

Non-ordinary states of consciousness

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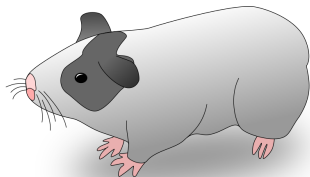
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Acknowledgment

Some collaborators

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



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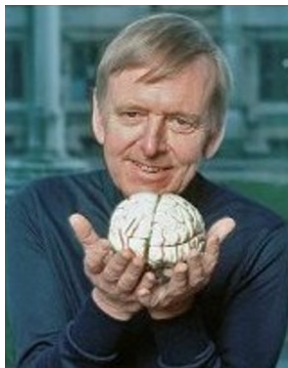


Historical context

Large-scale emergence

- ▶ 200k-100k BCE – Homo sapiens
- ▶ 3400-3100 BCE – Written language
- ▶ 1500-200 BCE – Conscious thinking¹

Supported by latent semantic analysis²



¹Jaynes (1976)

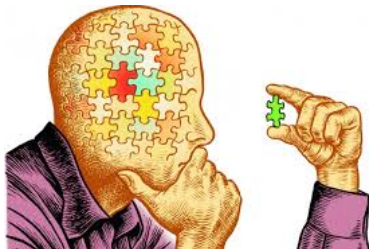
²Diuk, Slezak, Raskovsky, Sigman, and Cecchi (2012)



Conscious thinking: A modern status quo

Some features of conscious thinking

- ▶ spatialization of time
- ▶ concept of *me*
- ▶ concept of *I* (i.e. the part of me that is conscious)
- ▶ narratization
- ▶ concentration (i.e. conscious attention)



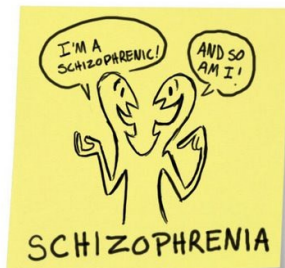
Probably a “software” change, not an anatomical change³

³Dennett (1986)

Before conscious thinking

Bicameral mind⁴

- ▶ no metacognitive awareness
- ▶ no executive monitoring
- ▶ no autobiographical memory
- ▶ no experience of an introspectable “mind-space”



Internally communicated by hallucination

(Once an evolutionary innovation, schizophrenia is now often considered a psychopathology!)

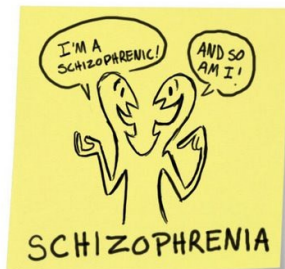
⁴Williams (2011)



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Optimal performance

Conscious thinking has costs⁵

- ▶ maladaptive rumination
- ▶ jealousy, guilt
- ▶ negligent inattentiveness due to excessive planning



Optimal performance often involves non-ordinary consciousness

- ▶ running⁶
- ▶ jazz improvisation⁷

→ An emerging mode of consciousness?

⁵Leary (2007)

⁶Csikszentmihalyi, Latter, and Duranso (2017)

⁷Limb and Braun (2008)



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Non-ordinary means what?

Which
phenomenology is important?

Clear neurological
correlates. For example:

Transient hypofrontality⁸

Or dynamic connectivity⁹



⁸Dietrich (2003)

⁹Santosa, Aarabi, Perlman, and Huppert (2017)



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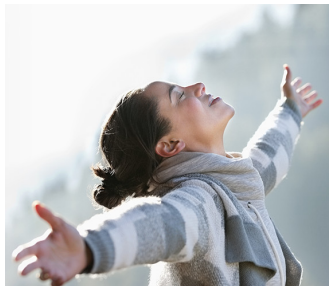
⁹Santosa et al. (2017)



Research focus

Non-ordinary states of consciousness
that support

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



Includes: flow, meditation, mindfulness

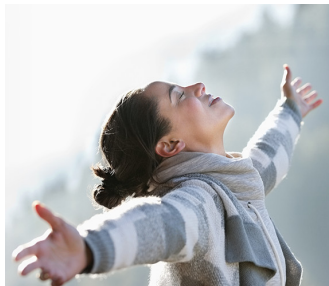
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Big challenges

Ephemeral, tricky to induce

Difficulty of studying non-ordinary states of consciousness is often underestimated.

