

Intensive Longitudinal Data (ILD)

- Ecological Momentary Assessment (EMA)
 - Intensive longitudinal data (ILD)
 - Experience sampling method (ESM)
 - Daily electronic diaries
 - Ambulatory assessment
 - Real-time cognitive assessment
 - Burst (trigger-based) measurements
 - Adaptive (Just-in-Time) intervention studies
 - quit smoking/drinking/drugs
 - staying on a diet
 - becoming more physically active

The image displays three mobile app screens for Ecological Momentary Assessment (EMA). Each screen has a close button (X) in the top right corner and a 'Back' button at the bottom.


Screen 1: Sleep Duration
Icon: A person sleeping in bed with a clock.
Text: "About how many hours did you actually sleep?"
Options: Radio buttons for "less than 30 minutes", "30 minutes", "1 hour", "1.5 hours", and "2 hours". The "2 hours" option is selected.
Bottom button: "Back"

Screen 2: Beverage Consumption
Text: "Since you woke up, did you drink:"
Options: Checkboxes for "water", "milk", "a caffeinated beverage (like coffee/tea/soda etc.)", "an alcoholic beverage (wine/beer/liquor etc.)", "a beverage containing sugar like juice or caffeine-free soda", and "another type of drink".
Bottom button: "Back"

Screen 3: Social Context
Text: "Who is with you at this moment?"
Options: Checkboxes for "no one", "family member", "partner/boyfriend/girlfriend", "friend", "colleague or classmate", "stranger", and "a pet". The "a pet" option is selected.
Bottom button: "Back"

Intensive Longitudinal Data (ILD)

- Multiple observations per day, one or more weeks of data
- (almost) Real-time recall
- No measurement tools except report: pain, sleep quality, mood, ...
- Capture dynamical nature of phenomena
- Higher frequency (more reliable)
- Natural environment (home, work, etc)



About how many hours did you **actually sleep**?

less than 30 minutes ☐

30 minutes ☐


1 hour ☐


1.5 hours ☐


2 hours ☒


Back


Since you woke up, did you drink:


 water ☐

 milk ☐

 a caffeinated beverage (like coffee/tea/soda etc.) ☐


 an alcoholic beverage (wine/beer/liquor etc.) ☐


 a beverage containing sugar like juice or caffeine-free soda ☐


 another type of drink ☐


Back


Who is with you at **this moment**?


 no one ☐


 family member ☐

 partner/boyfriend/girlfriend ☐

 friend ☐

 colleague or classmate ☐

 stranger ☐

 a pet ☒

Back

Examples

- Context (current location, situation, immediate experiences)
- Health Behaviors (sleep, pain, mood)
- Real-time cognitive assessment
- Dietary assessment
- Reactivity

