Advanced Statistical Methodology and Psychological Flourishing

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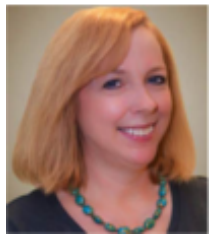
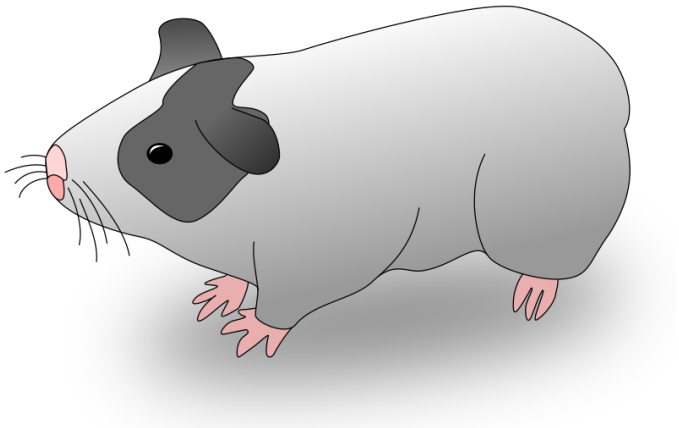
Acknowledgment

Some mentors and collaborators

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



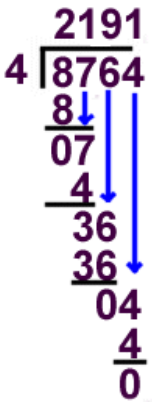





Funded in part by NIDA R25 DA-26119

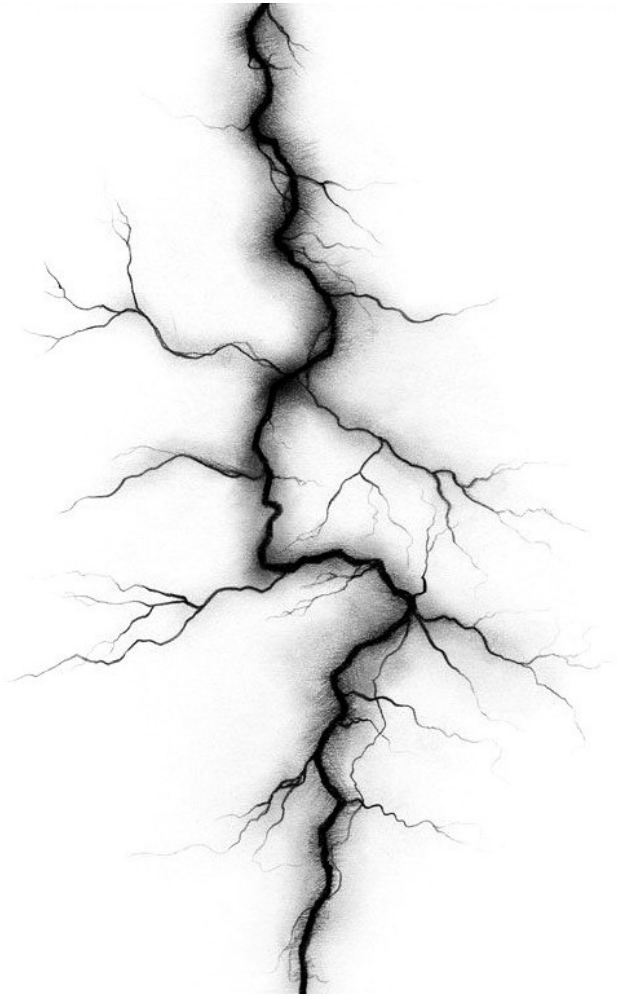
Automation in statistics

By hand Data science AI



Agenda

- OpenMx
- Heritability of cortical thickness
- Confidential analyses
- Substantive foray
- Flow & physical activities
- Neuroimaging (*if time permits*)
- Teaching



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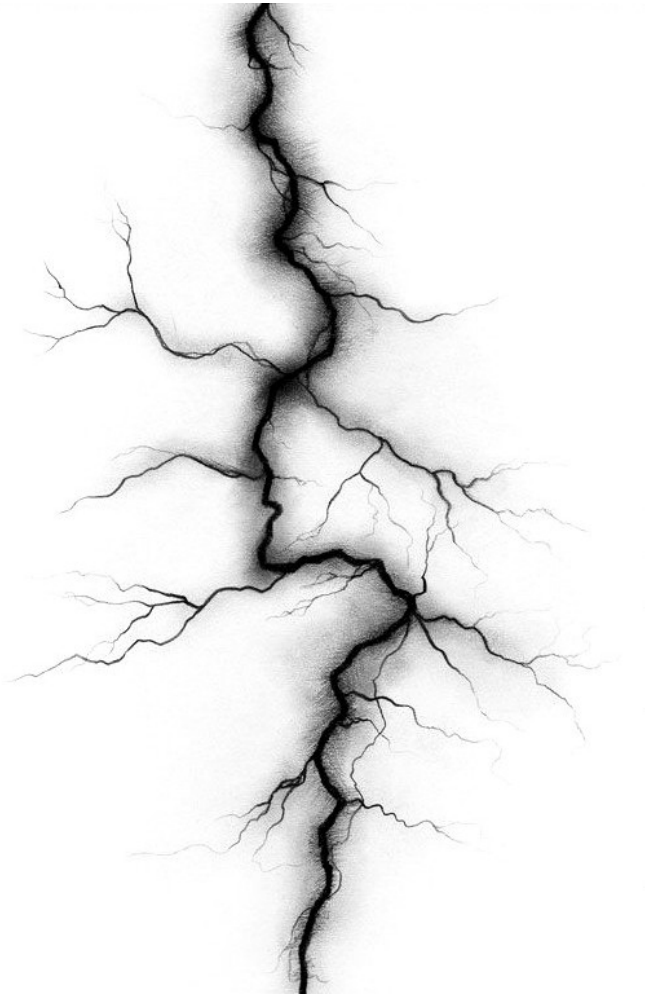

OpenMx

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]

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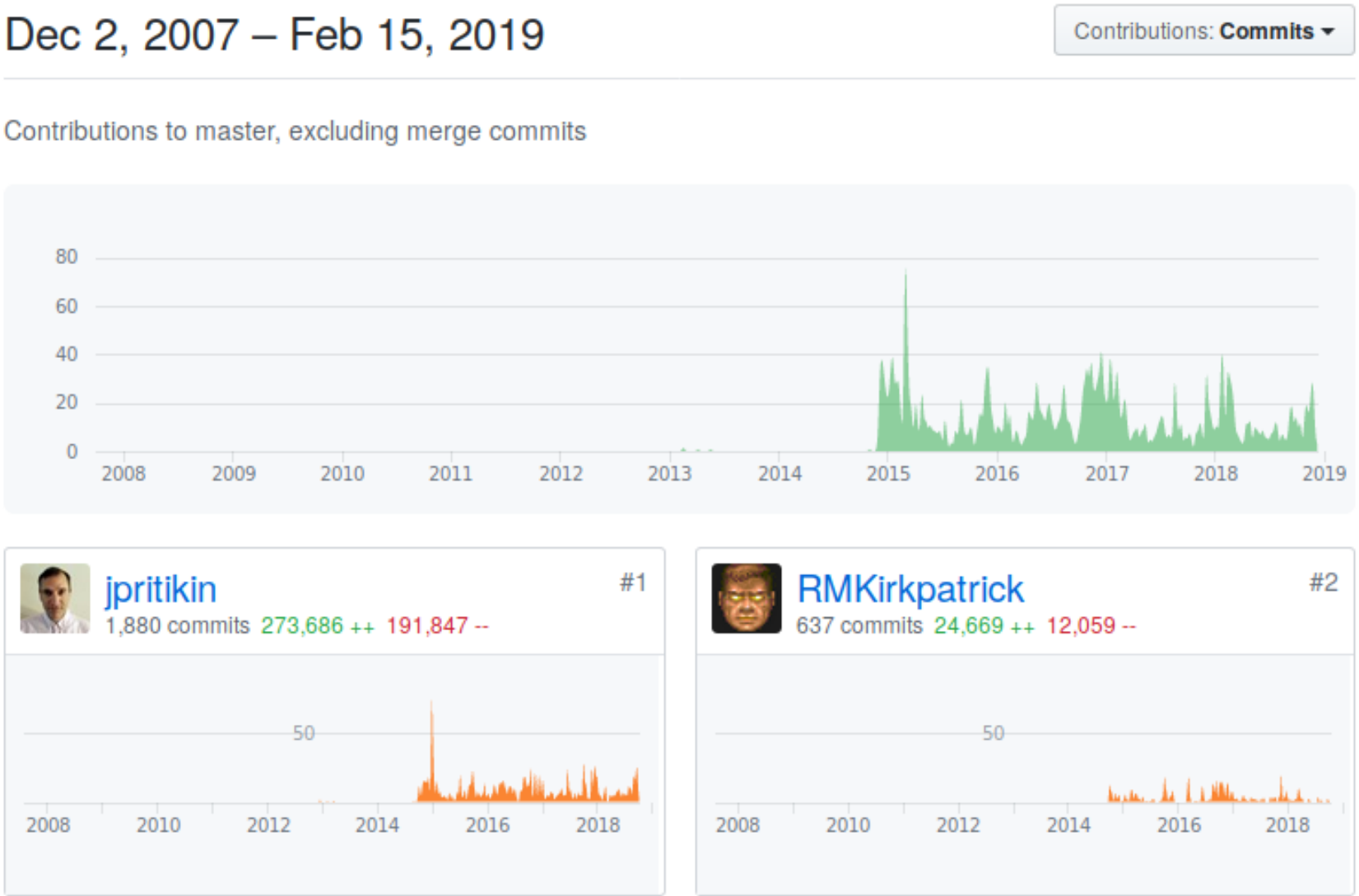
[2] Pritikin (2017a); Pritikin and Schmidt (2016); Pritikin, Hunter, and Boker (2015); Pritikin (2016)

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

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

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

7 years, 250k LOC



Potential student projects

Some ideas:

- Automatic conversion to Bayesian
- Copula for diverse link functions
- Analogue of quantile regression

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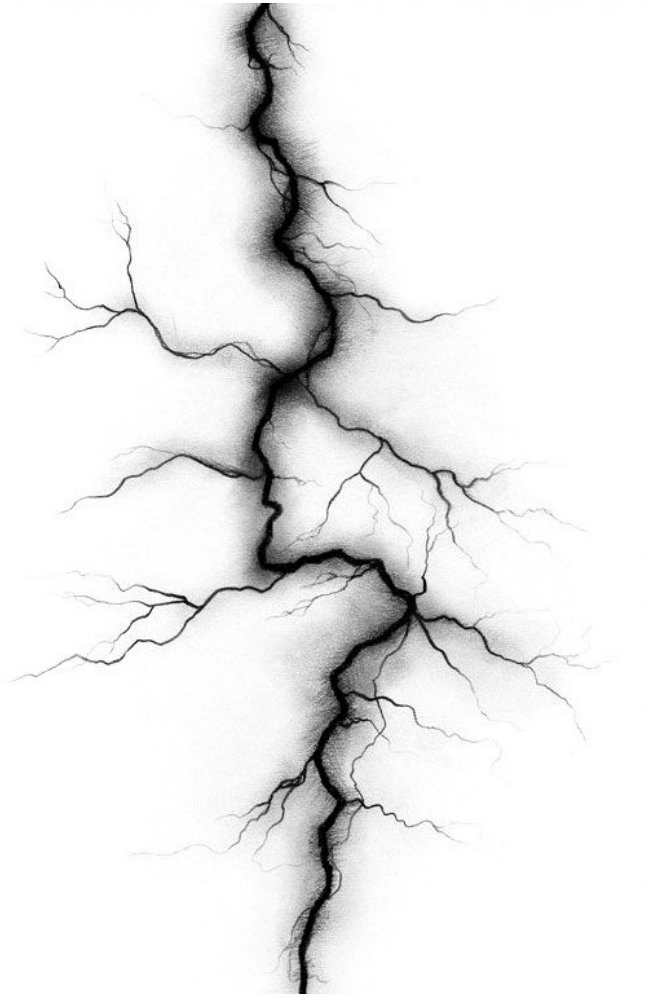


