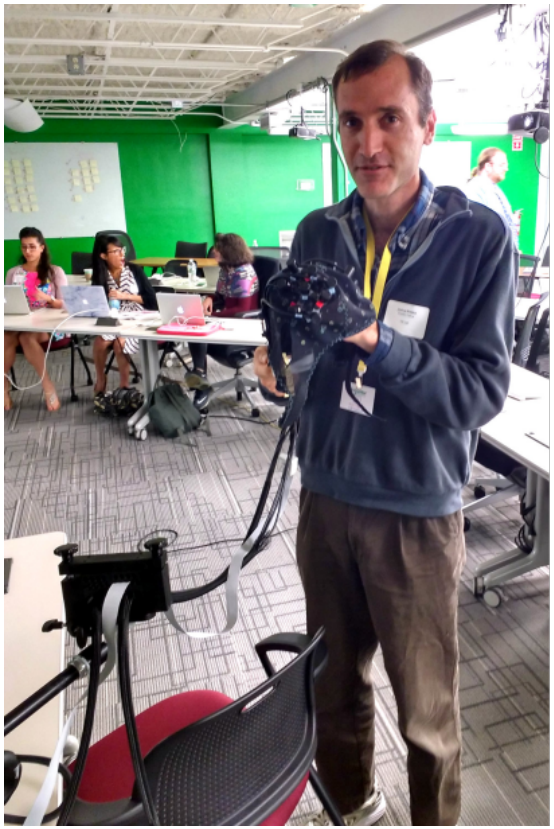
- Understanding human wellbeing (*if time permits*)

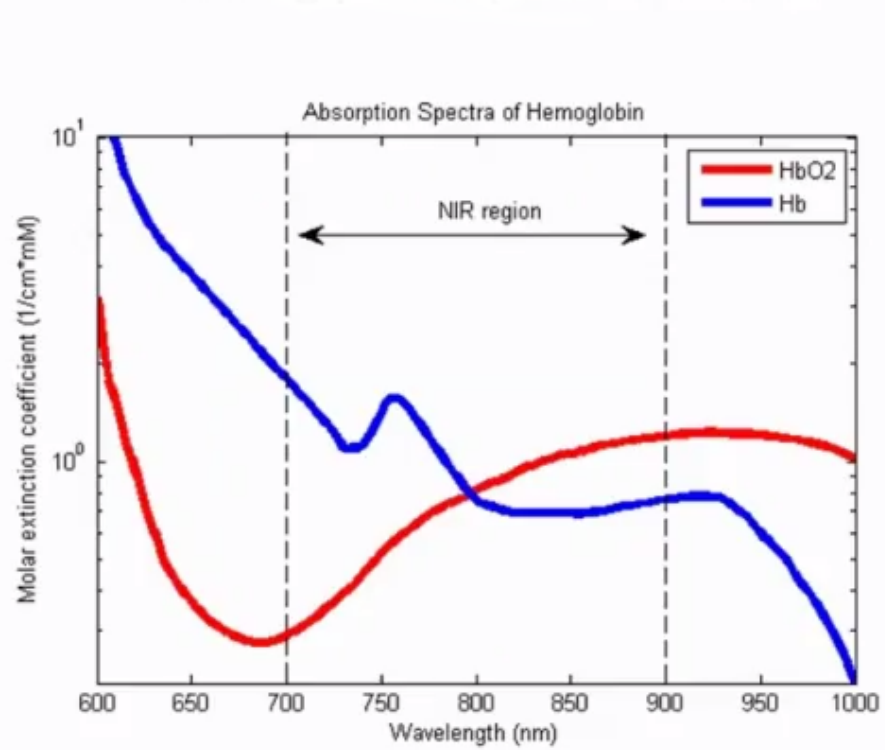


# 2017 fNIRS Workshop at Kingston, RI

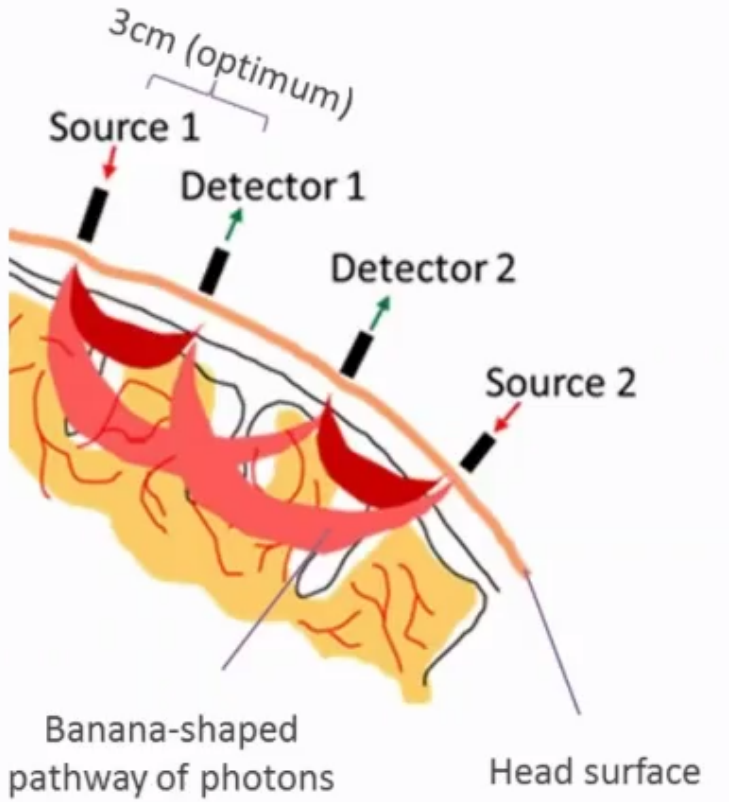


Possible future research direction

# Working principles of NIRS




Absorption spectra of Hb



# NIRS compared to MRI

Both measure the blood oxygen level-dependent (BOLD) response[26]

| method | resolution | | depth pervasion | mobility | cost |
|---|---|---|---|---|---|
| | temporal | spatial | | | |
| MRI | 1-2 s | 64 $mm^3$ | good | poor | >$1 million |
| NIRS | 100-400 ms | 100 $mm^3$ | 2-3 cm | good | ~$20-100k |