Examples: Context

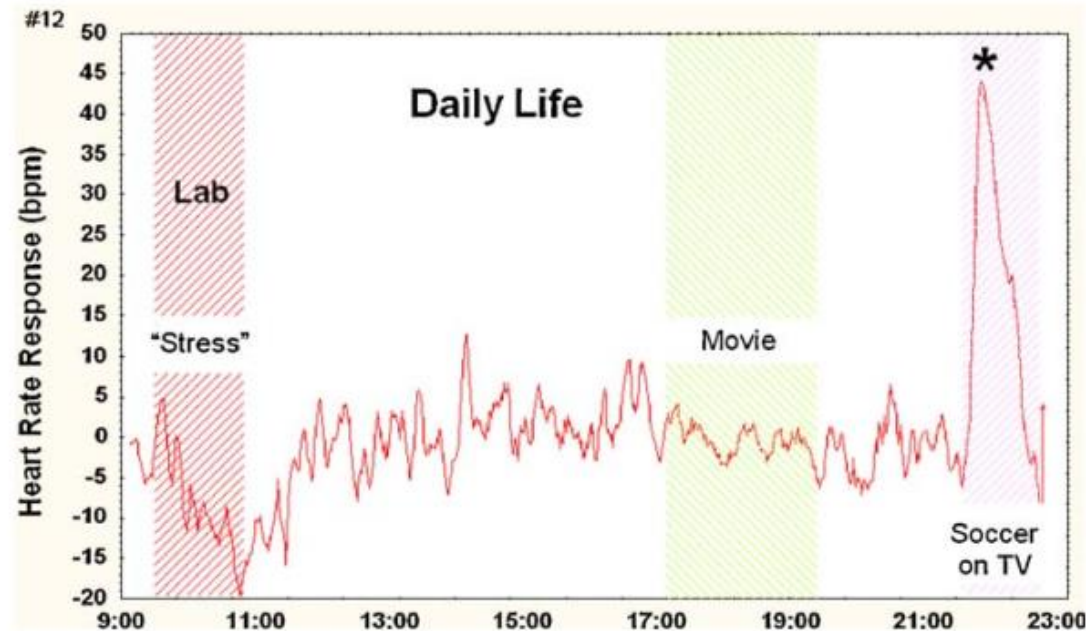


Fig. 1. Heart rate responses (1-min averages) of a study participant (subject 12) monitored with the LifeShirt during and after a laboratory stress protocol consisting of five resting baselines and mild-to-moderate mental stressors ("Lab"). Laboratory stress responses and responses to the movie were small compared to responses to a soccer game the participant watched at home. Note: heart rate was adjusted for ongoing physical activity.

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journal homepage: www.elsevier.com/locate/biopsycho



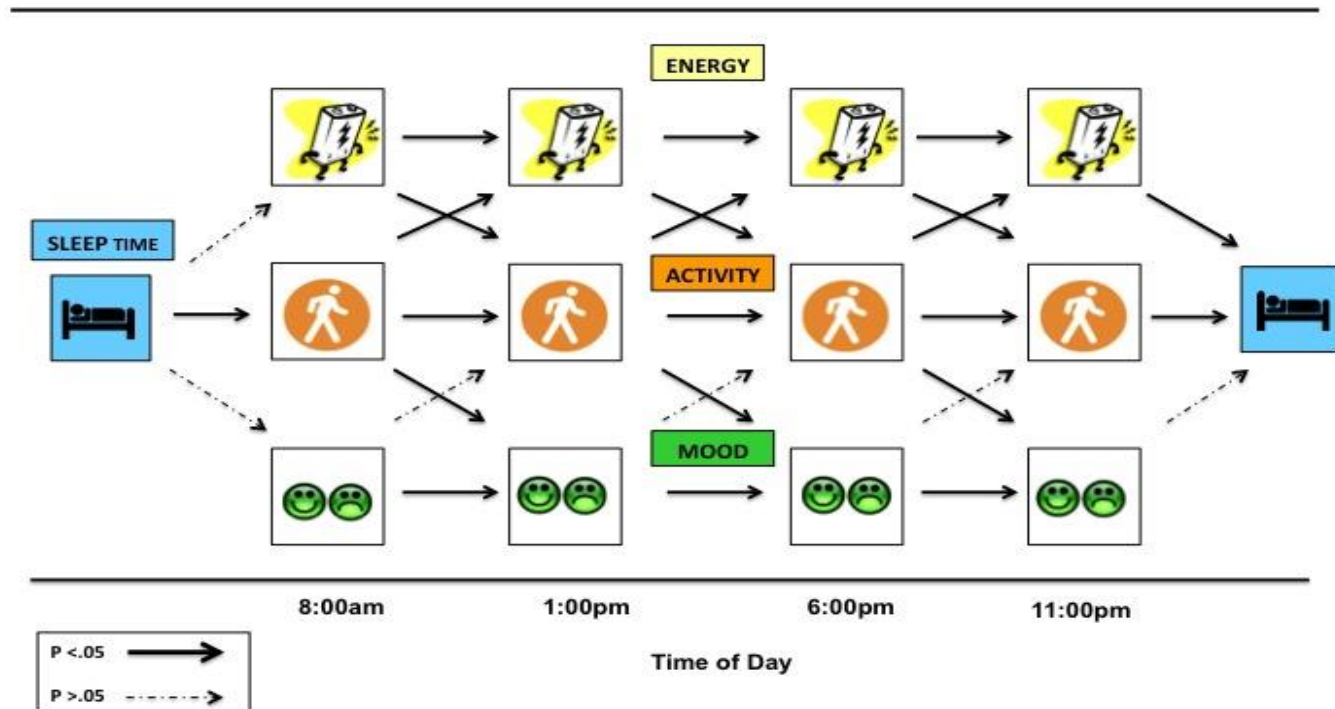
Emotions beyond the laboratory: Theoretical fundamentals, study design, and analytic strategies for advanced ambulatory assessment