Corticol thickness[6]

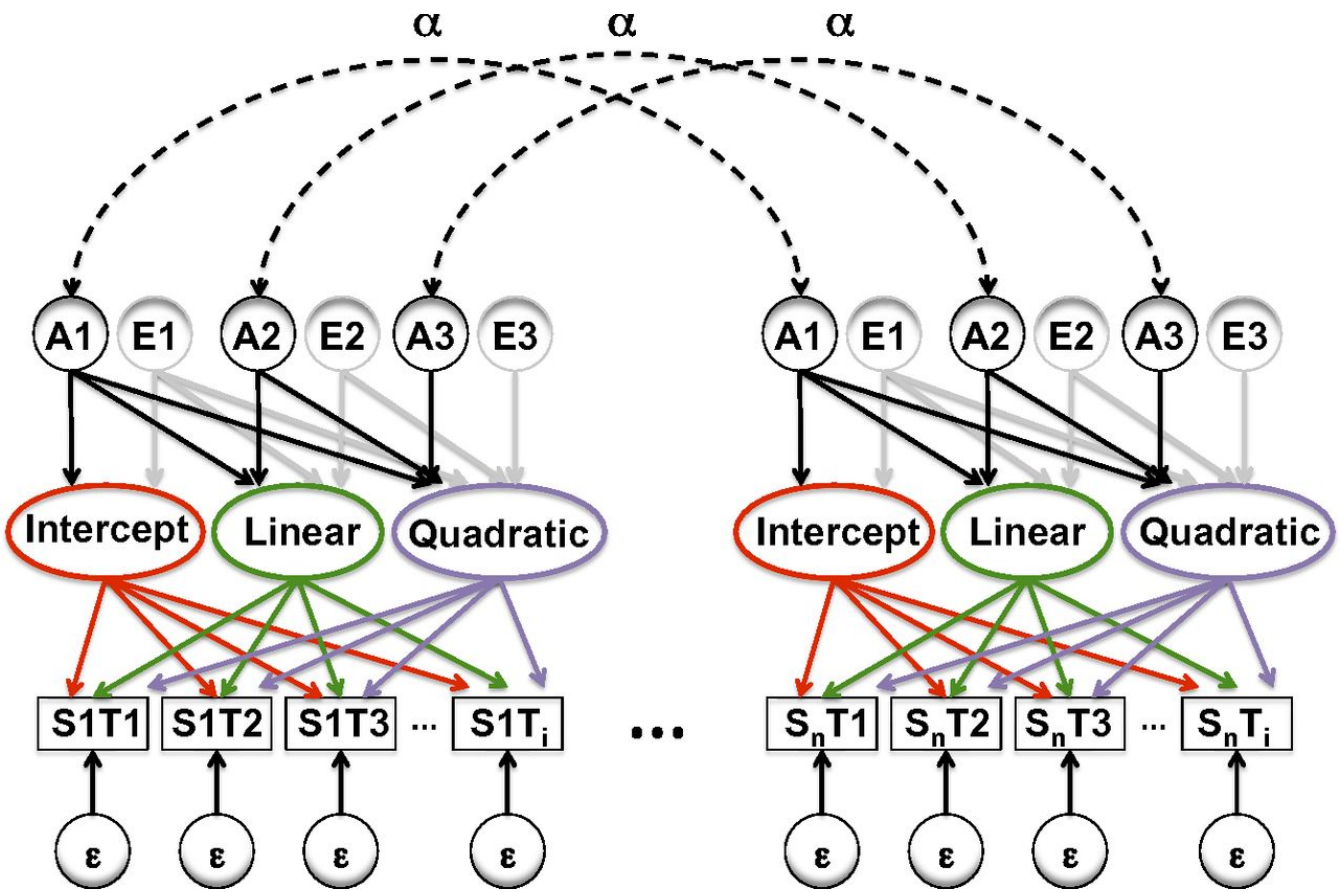
Application of OpenMx

Recently evolved phenotypes exhibits variability

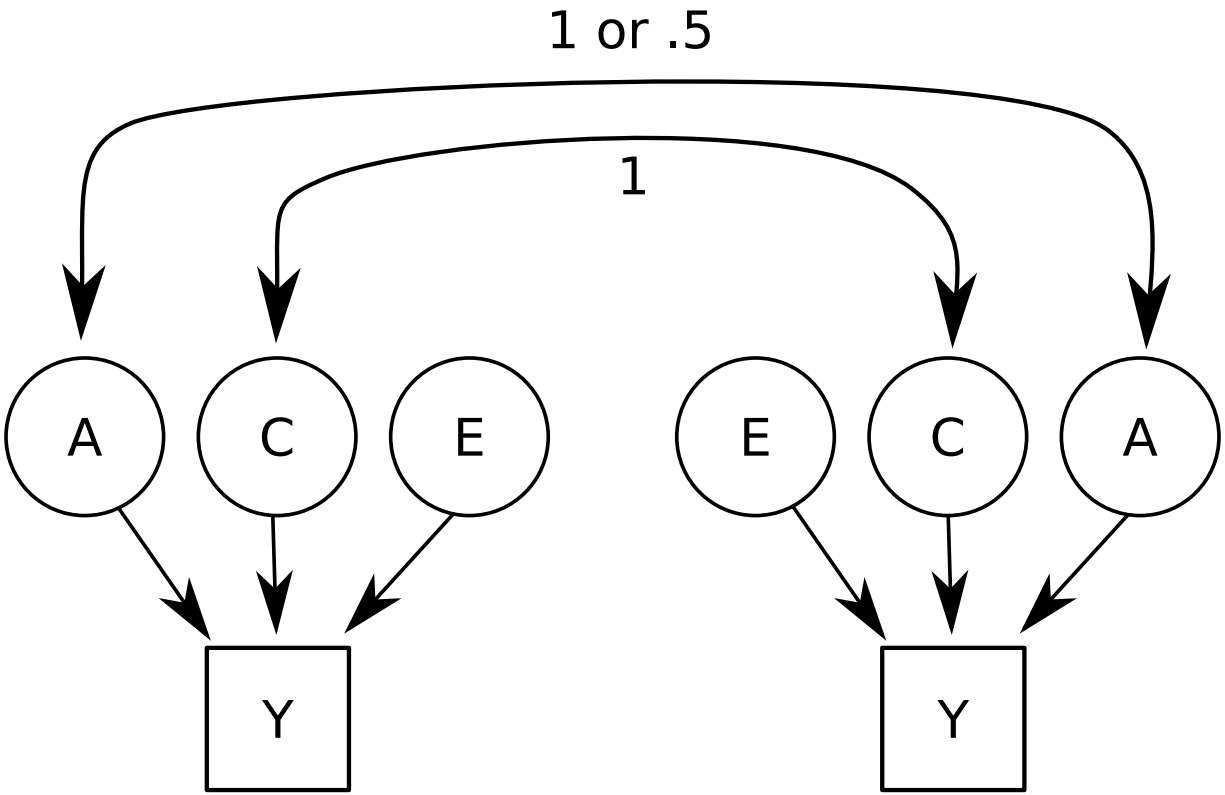
- 410 families
- 792 normally developing children, adolescents, and young adults
- Up to 8 MRI scans performed per individual
- Mean interval between scans was 2.4 yrs
- 1,748 MRI datasets acquired

[6] Schmitt et al. (2014)

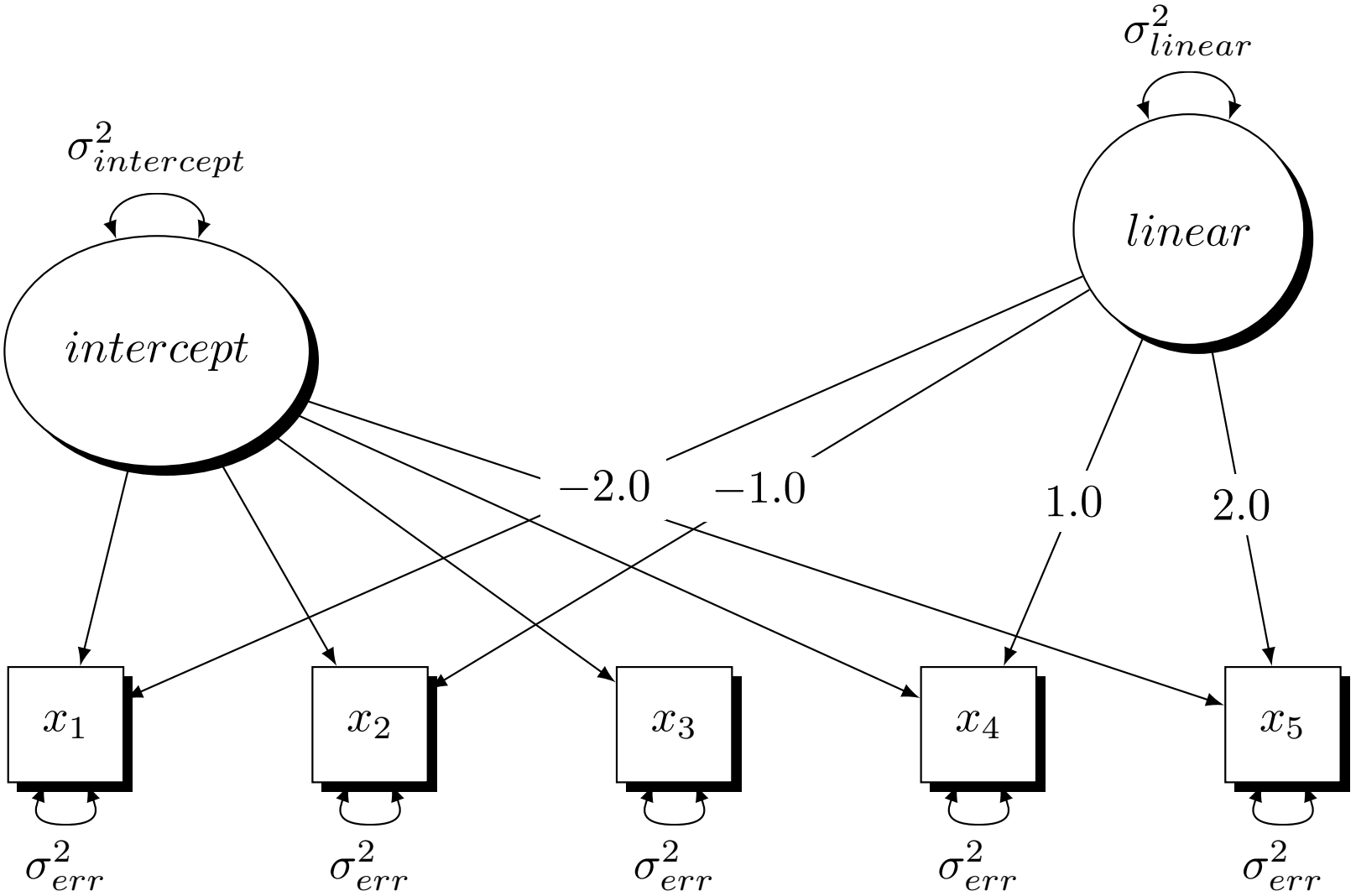
Genetically informative latent growth curve model