Wish to corroborate self-report by objective measures

Intensive data collection and advanced statistical methodology

- ▶ differences within and between people and environments
- ▶ deep vs shallow experience
- ▶ how do processes unfold over time
- ▶ highly personal data requires greater privacy protection



Projects, planned and ongoing

Overview

- ▶ RCPA: flow-related characteristics of physical activities
- ▶ fNIRS: objective physiological measures of non-ordinary states
- ▶ MQ: meditation quality self-report measure
- ▶ MIDDLE

Conclusion



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Exploratory survey

Are some physical activities
more conducive to flow than others?



Sample item (template)

Participant picks: **A**, **B**

How predictable is the action?

- ▶ **B** is much more predictable than **A**. (-2)
- ▶ **B** is somewhat more predictable than **A**. (-1)
- ▶ Both offer roughly equal predictability. (0)
- ▶ **A** is somewhat more predictable than **B**. (1)
- ▶ **A** is much more predictable than **B**. (2)



Sample item

Participant picks: **running, golf**

How predictable is the action?

- ▶ Golf is much more predictable than running. (-2)
- ▶ Golf is somewhat more predictable than running. (-1)
- ▶ Both offer roughly equal predictability. (0)
- ▶ Running is somewhat more predictable than golf. (1)
- ▶ Running is much more predictable than golf. (2)

20 plausible flow preconditions were included¹⁰

¹⁰Kotler (2014); Sawyer (2007); Wegner (2002)



Demographics, sex & country

category	count	%
	5	2
Female	145	65
Male	72	32

category	count	%
	10	5
australia	6	3
austria	4	2
canada	4	2
germany	20	9
other	13	6
united kingdom	32	14
usa	133	60

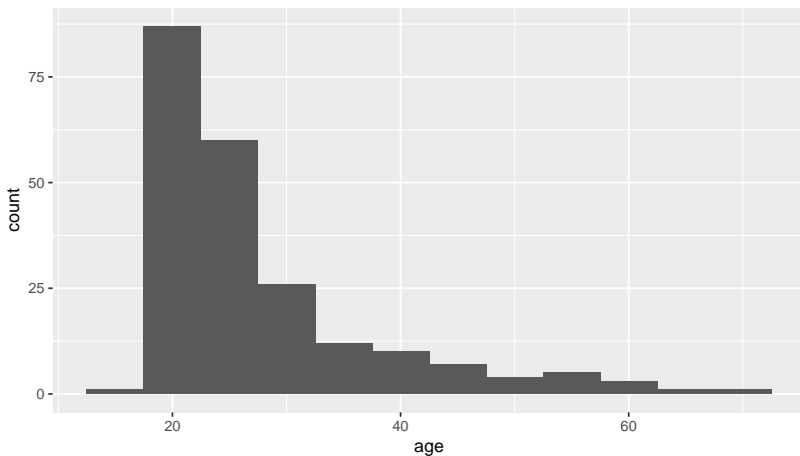


Demographics, education

category	count	%
Less than high school degree	3	1
High school degree or equivalent (e.g., GED)	22	10
Some college but no degree	63	28
Associate degree	9	4
Bachelor degree	72	32
Graduate degree	48	22



Demographics, age



Data and parameters

$$i = 1 \dots I \quad \text{indexes participants} \quad (1)$$

$$j = 1 \dots J \quad \text{indexes facets} \quad (2)$$

$$k = 1 \dots K \quad \text{indexes physical activities} \quad (3)$$

$$y_{ij}|k_a, k_b \in \{-2, -1, 0, 1, 2\} \quad k_a \text{ vs } k_b \text{ by person } i \text{ on facet } j \quad (4)$$