Frank H. Wilhelm^{a,*}, Paul Grossman^b

^aUniversity of Basel, Institute for Psychology, Department of Clinical Psychology and Psychotherapy, Muesmattenstrasse 60/62, CH-4055 Basel, Switzerland

^bUniversity of Basel Hospital, Division of Internal Medicine, Department of Psychosomatic Medicine, CH-4055 Basel, Switzerland

Examples: Within-day interplay of Energy, Mood, Physical Activity



Original Investigation

December 12, 2018

Real-time Mobile Monitoring of the Dynamic Associations Among Motor Activity, Energy, Mood, and Sleep in Adults With Bipolar Disorder

Kathleen Ries Merikangas, PhD¹; Joel Swendsen, PhD^{2,3}; Ian B. Hickie, MBBS⁴; et al

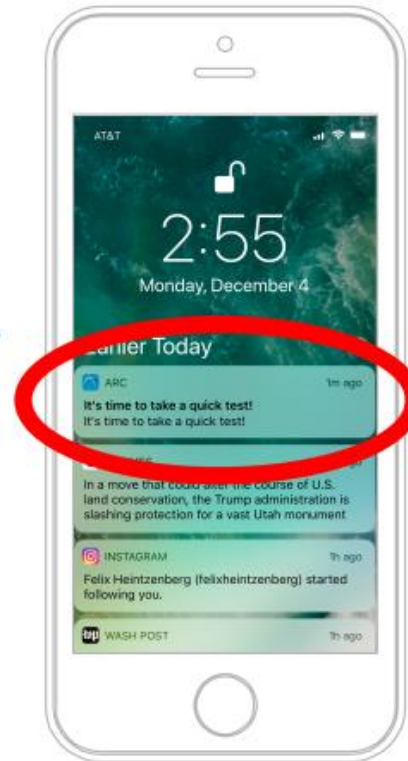
[Author Affiliations](#) | [Article Information](#)

JAMA Psychiatry. 2019;76(2):190-198. doi:10.1001/jamapsychiatry.2018.3546

FREE

Examples: Real-time cognitive assessment

Get a notification that it is “Time to take a quick test”, tap on the notification and begin the test.



higher frequency;
natural environment

High Frequency Cognitive Assessments in Alzheimer's Disease

Jason Hasse(N)s-t-Aß, PhD
Associate Professor
Neurology and Psychological & Brain Sciences
Director, Cognitive Technology Research Laboratory
Washington University in St. Louis

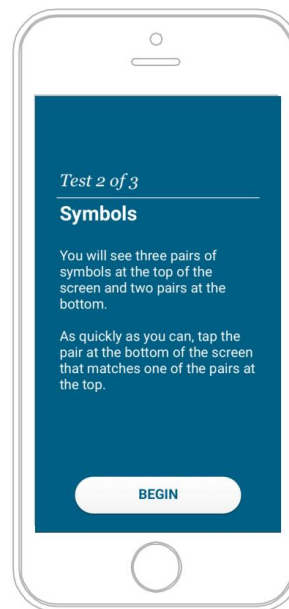
Applications: Real-time cognitive assessment