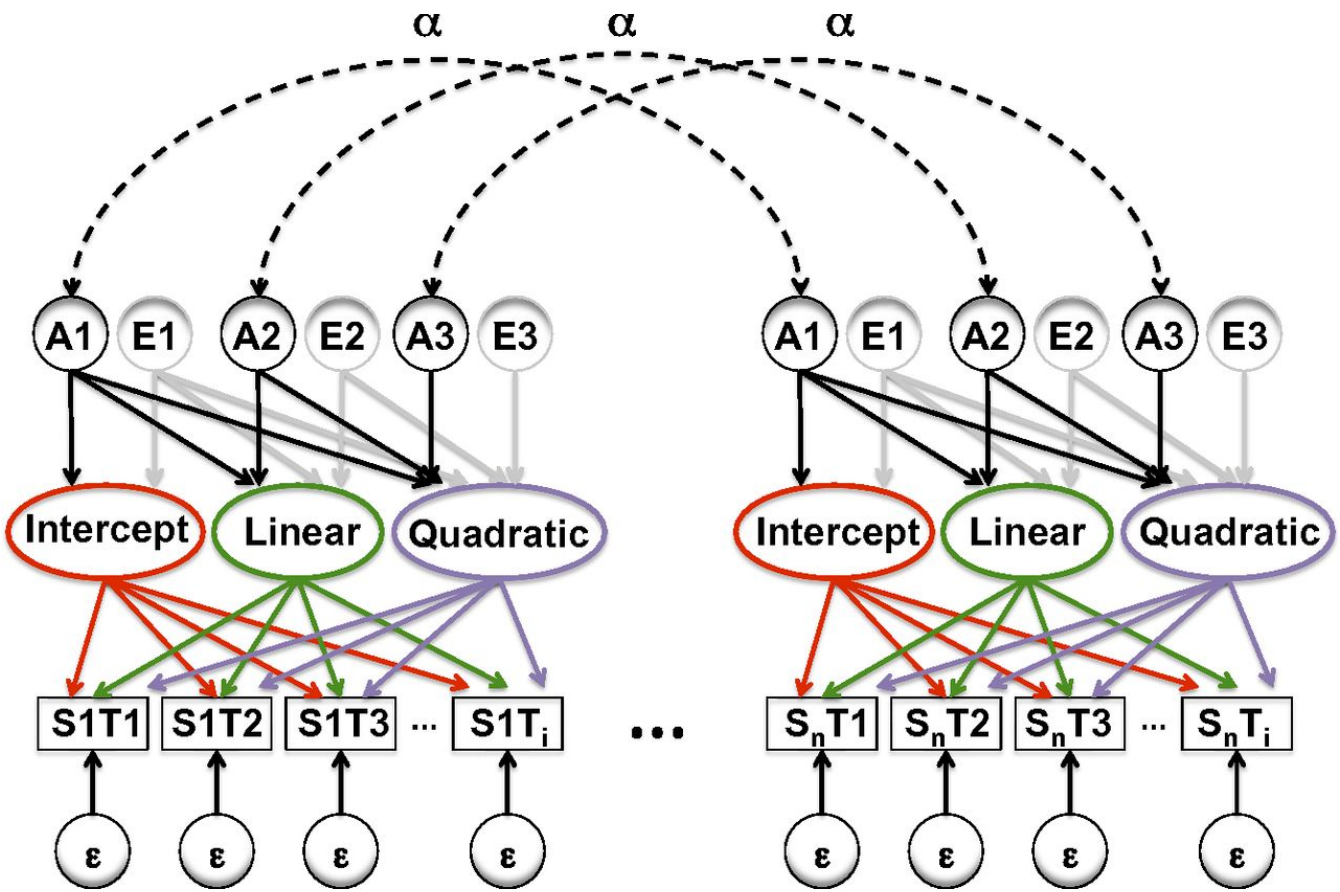
Univariate twin model



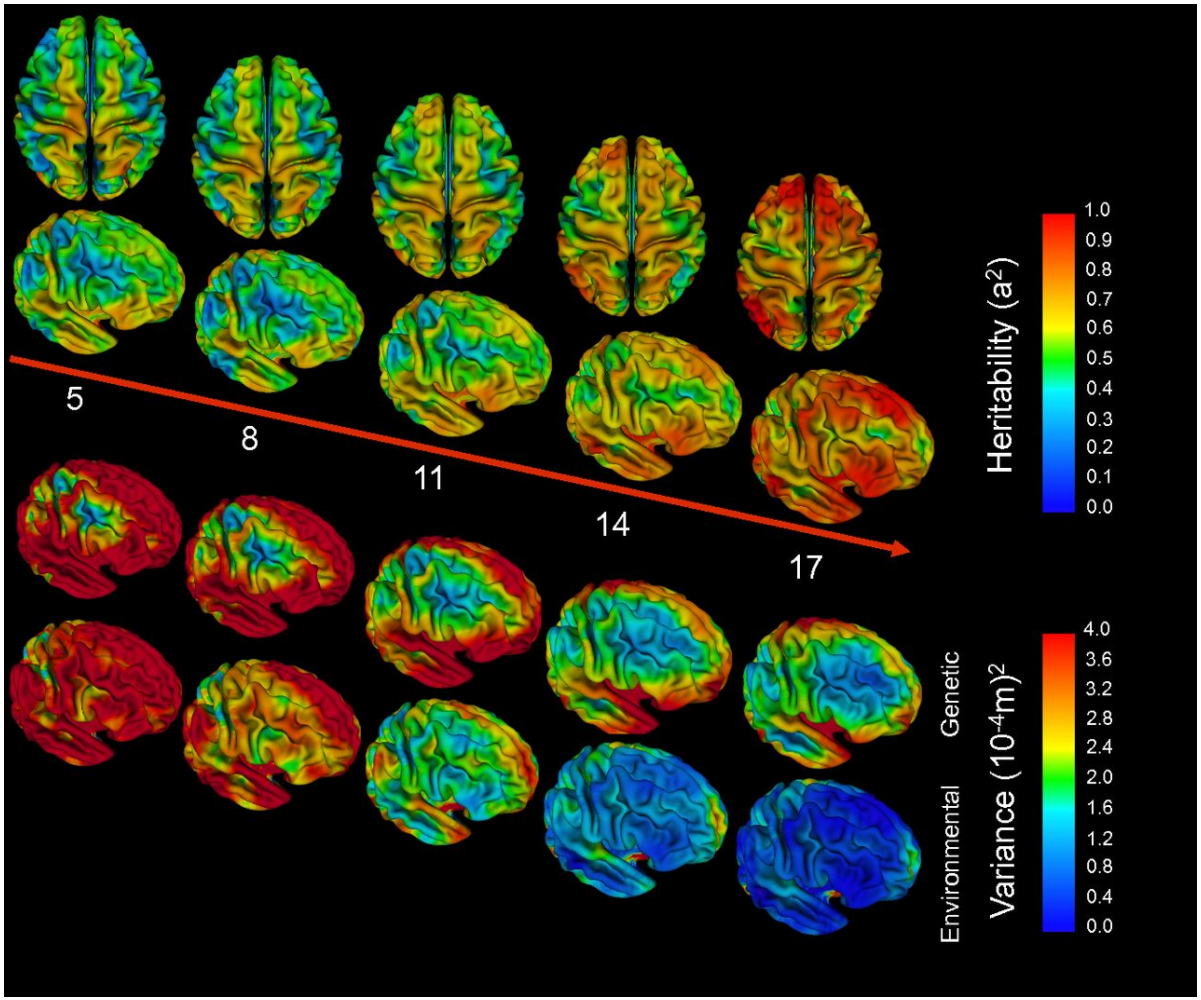
Latent growth curve



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
Genetic
Environmental
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

[7] Schmitt et al. (2014)
[8] Pritikin, Schmitt, and Neale (in press)

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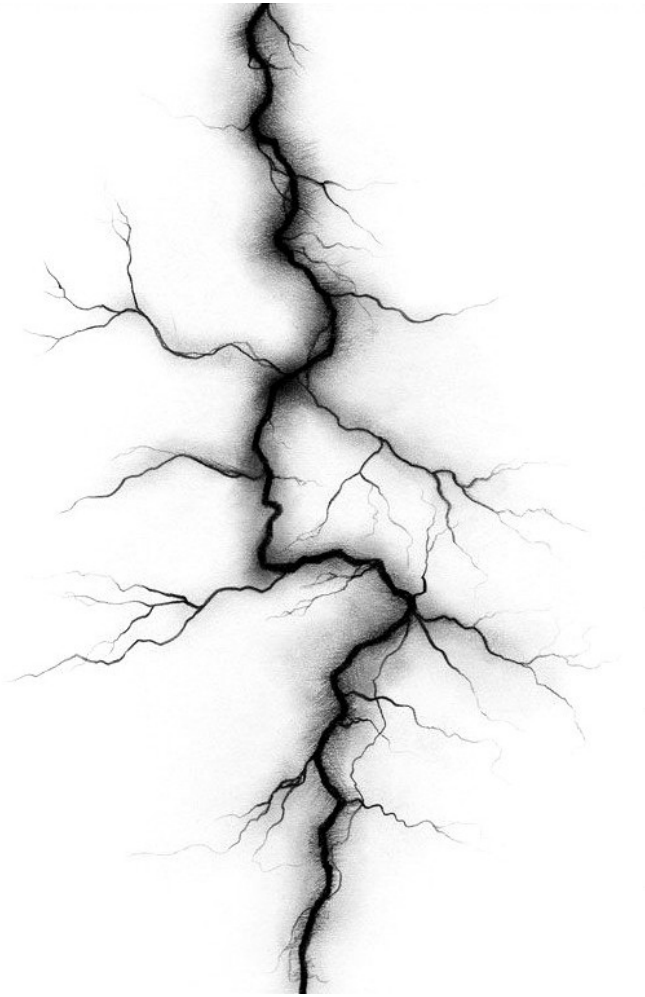


Confidential analyses

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)

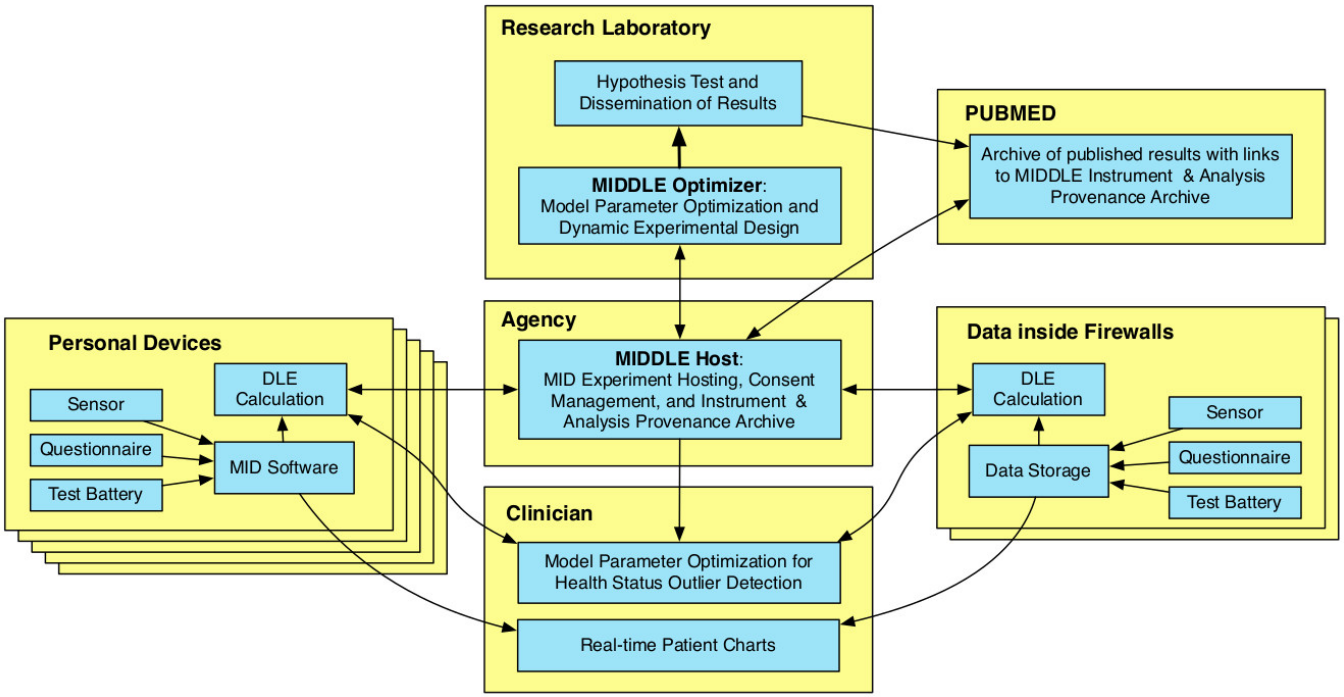
$$\begin{aligned}\sum_{i=1}^{I} \log L(x_i|\theta) = &\log L(x_1|\theta) \\ &\log L(x_2|\theta)+ \\ &\log L(x_3|\theta)+ \\ &\log L(x_4|\theta)+ \\ &\cdots + \\ &\log L(x_I|\theta) \end{aligned} \tag{4}$$