$$\theta_{kj} \quad \text{activity } k\text{'s score on facet } j \quad (5)$$

$$\tau_1, \tau_2 \quad \text{category thresholds} \quad (6)$$

$$\alpha_j \quad \text{slope for facet } j \quad (7)$$

$$\lambda_j \quad \text{factor loading for facet } j \quad (8)$$

$$\pi_k \quad \text{activity } k\text{'s latent flow score} \quad (9)$$



Priors and model

$$\pi_k \sim \mathcal{N}(0, 1) \quad (10)$$

$$\lambda_j \sim \mathcal{N}(0, 5) \quad (11)$$

$$\theta_k \sim \mathcal{N}(\pi_k \lambda, 1) \quad (12)$$

$$\tau_1, \tau_2 \sim \mathcal{N}(0, 5) \quad (13)$$

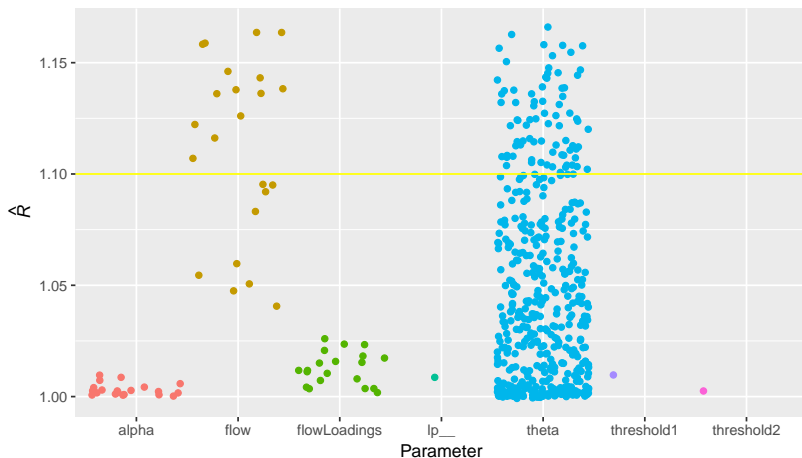
$$\log \alpha_j \sim \mathcal{N}(0, 1) \quad (14)$$

$$\text{logit} [\Pr(y_{ij}|k_a, k_b)] = \alpha_j [\theta_{k_a} - \theta_{k_b} + f(y_{ij})] \quad (15)$$

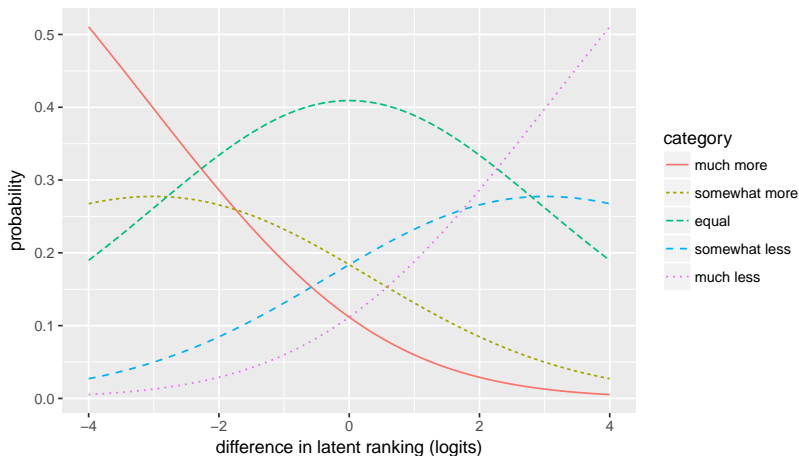
$$\text{where } f(r) \equiv \begin{cases} -(\tau_1 + \tau_2) & r = -2 \\ -\tau_1 & r = -1 \\ 0 & r = 0 \\ \tau_1 & r = 1 \\ (\tau_1 + \tau_2) & r = 2 \end{cases} \quad (16)$$