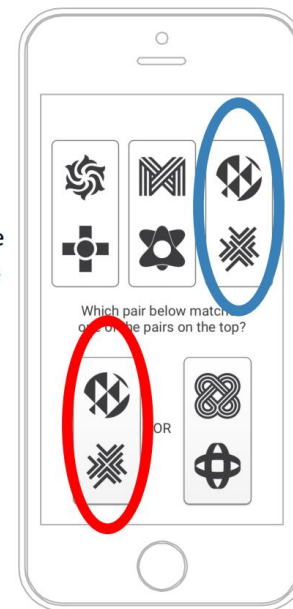
SYMBOLS Test (20-30 seconds) Processing Speed

DI
Dominant
Alzheimer

SYMBOLS Test
Participants are asked
Which pair below
matches one of the pairs
on top?



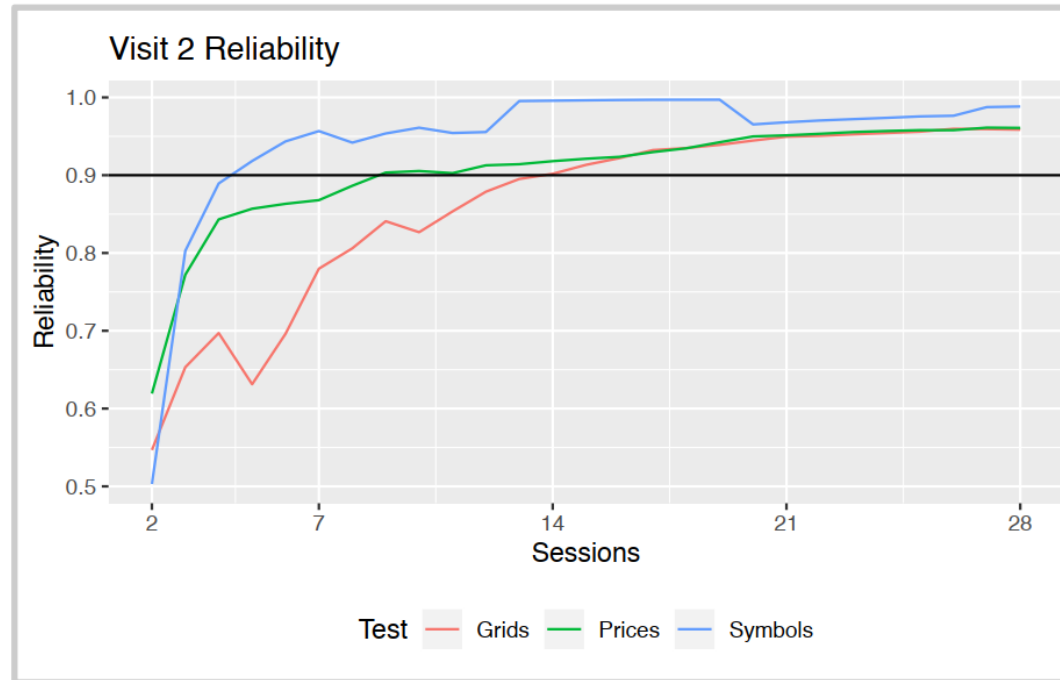
SYMBOLS Test
Participants complete
12 items as quickly as
possible. Primary
outcome: Number
correct and response
time.