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[9]

Apply to federal health agencies for funding

[9] Boker et al. (2015)

Potential student projects

Some ideas:

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

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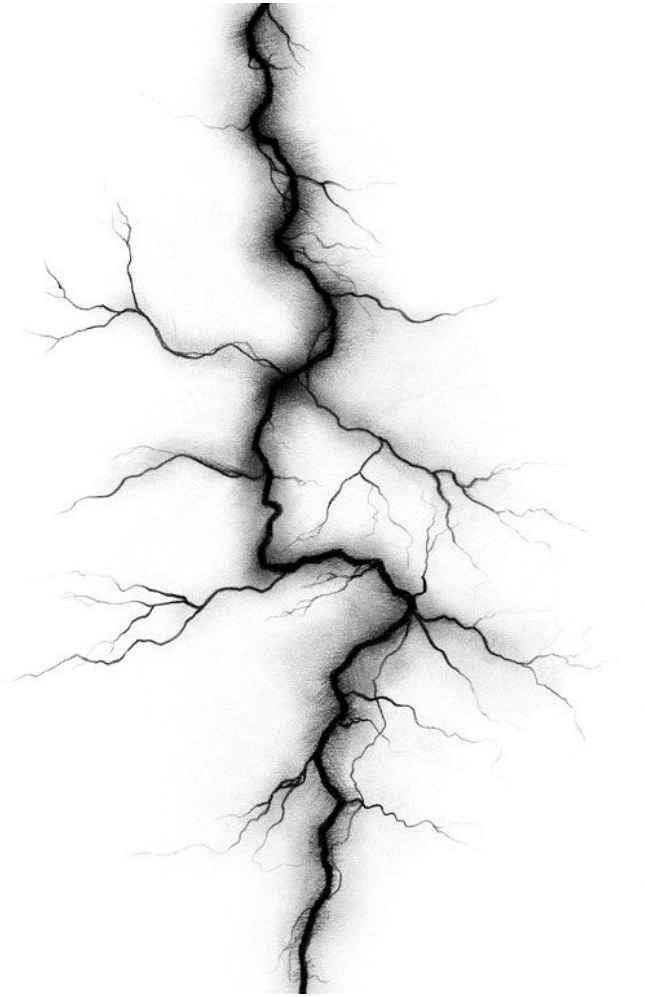
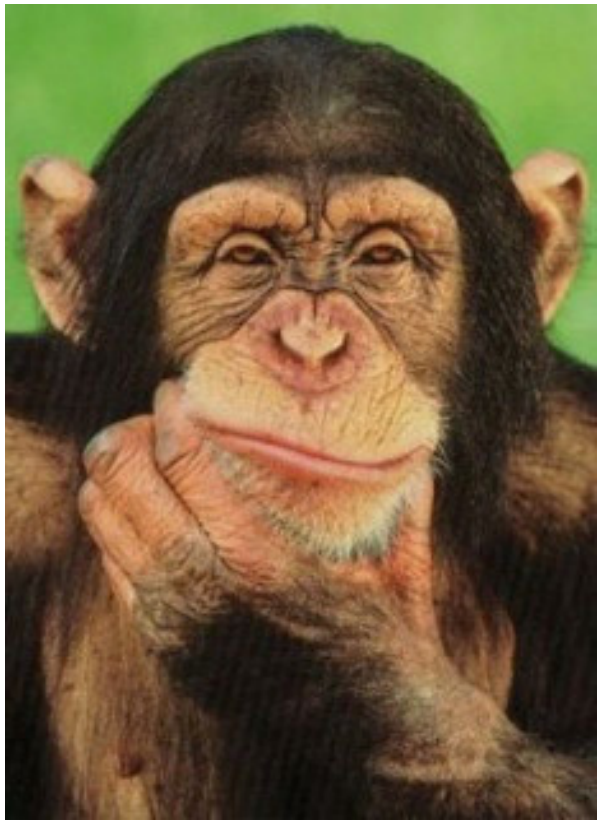


History of sophisticated thinking

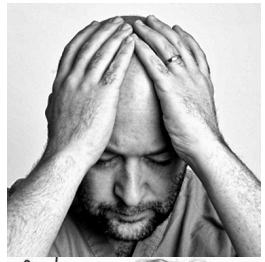
Recent evolution

- 1-1.8 MYO – Cooking[10]
- 200k-100k BCE – Homo sapiens
- 3400-3100 BCE – Written language
- 1500-200 BCE – Sophisticated thinking



[10] Wrangham (2009)

Ouch

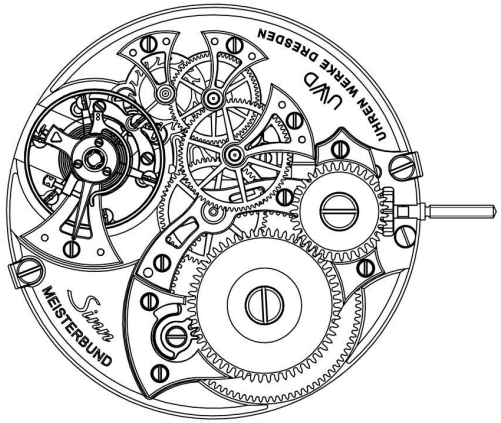


Conscious thinking has costs[11]

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

[11] Leary (2007)

Solutions



Think better (e.g., cognitive behavioral therapy[12])

Temporarily cease thinking (to some extent)

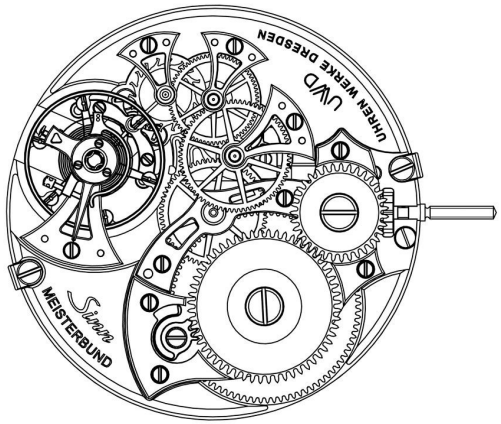
- Selflessness (i.e., dissolution of the self non-self boundary)
- Timelessness
- Effortlessness (i.e., spontaneous or involuntary)

In part due to hypofrontality[13]

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

[13] Dietrich (2003)

Solutions



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[12] Butler et al. (2006)
[13] 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[14]

Excludes: dreaming, daydreaming, hypnosis

[14] Pollan (2018)

Big challenges

Tricky to induce in the lab

Ephemeral

In prior work,
difficulty of conducting research
has been often underestimated

Big challenges

. . . and it's gone

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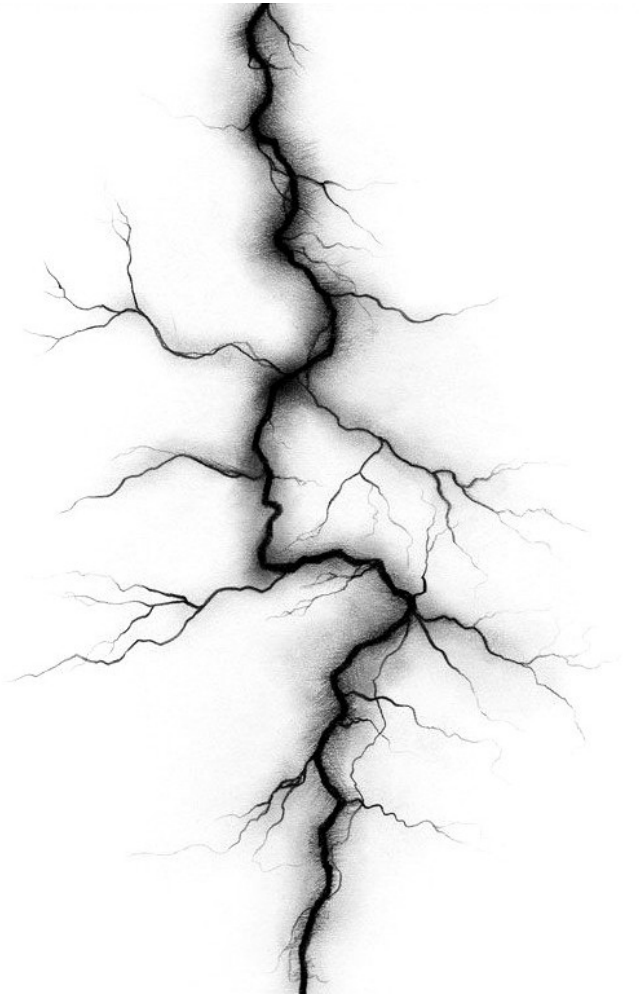


Optimal performance

Flow involves[15]

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

Contexts:

- Running[16]
- Jazz improvisation[17]
- Etc. . .

[15] Keller and Landhäußer (2012)
[16] Csikszentmihalyi, Latter, and Duranso (2017)
[17] Limb and Braun (2008)

Exploratory survey

Personal factors

- Psychological[18]
- Physiological[19]
- Neurological[20]

What about situational factors?

