Measuring and Modeling Intensive Longitudinal Health Behaviors: Overview of Projects in the Intensive Longitudinal Health Behavior Network (ILHBN), Part I

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Overview of the ILHBN

The ILHBN is a cooperative agreement network consisting of 7 U01 projects and 1 U24 Research Coordinating Center to study health behavior changes such as the prevention of suicidal thoughts and behaviors, smoking, drug use, and alcohol use; and the promotion of mental health, sleep, and physical activities, and decreases in sedentary behavior. The overarching mission of the ILHBN is to:

- Introduce innovations into longstanding health behavioral theories
- Advance the field of theory-driven behavior change interventions
- Provide a framework to guide future intensive longitudinal studies of health behaviors

Snapshot of Modeling Approaches

Studies	Supervised	Unsupervised/Hybrid
Study I	Dynamic factor analysis	Deep learning models
	Multilevel time series models	Concurrent fusion
	Mixed Markov models	Temporal fusion
Study II	Hazard modeling	Change point analysis
	Time series models	
Study III	SVM, Naive Bayes	Anomaly Detection
Study IV	Meta-analysis of dynamic models, graphical tools to depict overlapping dynamic concepts	

Study I

- Title: Mobile Assessment for the Prediction of Suicide (MAPS)
- Scientists: Nicholas Allen[1], Randy Auerbach[2] (MPIs), David Brent[3], Jeff Cohn[3,4] & Louis-Philippe Morency[4]; [1] U of Oregon; [2] Columbia U; [3] U of Pitt; [4] Carnegie Melon U
- Goal: Prediction of suicidal thoughts and behaviors in youth
- Theoretical framework: Psychache Theory; Interpersonal Theory of Suicide; Diasthesis Stress Theory
- Measurement: Over 6 months, ongoing smartphone and mobile sensor data; daily ecological momentary assessment (EMA) with clinical follow-up at 1, 3, and 6 months

Figure 1: Overview of Study Design

Figure 2: Examples of Continuous Mobile Sensing Variables

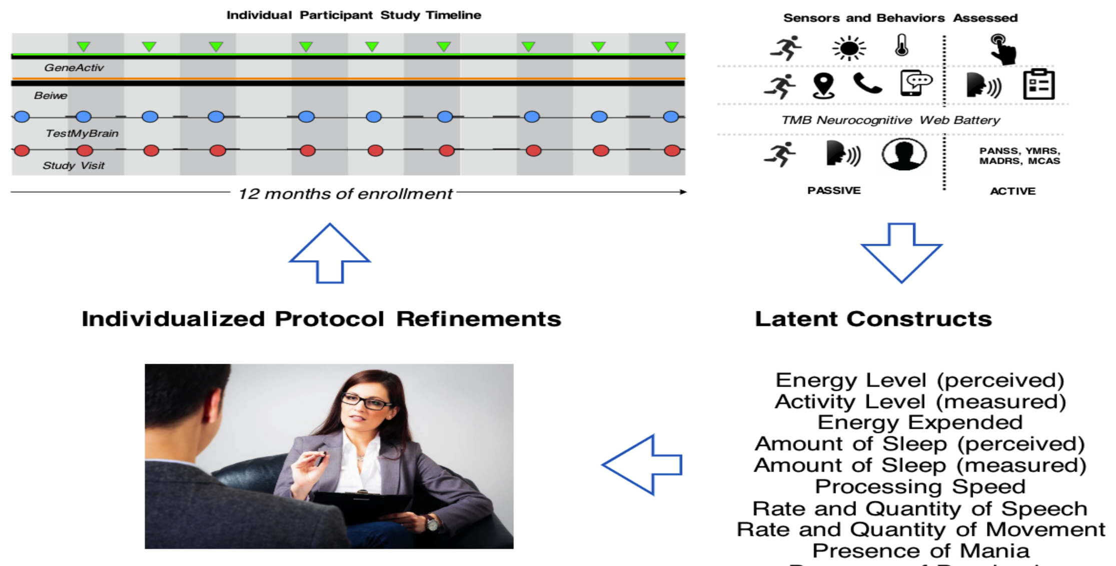
Feature	Andriod	iOS
In-call voice sample	✔	
All typed text	✔	✔
Facial expressions	✔	✔
Geographic Location GPS	✔	✔
Music choice	✔	✔*
Accelerometer.Gyro	✔	✔
Ambient light	✔	
Charging time	✔	✔
Screen-on time	✔	
App usage	✔	
Screen touch events	✔	
SMS frequency	✔	
SMS transcripts	✔	
Call frequency	✔	✔
Video diary	✔	✔
Audio diary	✔	✔
EMA	✔	✔
Barometer	✔	✔
Wearables	✔	✔