High Frequency Cognitive
Assessments in Alzheimer's Disease

Jason Hasse(N)s-t-Aß, PhD
Associate Professor
Neurology and Psychological & Brain Sciences
Director, Cognitive Technology Research Laboratory
Washington University in St. Louis

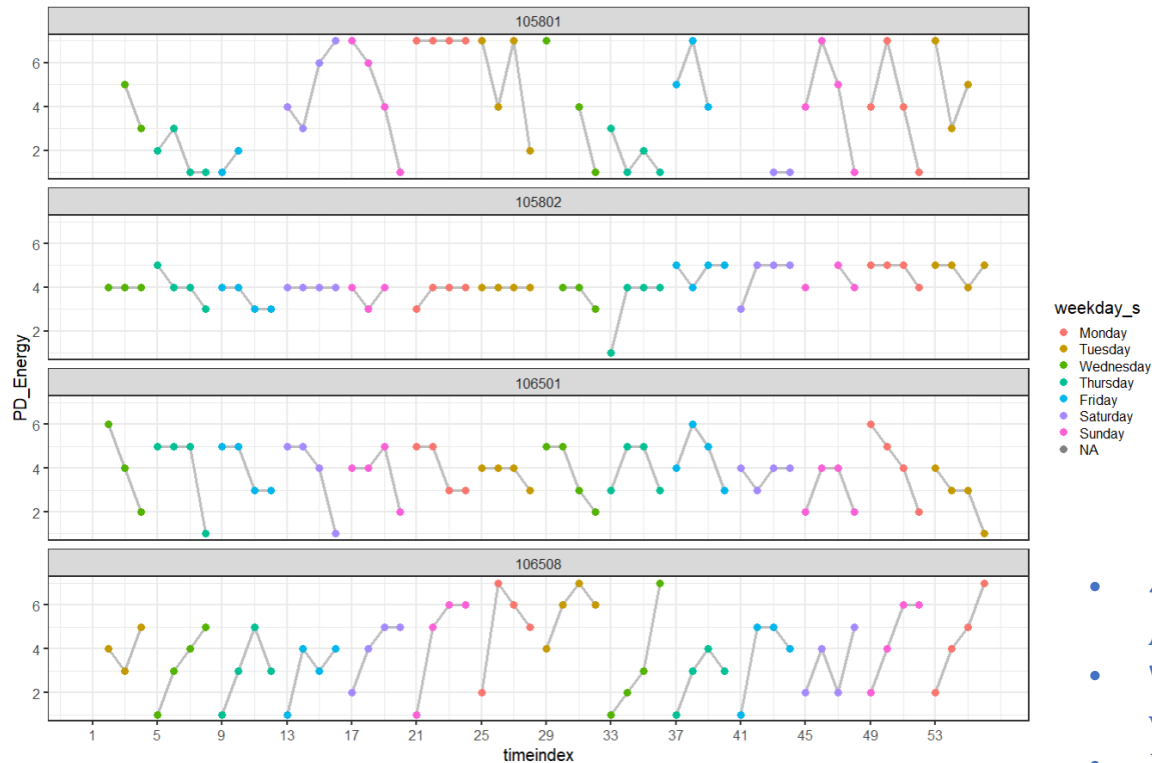
Applications: Real-time cognitive assessment



High Frequency Cognitive Assessments in Alzheimer's Disease

Jason Hasse(N)s- τ -A β , PhD
Associate Professor
Neurology and Psychological & Brain Sciences
Director, Cognitive Technology Research Laboratory
Washington University in St. Louis

Example: How/what to model?



- 4 assessments per day (Morning, Noon, Afternoon, Evening), two weeks
- What to model? Subject-specific mean, variance, autocorrelation?
- How to take into account diurnal and weekly trends?
- Is there a structural change? In mean, variance, autocorrelation?