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

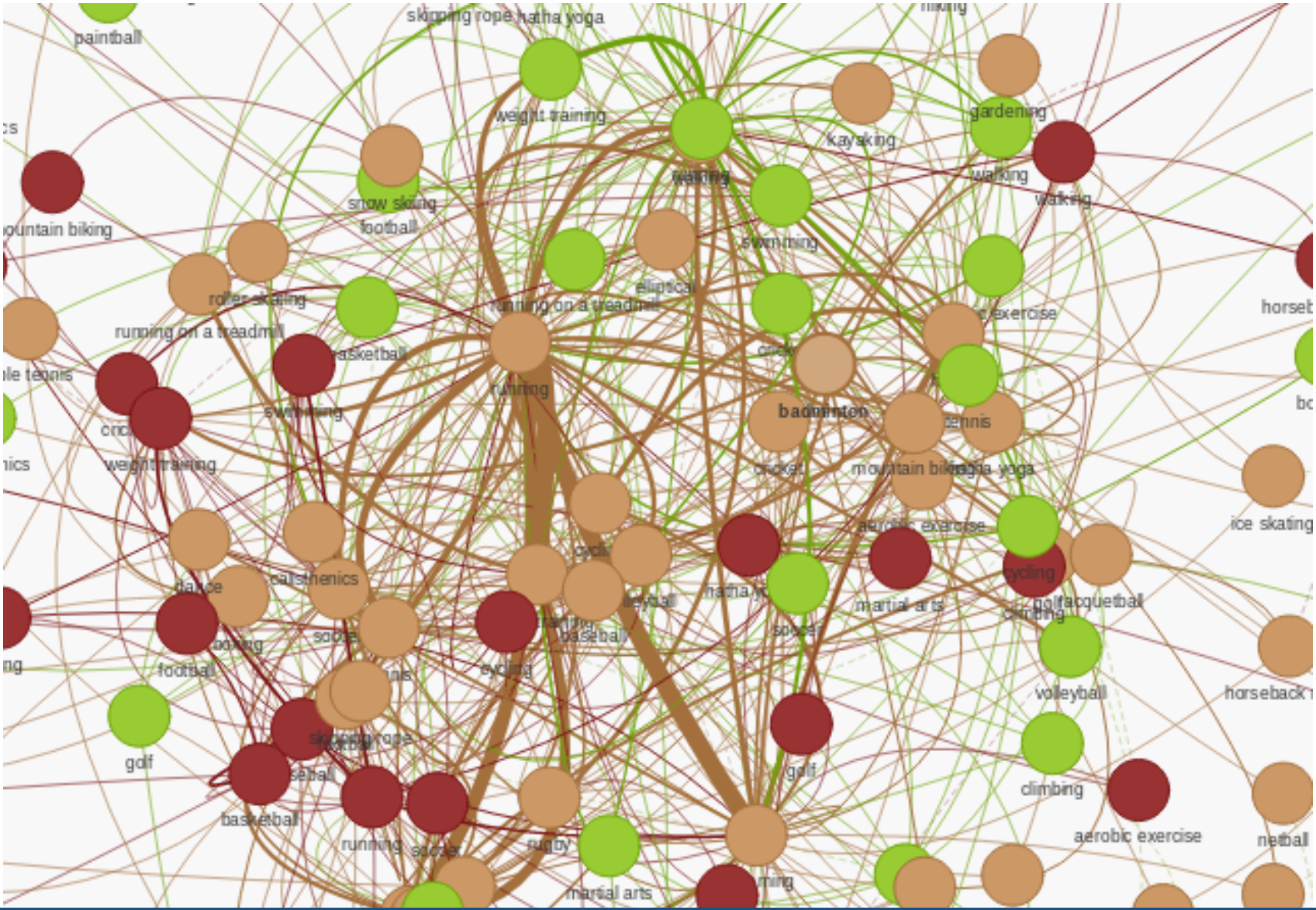
How predictable is the action?

- 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 item inspired by prior research on flow[21]

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

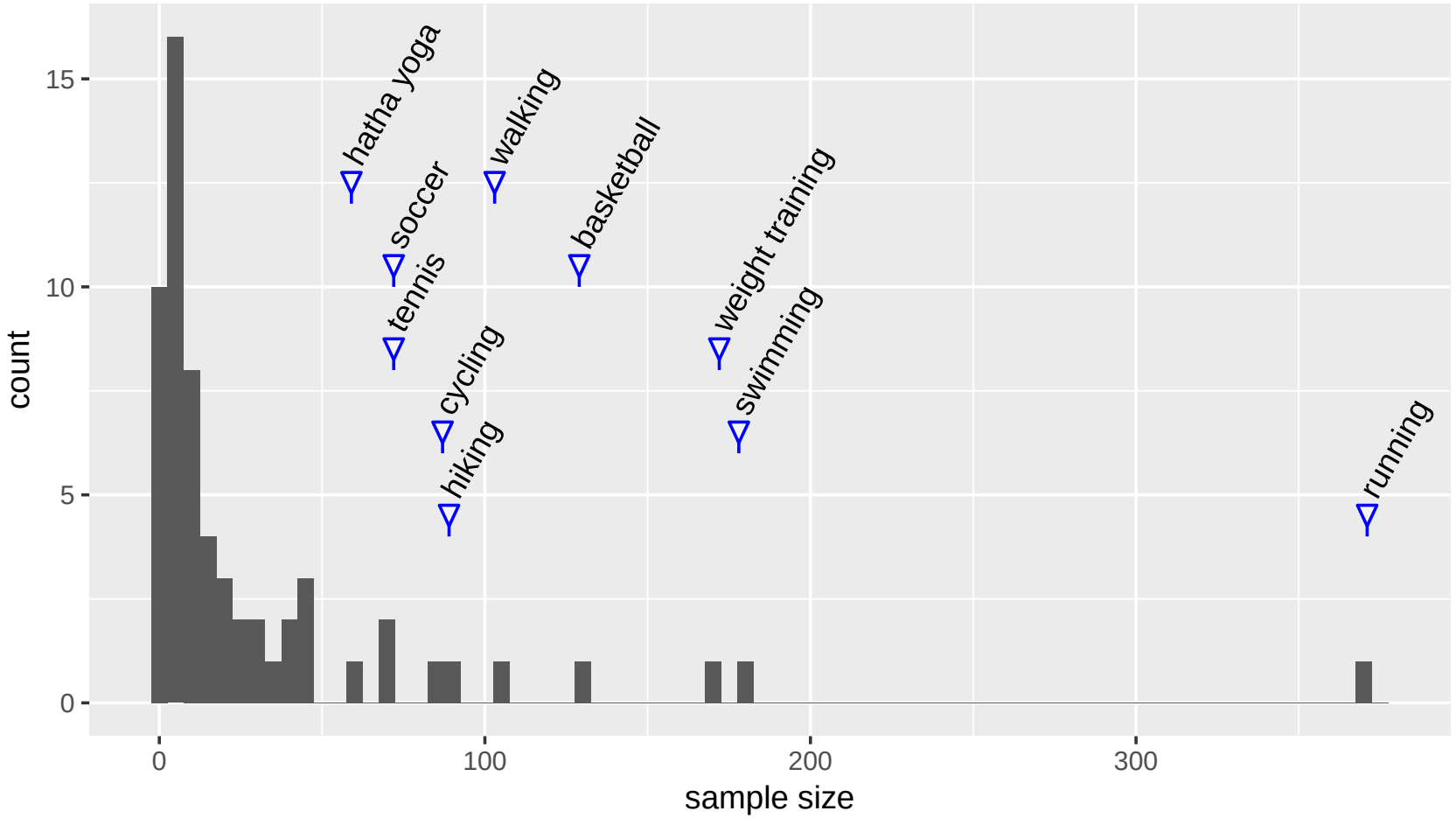
Lots of comparisons



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%)

Sample size distribution



Saturated model, data and parameters

$$i = 1 \dots I \quad \text{indexes participants} \tag{5}$$
$$j = 1 \dots J \quad \text{indexes items} \tag{6}$$
$$k = 1 \dots K \quad \text{indexes physical activities} \tag{7}$$
$$y_{ij} | k_a, k_b \quad k_a \text{ vs } k_b \text{ by person } i \text{ on item } j \tag{8}$$

$$\tau_1, \tau_2 \quad \text{category thresholds} \tag{9}$$
$$\theta_{kj} \quad \text{activity } k\text{'s score on item } j \tag{10}$$
$$\sigma_j \quad \text{standard deviation for item } j \tag{11}$$
$$\Sigma_{j \times j} \quad \text{item correlation matrix (lower Cholesky factor)} \tag{12}$$

Saturated model, priors and likelihood

$$\Sigma \sim \text{lkj}(2) \tag{13}$$

$$\log \sigma_j \sim \mathcal{N}(0, 1) \tag{14}$$

$$\theta \sim \sigma \cdot \Sigma \, \mathcal{N}(0, 1) \tag{15}$$

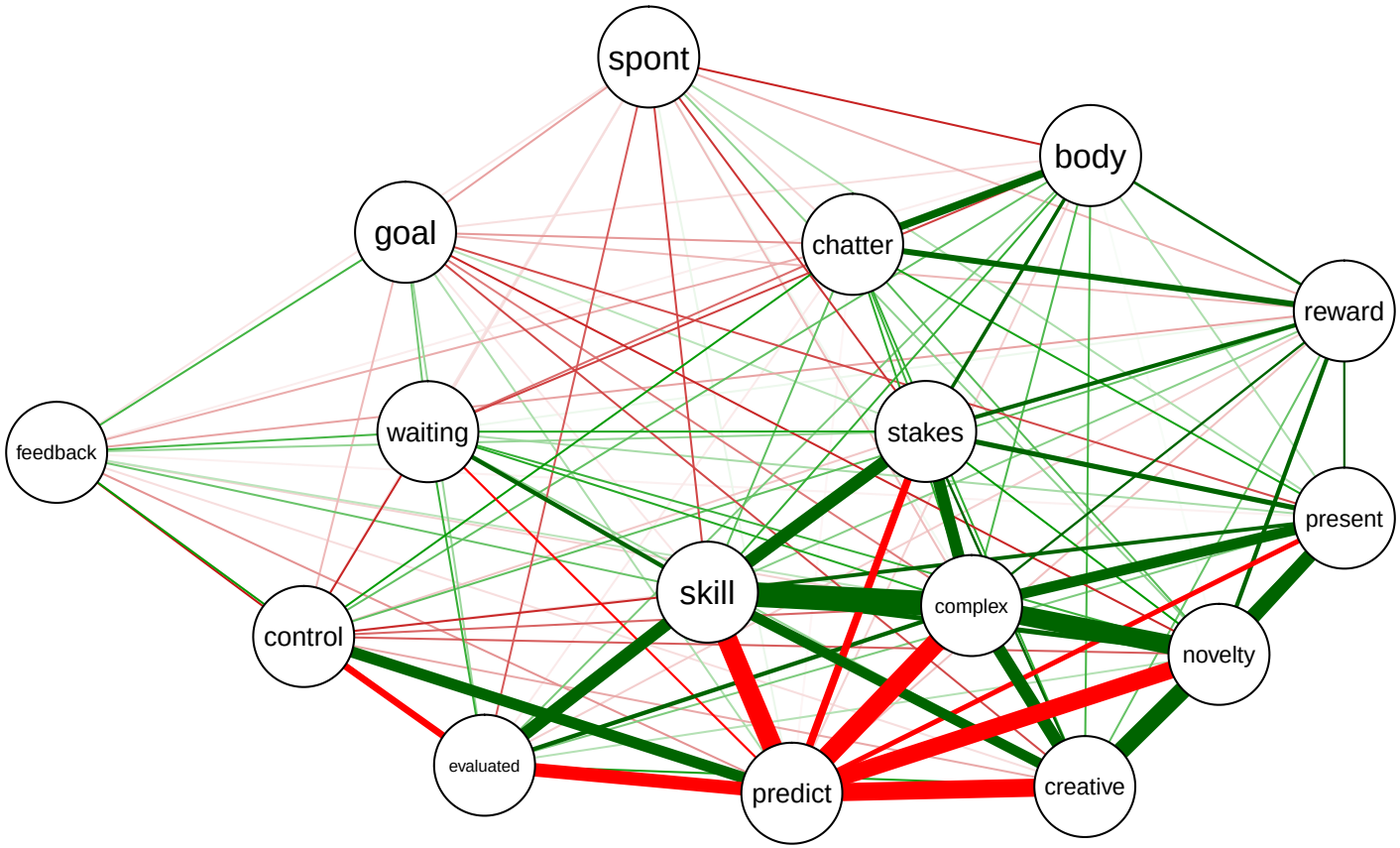
$$\tau_1, \tau_2 \sim \mathcal{N}(0, 5) \tag{16}$$

$$\text{logit}\left[\Pr(y_{ij}|k_a, k_b)\right] = \alpha\left[\theta_{k_a} - \theta_{k_b} + f(y_{ij})\right] \tag{17}$$

$$\text{where } \alpha \equiv (\bar{\sigma}^2)^3 \tag{18}$$

$$\text{and } f(r) \equiv \begin{cases} -(\tau_1 + \tau_2) & r = \text{much less} \\ -\tau_1 & r = \text{somewhat less} \\ 0 & r = \text{equal} \\ \tau_1 & r = \text{somewhat more} \\ (\tau_1 + \tau_2) & r = \text{much more} \end{cases} \tag{19}$$

Correlation matrix



Weakly connected: goal, feedback, spontaneity (spont);
Wrong sign: control, evaluated, waiting