*=ITunes only

Study II

- Title: Robust predictors of mania and psychosis
- Scientists: Justin Baker[1], Scott Rauch[1] (MPIs), Ian Barnett[2] et al; [1] McLean Hospital and Harvard Medical School; [2]U of Pennsylvania
- Goal: Predict the occurrence of mania/psychosis from preceding behavioral changes
- Theoretical framework: Energy Balance Abnormality (Processing Speed); Cognitive Control
- Measurement: Over 1 year, ongoing smartphone and mobile sensor data, and up to 10 study visits (w/ actigraphy data)

Figure 3: Overview of Study Design



One possible analysis: Change point analysis to represent a p-variate process on day j with change point at k as:

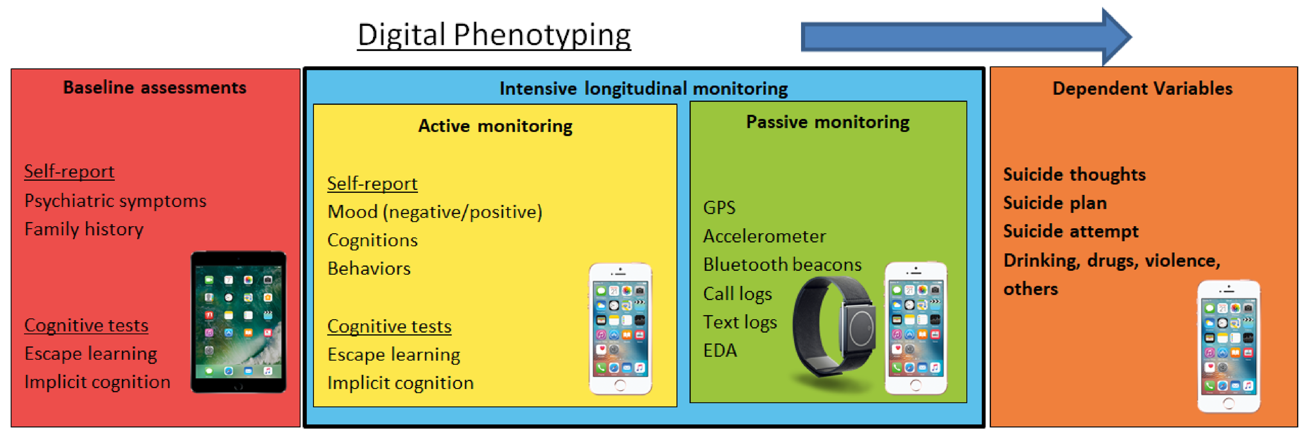
$$\begin{aligned} \boldsymbol{Y}_j &= \boldsymbol{\mu}_j + \mathrm{I}(j \geq k)\boldsymbol{\beta}_j + \boldsymbol{\epsilon}_j;\ \boldsymbol{\epsilon}_j \sim \mathrm{MVN}(\mathbf{0}, \boldsymbol{\Sigma});\ \boldsymbol{\mu}_j = \boldsymbol{\alpha} + \boldsymbol{\gamma}_j; \\ \boldsymbol{\beta}_j &= \text{shifts after change point } k;\ \boldsymbol{\gamma}_j = \text{day of week effects}, \end{aligned}$$