ILD Data

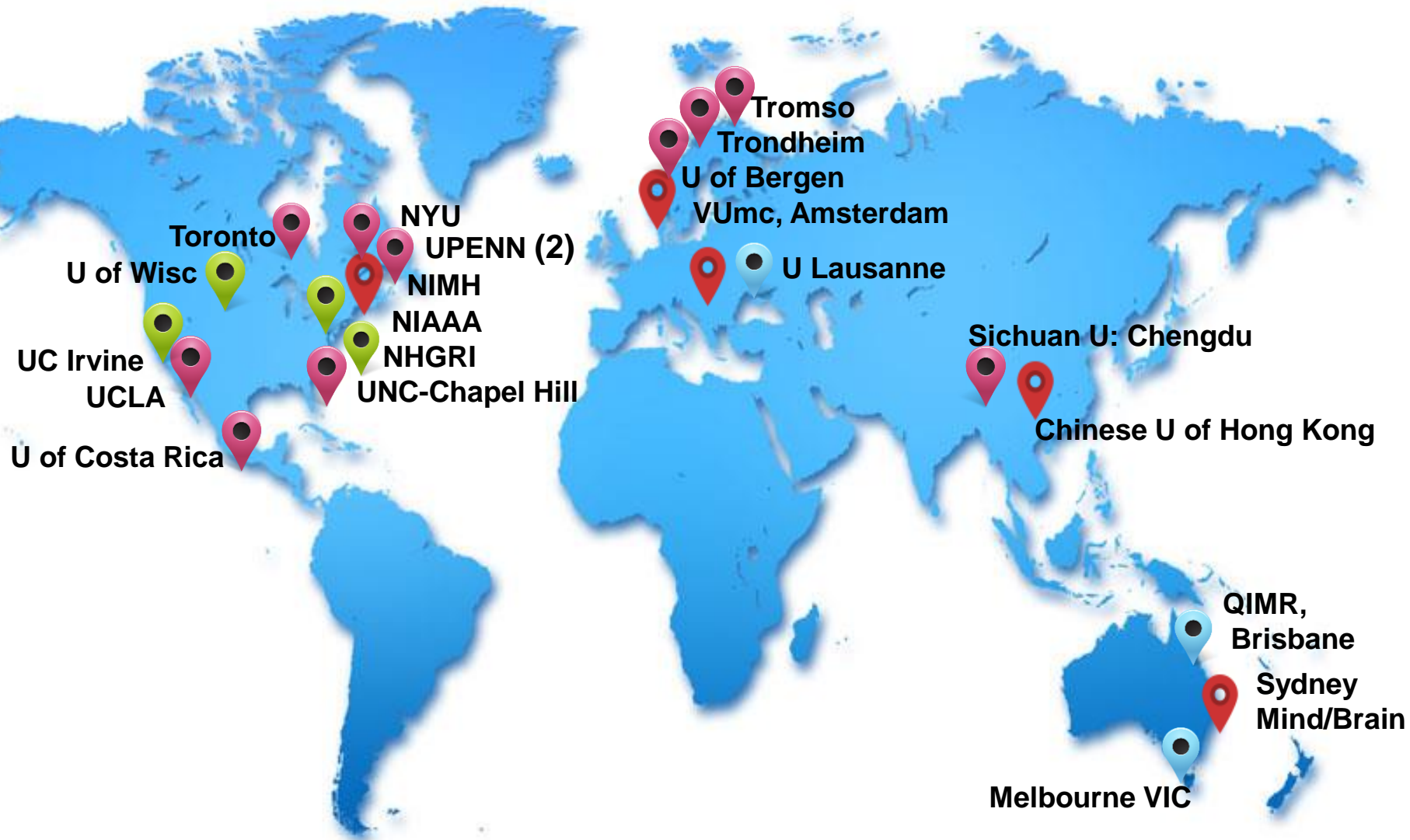
Challenges:

- Clustering (over time, within assessment)
- Temporal dynamics
- Multivariate mixed data types
 - Binary (had meal, smoking urge)
 - Categorical (type of foods, current location)
 - Ordinal (sadness, anxiety)
 - Truncated (pain level)
- Trends: Diurnal (within-day), Weekly, Seasonal
- Subject-specific vs population-level modeling
 - Within-subject clustering, between/within subject variability
 - Normalization of subject-specific interpretation of the scales (1-7, 1-10)
 - Bringing context: workdays vs workfree days, weekdays vs weekends
- Missing data