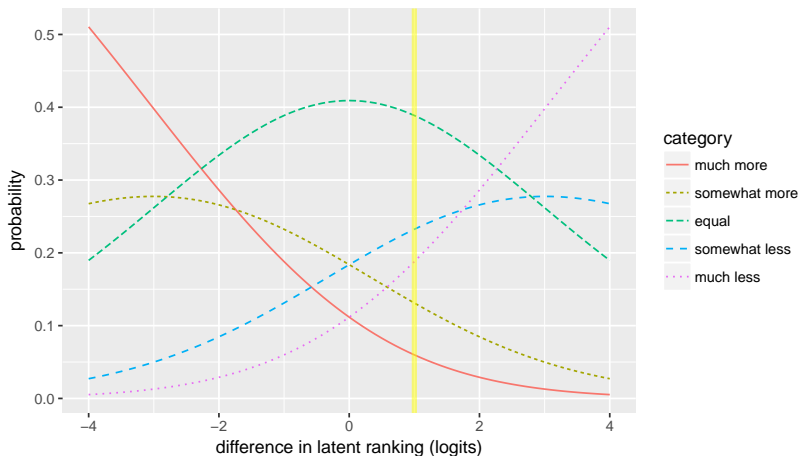
\hat{R} convergence diagnostic



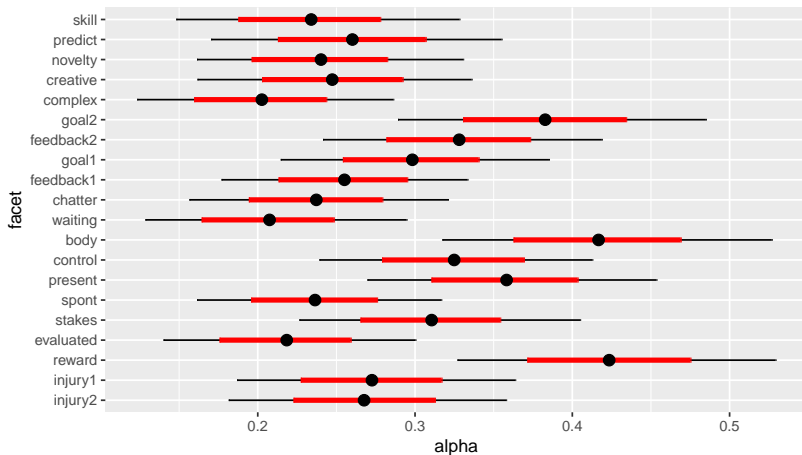
Response curves



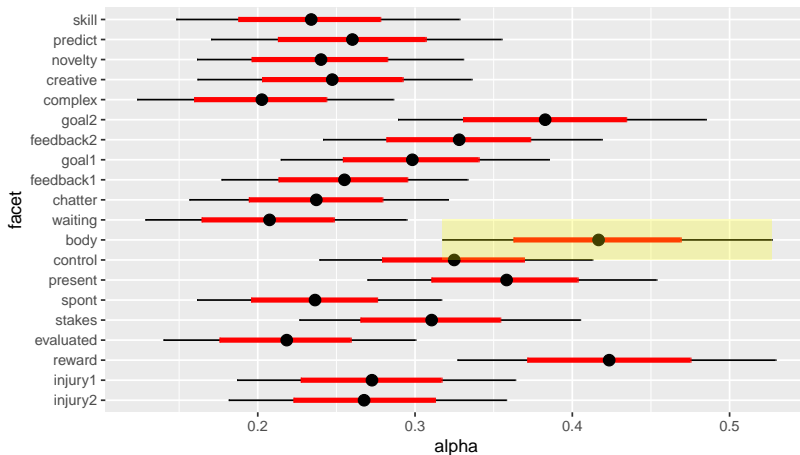
Response curves at 1.0



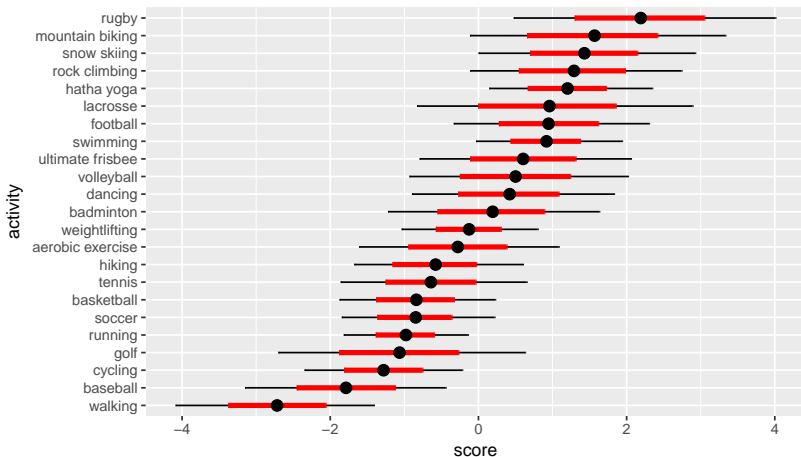
Discrimination



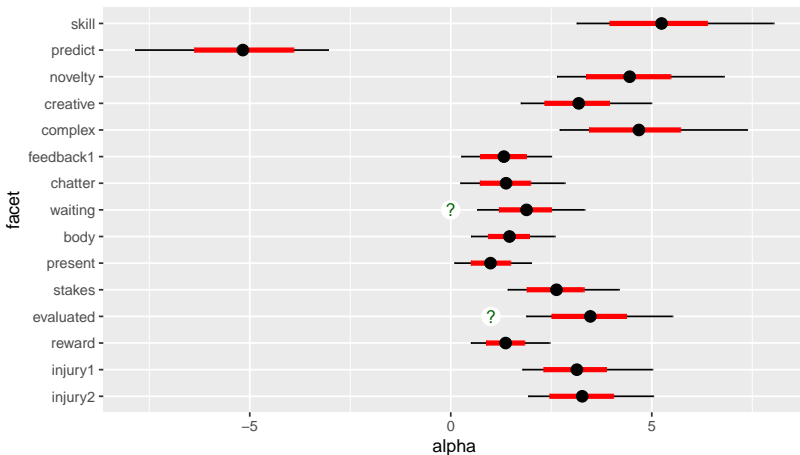
Discrimination, bodily involvement



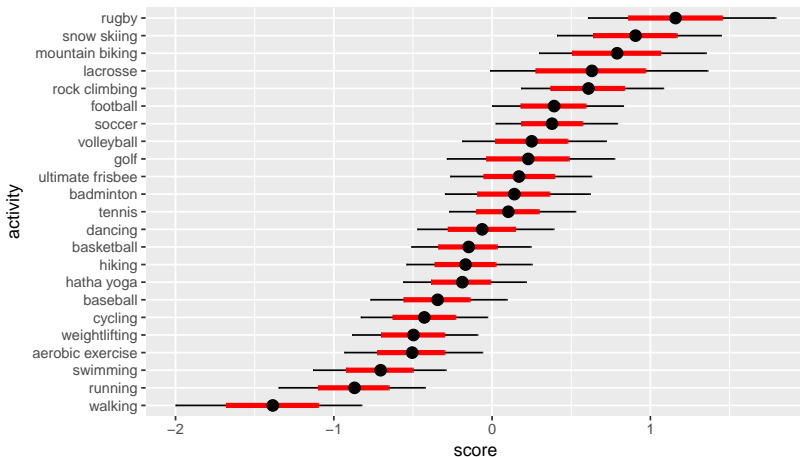