Likelihood ratio tests for H_0: $\boldsymbol{\beta} = \mathbf{0}$, with derivations of asymptotic distribution of test statistic

Study III

- Title: Intensive Longitudinal Monitoring of Suicidal and Related Behaviors
- Scientists: Matthew Nock (PI)[1], Evan Kleiman[1], John Torous[2], et al; [1]Harvard U and [2]Medical School
- Goal: Identify digital phenotype of suicidal individuals, dynamic trajectories of suicidal thoughts and behaviors over time, and objective/subjective markers of risk

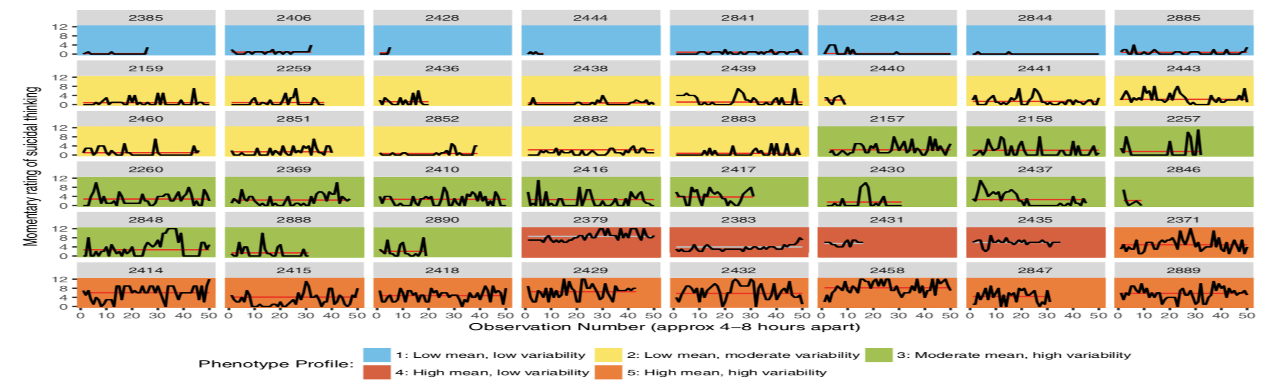
Figure 4: Overview of Study Design



Study III (Contd.)

- Theoretical framework: Data-driven
- Measurement: Over 6 months, ongoing smartphone and mobile sensor data; daily and weekly EMA

Figure 5: Time Series Plots of Individual Trajectories



Study IV

- Study title: An Ontology for the Study of Affective Dynamics
- Scientists: Sy-Miin Chow[1], Nilam Ram[1], Akhil Kumar[1], Timothy Brick[1], Zita Oravecz[1], Peter Molenaar[1], Kai Larsen[2]; [1] Penn State U; [2]U of Colorado Boulder
- Goal: Develop a shared knowledge base to define methods, models, and time scales for studying affective dynamics, and their correlates with selected health behaviors.
- Affect is a central component of many of the U01 studies – either as a predictor, or the dependent variable
- Distinct methods and models have been used to study affective dynamics – different terms to describe the same modeling parameter; different parameters are coined the same name

<u>Univariate, discrete-time</u>	:	$Sad_{i,t} = \rho Sad_{i,t-1} + \text{noise}_{it}$
<u>Univariate, continuous-time</u>	:	$dSad_i(t) = \beta(Base - Sad_i(t))dt + \sigma d\text{noise}_i(t)$
<u>Multivariate</u>	:	Vector AR, regime-switching VAR and SDEs etc.

Table 1: Reported Time Scales for Selected Dynamic Features of Affect

Concepts/Measures	Time Scales	Selected References
Emotional variability (iSD)	Macro, micro	
@ Emotional reactivity	Meso, macro	
@ Transitions & durations from state-space grids	Micro	Hollenstein (2015)
@ Dynamic flexibility	Micro	Hollenstein (2015)
@ Inertia	Micro (secs, hrs)	Kuppens et al. (2010, 2015)
@Centralizing tendency	Micro (hours)	Oravecz et al. (2011)

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