Factor model, data and parameters

$$i = 1 \ldots I \quad \text{indexes participants} \tag{20}$$
$$j = 1 \ldots J \quad \text{indexes items} \tag{21}$$
$$k = 1 \ldots K \quad \text{indexes physical activities} \tag{22}$$
$$y_{ij} | k_a, k_b \quad k_a \text{ vs } k_b \text{ by person } i \text{ on item } j \tag{23}$$

$$\tau_1, \tau_2 \quad \text{category thresholds} \tag{24}$$
$$\theta_{kj} \quad \text{activity } k\text{'s score on item } j \tag{25}$$
$$\sigma_j \quad \text{standard deviation for item } j \tag{26}$$
$$\lambda_j \quad \text{factor loading for item } j \tag{27}$$
$$\pi_k \quad \text{latent flow score for activity } k \tag{28}$$

Factor model, priors and likelihood

$$\log \sigma_j \sim \mathcal{N}(0, 1) \tag{29}$$

$$\theta_{kj} \sim \sigma_j \cdot \mathcal{N}(\pi_k \lambda_j, 1) \tag{30}$$

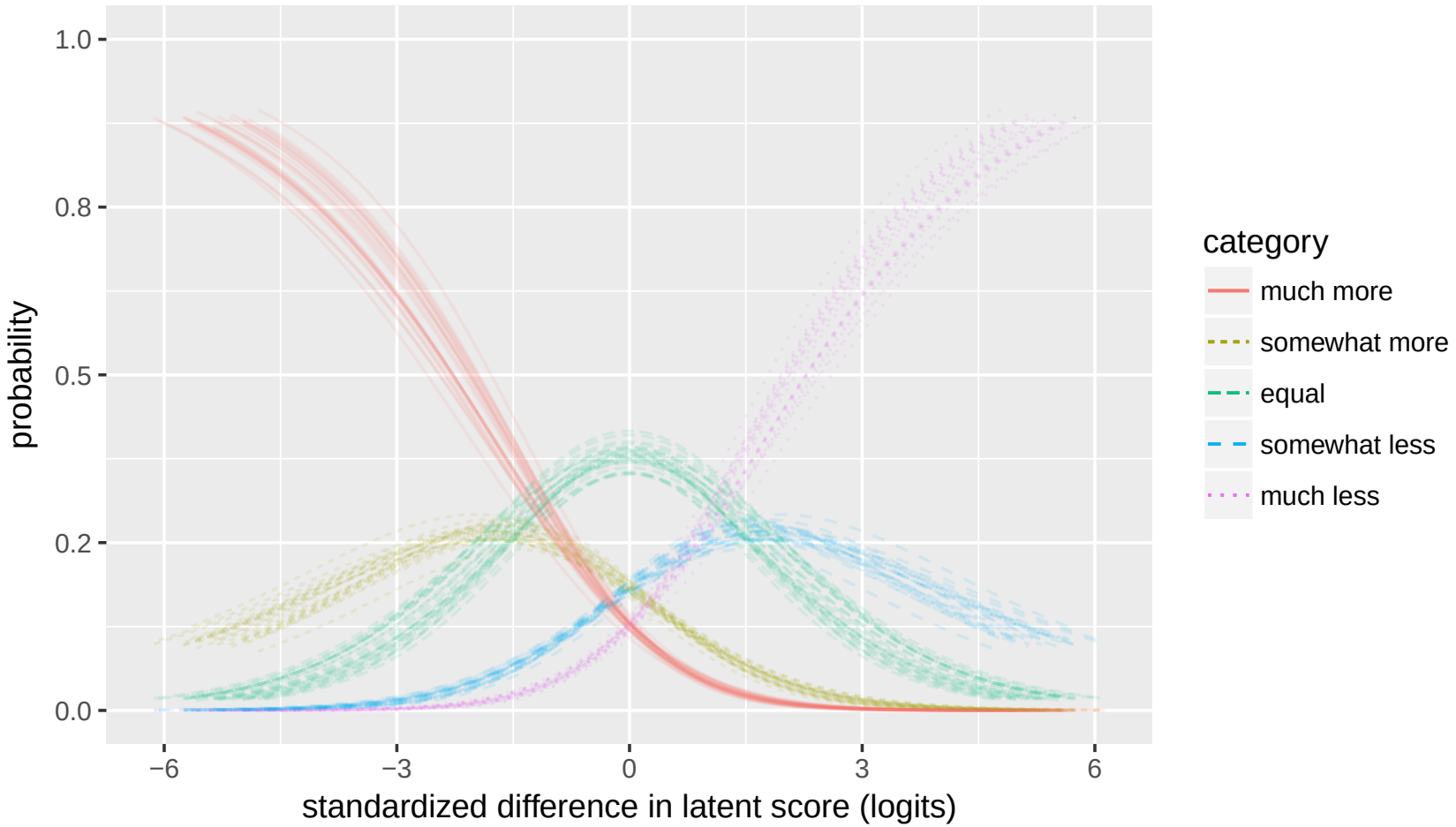
$$\tau_1, \tau_2 \sim \mathcal{N}(0, 5) \tag{31}$$

$$\text{logit}\left[\Pr(y_{ij}|k_a, k_b)\right] = \alpha\left[\theta_{k_a} - \theta_{k_b} + f(y_{ij})\right] \tag{32}$$

$$\text{where } \alpha \equiv \left[\frac{1}{J}\sum_{j=1}^{J}(1 + \lambda_j^2)\sigma_j^2\right]^3 \tag{33}$$

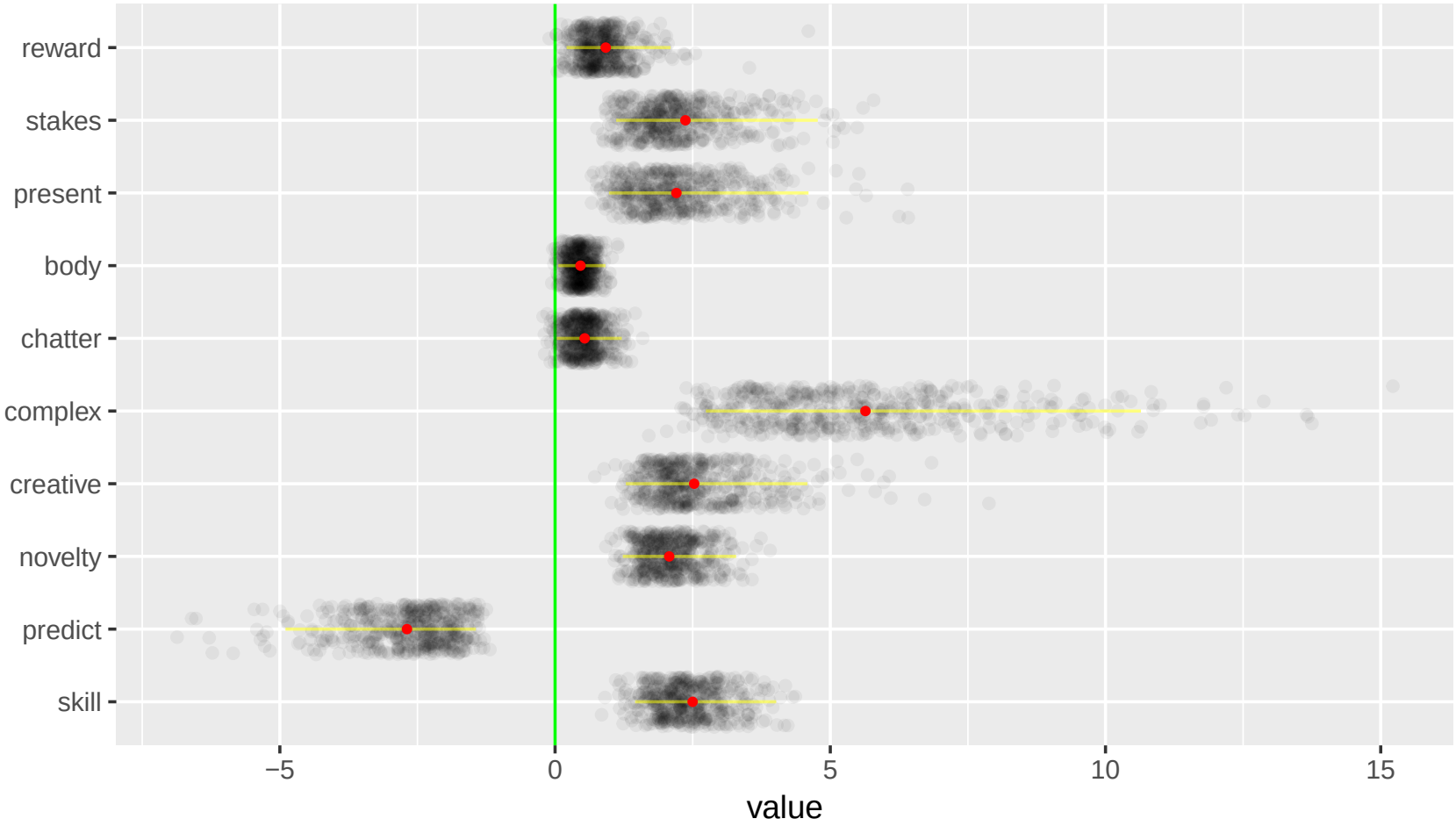
$$\text{and } f(y) \equiv \begin{cases} -(\tau_1 + \tau_2) & y = \text{much less} \\ -\tau_1 & y = \text{somewhat less} \\ 0 & y = \text{equal} \\ \tau_1 & y = \text{somewhat more} \\ (\tau_1 + \tau_2) & y = \text{much more} \end{cases} \tag{34}$$

Response curves



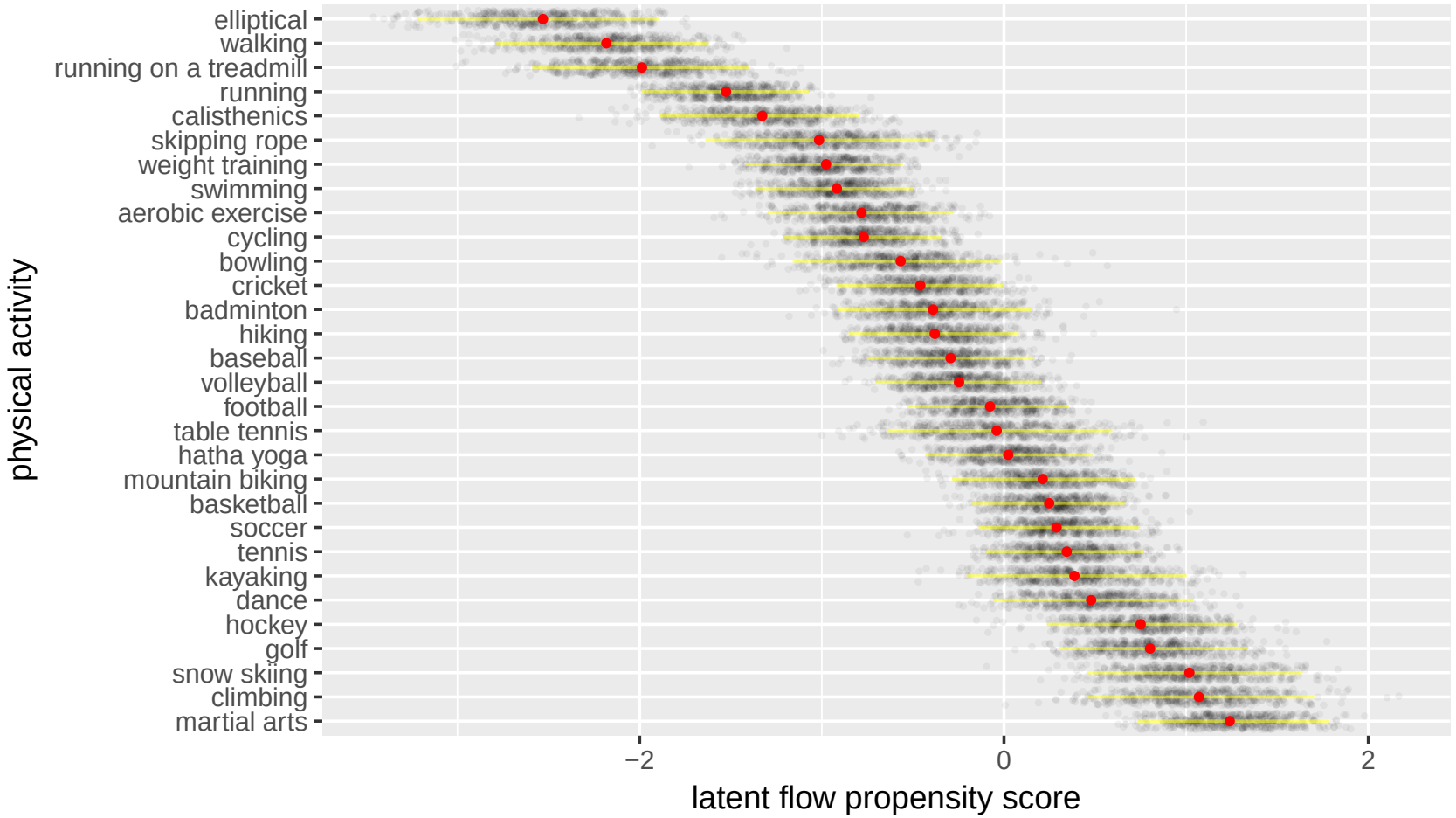
Response curves at 1.5

Posterior item loadings



Posterior flow propensity scores

For activities with a sample size > 10



Possible student projects

Some ideas:

- Get more data on high flow propensity areas (e.g., martial arts)
- Manipulate "stationary" cycling environment using virtual reality
- Check measurement invariance in a new sample. Does the item correlation structure generalize?

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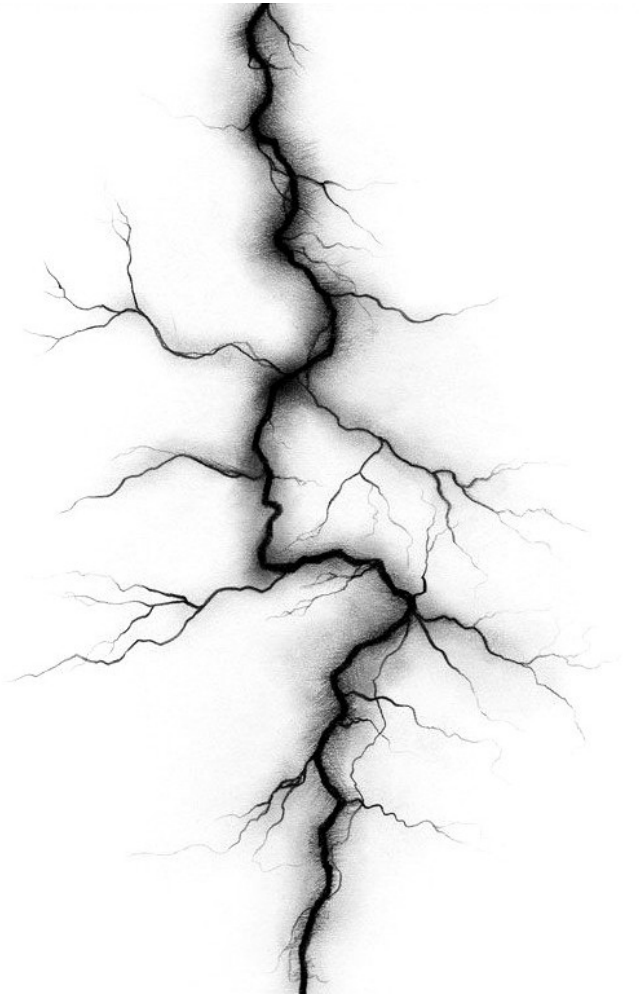
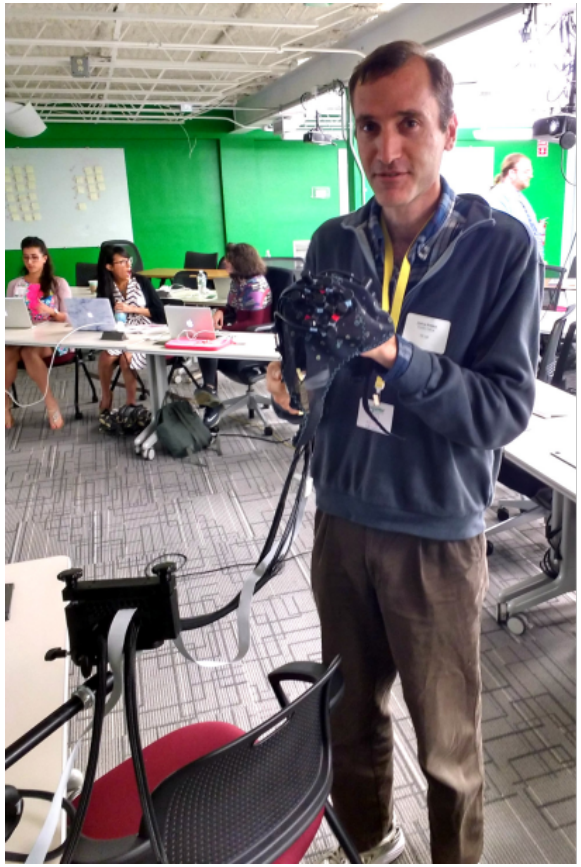
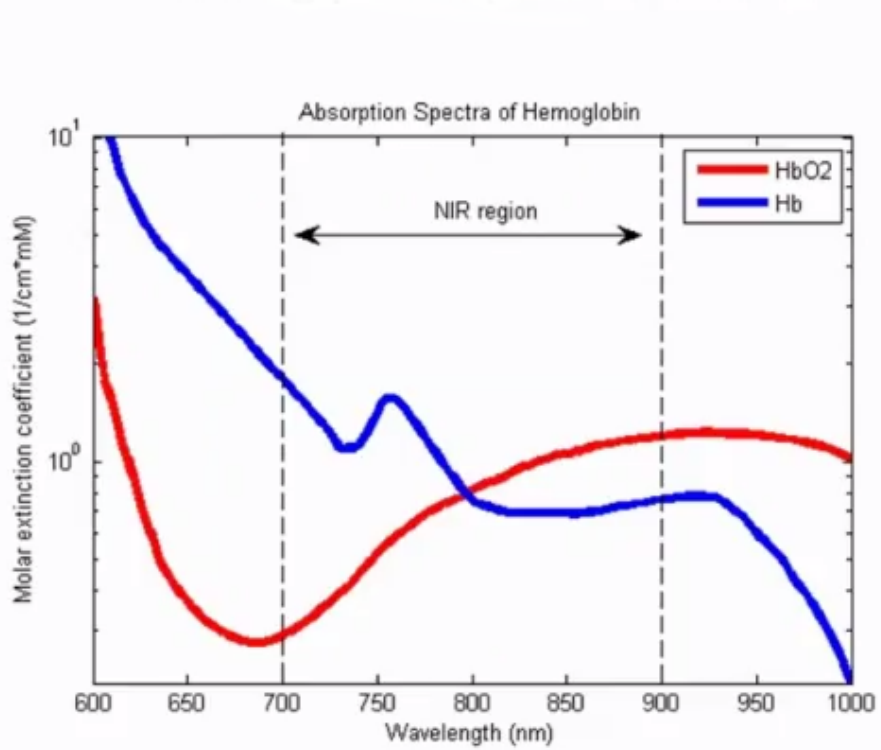


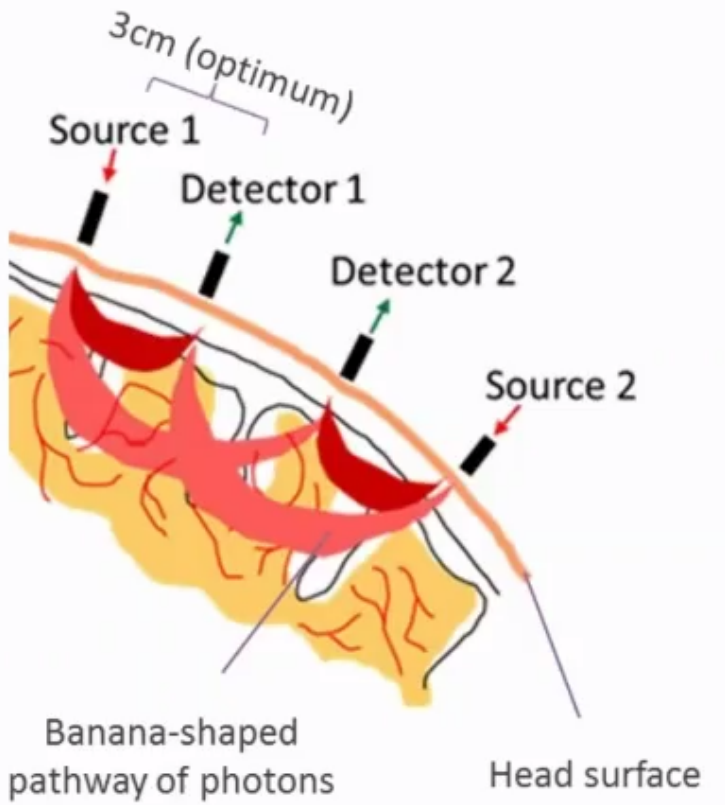
2017 fNIRS Workshop at Kingston, RI



Working principles of NIRS



Absorption spectra of Hb



NIRS compared to MRI

Both measure the blood oxygen level-dependent (BOLD) response[22]

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

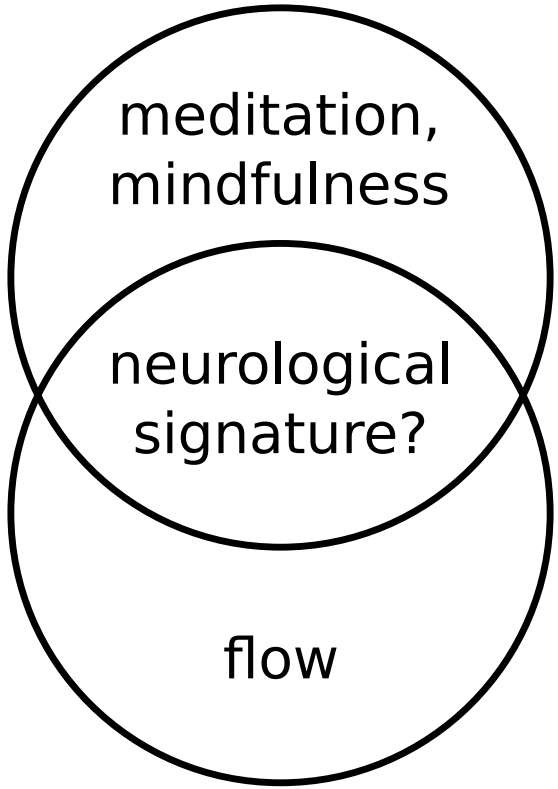
(Table from Min, Marzelli, & Yoo, 2010)

New tech on the horizon (2 μm^3 spatial resolution)[23]

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

[23] `https://www.openwater.cc`

Triangulate



Flow inductions

Tetris, pong[24]

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

Wim Hof method

Simple method:

- Cold exposure
- Breathing
- Commitment

Clear physiological correlates[25]