How much of your body is involved?



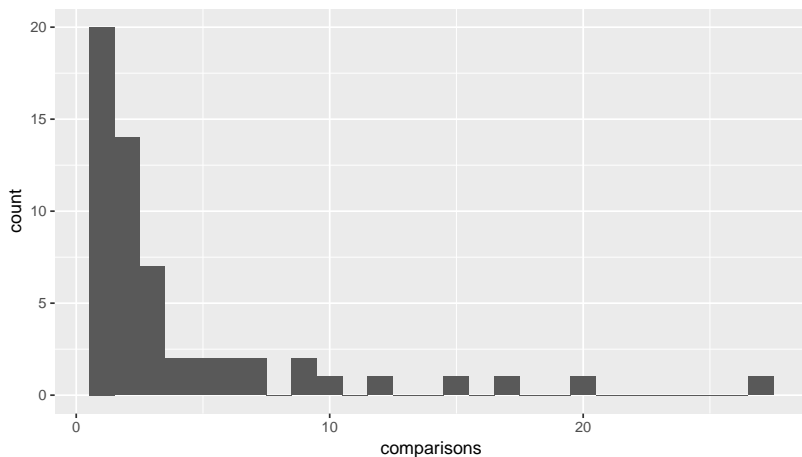
Latent flow score, loadings



Preliminary flow score



Comparisons per physical activity



Projects, planned and ongoing

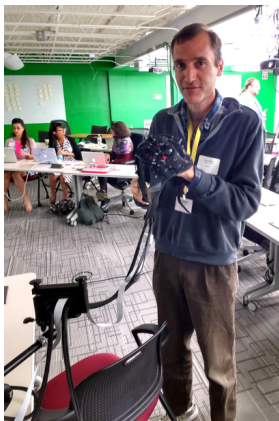
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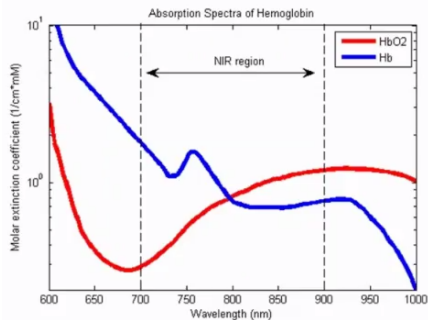
Conclusion