(Table from Min, Marzelli, & Yoo, 2010)

New tech on the horizon (2 $\mu m^3$ spatial resolution)[27]

[26] Cui, Bray, Bryant, Glover, and Reiss (2011)

[27] https://www.openwater.cc

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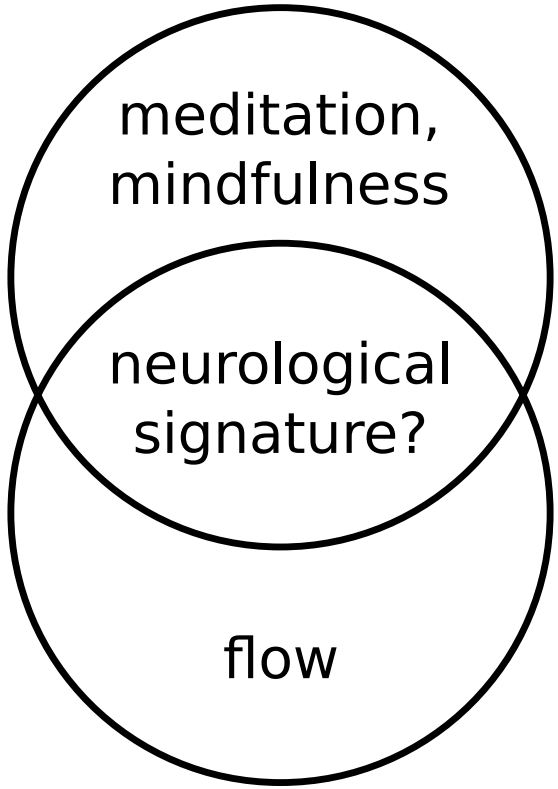
# Triangulate




# Flow inductions



Tetris, pong[28]

[28] Yoshida et al. (2014); de Sampaio Barros, Araújo-Moreira, Trevelin, and Radel (2018)

# Wim Hof method

Not mere relaxation

Clear physiological correlates[29]

Simple method:

- Cold exposure
- Breathing
- Commitment

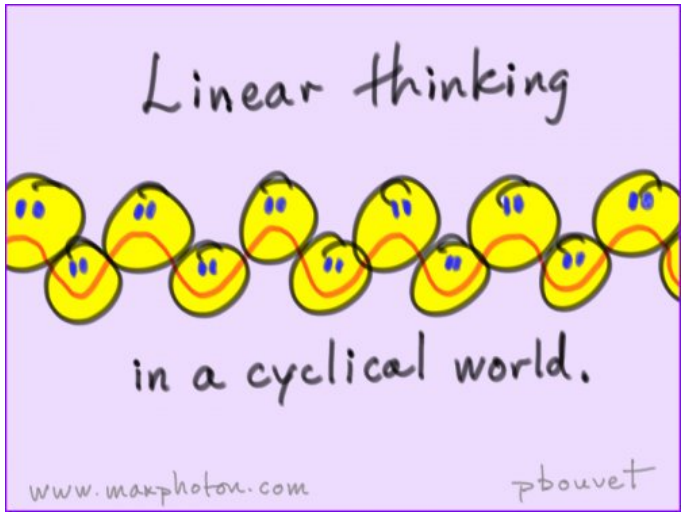
[29] Kox et al. (2014); Muzik, Reilly, and Diwadkar (2018)

# Data analysis challenge

Multivariate, multilevel time series data

Possible approaches:

- Windowed cross correlation
- Autoregressive models
- State space models
- Dynamic connectivity[30]
- Novel methods[31]




[30] Santosa, Aarabi, Perlman, and Huppert (2017)
[31] Pritikin, Hunter, et al. (2017); Pritikin (2017b)

# Next steps

## Speculative

With Co-PI Tim Brick,
assistant professor at Penn State Univ

Apply for a grant from

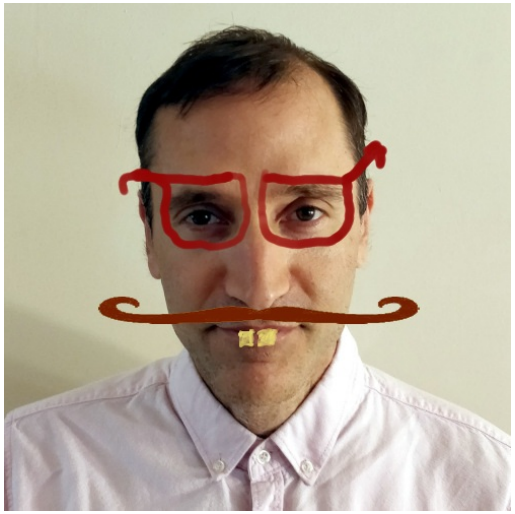
- John Templeton Foundation
- The Mind and Life Institute
- Nat'l Institute of Mental Health?

# Questions?

# Summary

Think of

- Applied Statistician
- Data Scientist
- Software Engineer
- Your friendly collaborator
- Psychological Flourishing



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