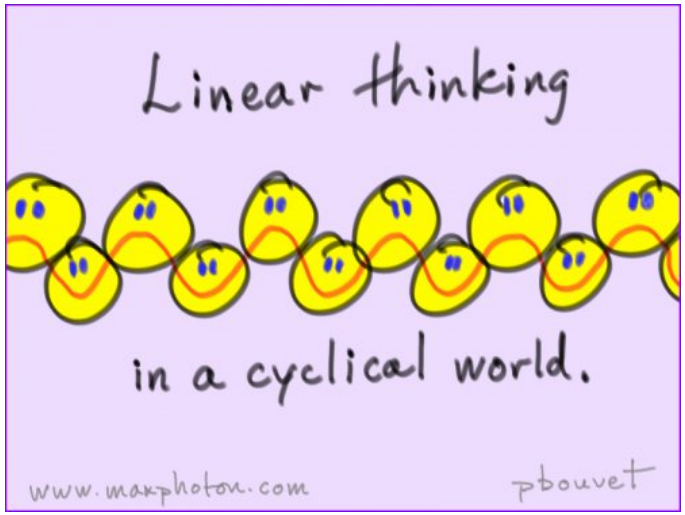
[25] Kox et al. (2014); Muzik, Reilly, and Diwadkar (2018)

Data analysis challenge

Multivariate, multilevel time series data

Possible approaches:

- Windowed cross correlation
- Autoregressive models
- State space models
- Dynamic connectivity[26]
- Novel methods[27]



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

Next steps

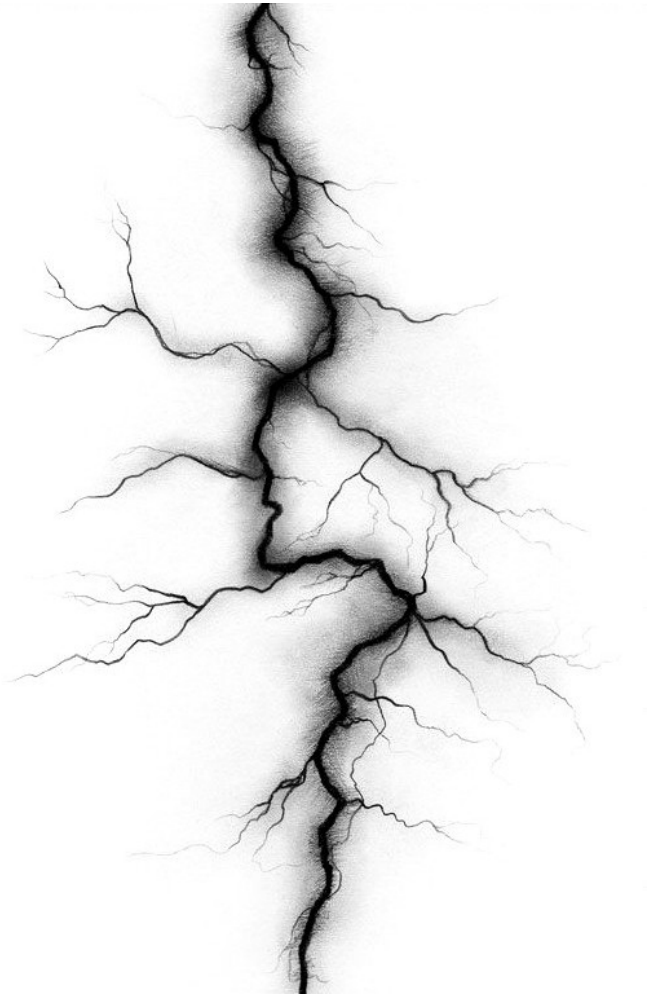
With Co-PI Tim Brick,
assistant professor at Penn State Univ

Apply for a grant from

- John Templeton Foundation
- The Mind and Life Institute

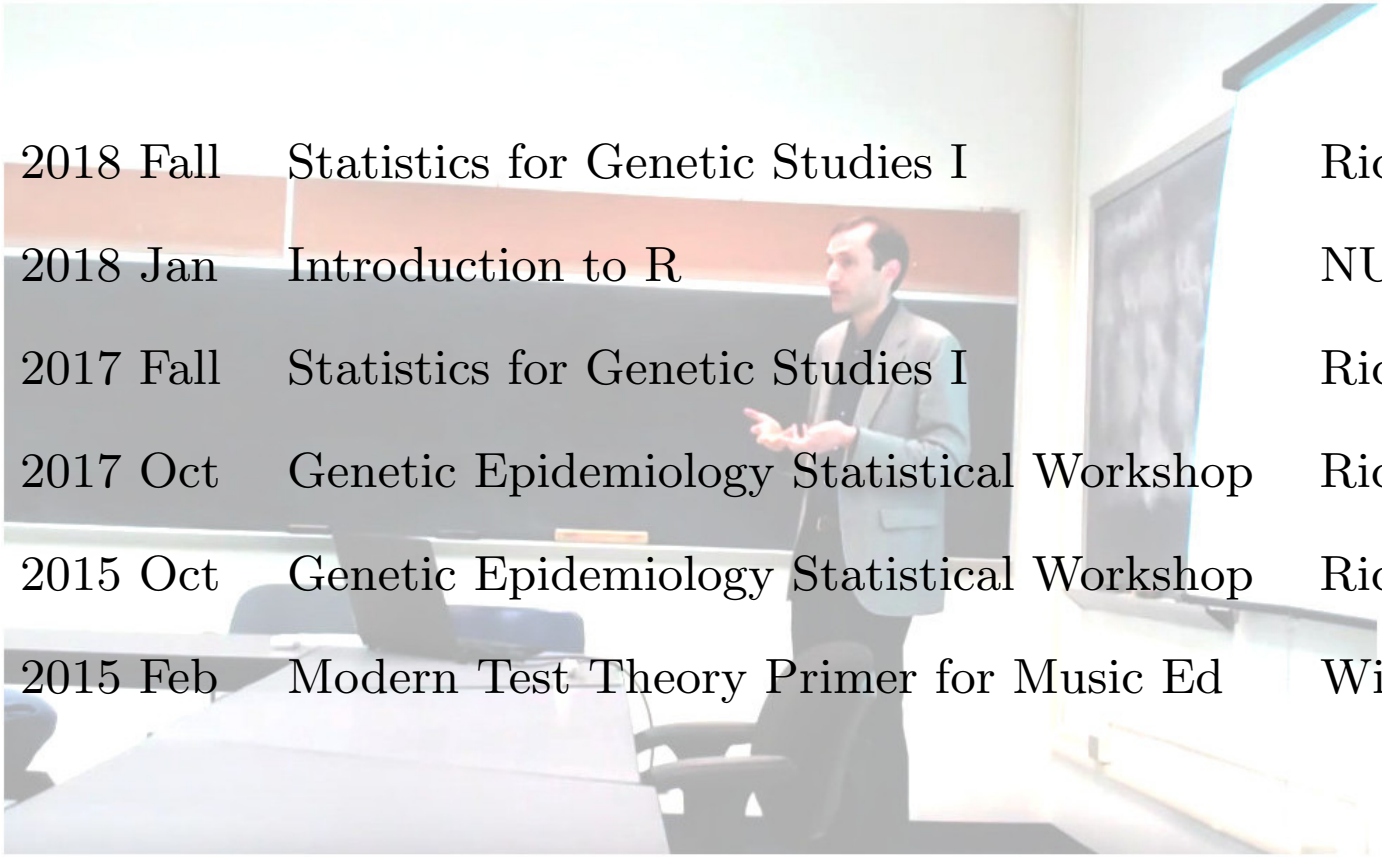
Agenda

- OpenMx
- Heritability of cortical thickness
- Confidential analyses
- Substantive foray
- Flow & physical activities
- Neuroimaging (*if time permits*)
- Teaching



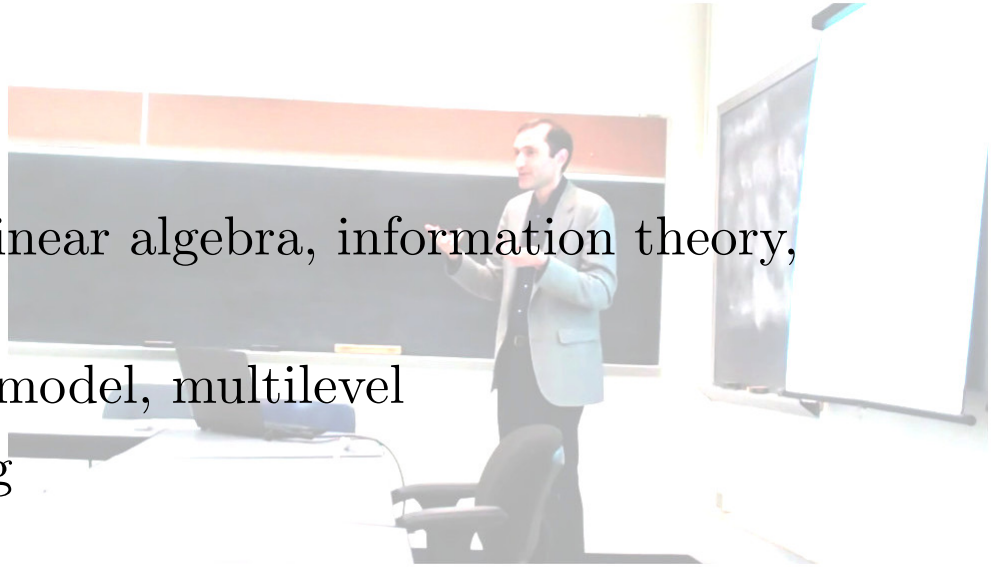
Some experience

Lectures given (1-9 hrs each course)



2018 Fall	Statistics for Genetic Studies I	Richmond, VA
2018 Jan	Introduction to R	NUS, Singapore
2017 Fall	Statistics for Genetic Studies I	Richmond, VA
2017 Oct	Genetic Epidemiology Statistical Workshop	Richmond, VA
2015 Oct	Genetic Epidemiology Statistical Workshop	Richmond, VA
2015 Feb	Modern Test Theory Primer for Music Ed	Williamsburg, VA

Prepared to teach



- Mathematical foundations (linear algebra, information theory, probability)
- Regression, ANOVA, mixed model, multilevel
- Structural equation modeling
- Bayesian methods
- Machine learning
- Measurement (Item Response Theory)
- Dynamical systems (state space models)
- Scientific practice for open science and reproducibility

Philosophy and style

Computer programming is a core skill[28]

- Statistical analysis is becoming more programming oriented (e.g. OpenMx, Stan)
- Reproducibility; Avoid copy & paste of results
- Can make easier to learn[29]

Humans can feel intimidated by me

- Psychological safety "being able to show and employ one's self without fear of negative consequences of self-image, status or career"[30]
- Humor

[28] Falk and Pritikin (2018)
[29] Pritikin and Schmidt (2016)
[30] Kahn 1990, p. 708

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One of my idols

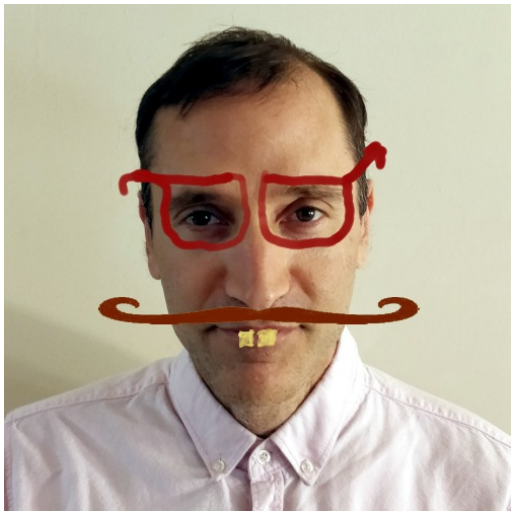
- **Name**: James Mickens
- **Affiliation**: Harvard University
- **Link**: `https://www.usenix.org/conference/usenixsecurity18/presentation/mickens`
- Hilarious and riveting

Questions?

Summary

Who I am

- Your friendly collaborator
- Applied Statistician; Data Scientist
- Software Engineer
- Substantive interest: Psychological Flourishing



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http://exuberant-island.surge.sh/

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