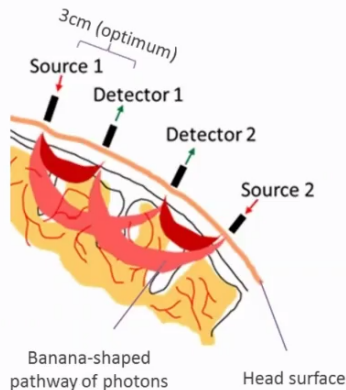
2017 fNIRS Workshop at Kingston, RI



Working principles of fNIRS



Absorption spectra of Hb



fNIRS compared to fMRI

Both measure the blood oxygen level-dependent (BOLD) response¹¹

method	resolution		depth pervasion	mobility	cost
	temporal	spatial			
fMRI	1-2 s	64 mm ³	good	poor	>\$1 million
fNIRS	100-400 ms	100 mm ³	2-3 cm	good	~\$20-100k

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

¹¹Cui, Bray, Bryant, Glover, and Reiss (2011)



Simultaneous measurement of multiple subjects



How to define meditation/mindfulness?

Meditation may involve 1 or more of

- ▶ psychophysical relaxation
- ▶ self-focus skill or anchor
- ▶ altered state/mode of consciousness
- ▶ mystic experience
- ▶ enlightenment
- ▶ suspension of logical thought processes
- ▶ experience of mental silence

(Bond et al., 2009)

Difficult,¹² but ask a different question...

¹²Farias and Wikholm (2016)



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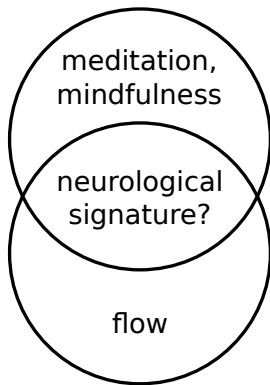
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Triangulate



What neurological signature?

Neurology:

- ▶ Explicit and implicit processing become entangled and, perhaps, integrated¹³

Phenomenology:

- ▶ selflessness (i.e., dissolution of the boundary dividing self from non-self)
- ▶ timelessness
- ▶ effortlessness (i.e., spontaneity)

involve brain regions near the surface of the neocortex¹⁴

¹³Berkovich-Ohana and Glicksohn (2014)

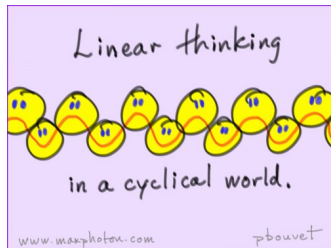
¹⁴Goldberg, Harel, and Malach (2006); Andrews-Hanna, Smallwood, and Spreng (2014); Pagnoni, Cekic, and Guo (2008); Johnstone, Bodling, Cohen, Christ, and Wegrzyn (2012); Rammsayer (1999)



Data analysis challenge

fNIRS produces
dense, multivariate, multilevel time
series data with intricate dynamics
that evolve over a range of time scales.

Possible approaches: windowed cross
correlation, autoregressive models,
state space models, or novel methods.¹⁵



¹⁵Pritikin, Hunter, von Oertzen, Brick, and Boker (2017); Pritikin (2017) ▶



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A new self-report measure

For studies that aim to examine the effects of meditation, a valid manipulation check would reduce **measurement error**.

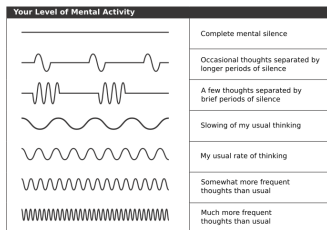
Meditation quality (MQ) instrument in development since 2012,¹⁶ based on experience of non-ordinary states.



¹⁶Pritikin and Schmidt (2013)



Mostly single-occasion measurements



- ▶ $N \approx 3500$
- ▶ 7 items on preparation/training
- ▶ 18 items on non-ordinary consciousness
- ▶ Data analyzed with modular, open-source tool for Item Response Theory¹⁷

¹⁷Pritikin, Hunter, and Boker (2015)



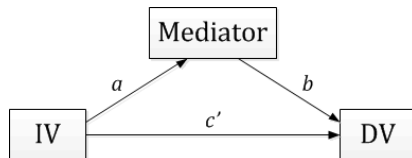
A mediation model

From experience
of non-ordinary consciousness

Expect enhanced

- ▶ self-concept clarity¹⁸
- ▶ self-control
- ▶ alignment between implicit and explicit goals

Leading to psychological well-being, fulfillment



¹⁸Campbell et al. (1996)



Incarcerated inmates

Compared to students,

- ▶ lower baselines for self-concept clarity, self-control, and alignment between implicit and explicit goals
- ▶ more time and motivation to practice¹⁹



Goal:

- ▶ Reduction in recidivism and drug (ab)use

¹⁹Johnson (2017)



Detailed research plan

Mindfulness RCT conducted in a prison,²⁰ replicate and extend

- ▶ intensive longitudinal measurement
 - ▶ helps minimize noise
 - ▶ can reveal time-varying, dynamic behavior.
- ▶ continuous time structural equation modeling²¹
 - ▶ can estimate autoregressive and cross-lag effects in time-independent units
 - ▶ permits investigation of the direction of causality

Gather evidence of longitudinal predictive validity for MQ as a mediator

Reduce recidivism and drug (ab)use

²⁰Malouf, Youman, Stuewig, Witt, and Tangney (2017)

²¹Driver, Oud, and Voelkle (2017)



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- ▶ **MIDDLE**

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MIDDLE

What if we could keep participant data private,
never revealed to researchers,
and still fit statistical models to data
and test hypotheses?



Statistical models

Given

x_i row x of data from person i (17)

θ parameter vector (18)

Full-information maximum likelihood often has the form

$$\sum_{i=1}^I L(x_i|\theta) = \dots \quad (19)$$

and rows are assumed independent and identically distributed.



Distributed likelihood evaluation (DLE)

$$\begin{aligned}\sum_{i=1}^I L(x_i|\theta) = & L(x_1|\theta) \\ & L(x_2|\theta) + \\ & L(x_3|\theta) + \\ & L(x_4|\theta) + \\ & \dots + \\ & L(x_I|\theta)\end{aligned}\tag{20}$$



Maintained individual data (MID)

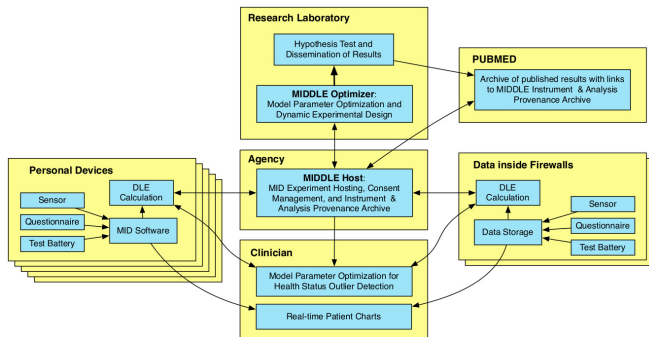


Your personal $L(x_i|\theta)$ runs on **your** smartphone

- ▶ Data remain private
- ▶ Can be encrypted and backed up
- ▶ Automatic data sharing across experiments
- ▶ Larger participant pool with more generalizable estimates



Status



Proof-of-concept stage²²

Will apply to federal health agencies for funding.

²²Boker et al. (2015)



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Advanced statistical methodology is key

The topic of non-ordinary states of consciousness **spans at least**

- ▶ neuroscience
- ▶ positive, clinical, cognitive, and sports psychology
- ▶ contemplative studies

To span so much ground, **my strengths include**

- ▶ expertise in applied statistics²³
- ▶ an affinity for interdisciplinary collaboration²⁴

²³Neale et al. (2016)

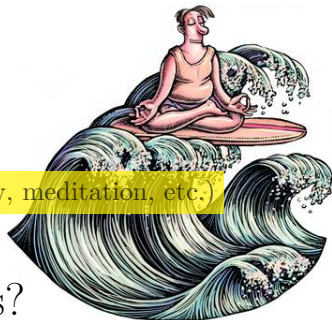
²⁴Such as in developmental child neurology (Kelly et al., 2015).



An emerging mode of consciousness?

Large-scale emergence

- ▶ 200k-100k BCE – Homo sapiens
- ▶ 3400-3100 BCE – Written language
- ▶ 1500-200 BCE – Conscious thinking
- ▶ 1970-2050 CE – Hypofrontality (flow, meditation, etc.)



Questions?

Thank you

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



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