Models

- Clustering
 - Multi-level modelling (between/within subject variability)
 - Marginal modelling (GEE)
 - Item Response Theory modelling
 - Structural Equation Modelling (SEMs)
- Temporal Dynamics
 - Time-varying (TVEM) modelling
 - Functional data modelling
 - Single-subject temporal analysis: N of 1, within-person study
 - Time-series (AR, ARMA, VAR, etc)
 - Hidden-Markov Models
 - (regime-switching) State-space models
 - Change-point and structural-break models
 - Multiple subjects: multilevel (time-series) modelling
 - Dynamic Structural Equation Models
- Mixed data types
 - Binary, truncated, ordinal, categorical time-series
 - Item Response modelling
 - Bayesian modelling

Motor Activity Research Consortium for Health (mMARCH)



mMARCH



Kathleen Merikangas, PhD
National Institute of Mental
Health



Andrew Leroux, PhD
University of Colorado at
Denver



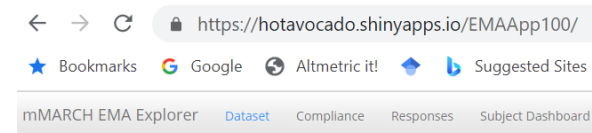
Mike Xiao, BA
Child Mind Institute, NYC

mMARCH

- Leverage mobile technology via
 - standardizing data collection protocols across sites
 - developing and applying novel analytical methods
- The range of scientific questions
 - interrelationship of physical activity, sleep and mood
 - interplay between sleep, stress, and alcohol use

mMARCH EMA Explorer: Shiny App

- quickly assesses the patterns of compliance and response
- facilitates exploration and visualization of EMA data
- pays special attention to the time-dependent and multi-level design
- hotavocado.shinyapps.io/EMAApp100/
 - Play with a synthetic dataset
 - Upload your dataset



Upload and Select Dataset

Select dataset:

Example data ▼

Select Dataset

Upload main dataset

Browse... No file selected

Upload max-values data for compliance

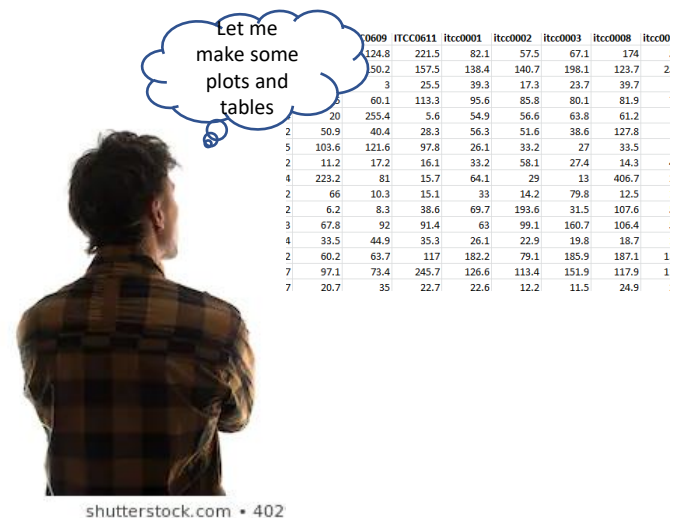
Browse... No file selected

Upload covariate dataset

Browse... No file selected

Observations in the Field

- The field is like a huge dataset, and we can process this information efficiently with our eyes and ears. The shiny app tries your eyes and ears for EMA data. From observing, you can gain insights and begin to ask questions and generate testable hypotheses.



Using the App: Aggregate Level Exploratory Visuals (boxplot)

Main Variable Options

Main Variable:
PD_sad

Color Variable Options

Color By:
SEX

Quantiles:
☒ Auto ☐ On ☐ Off

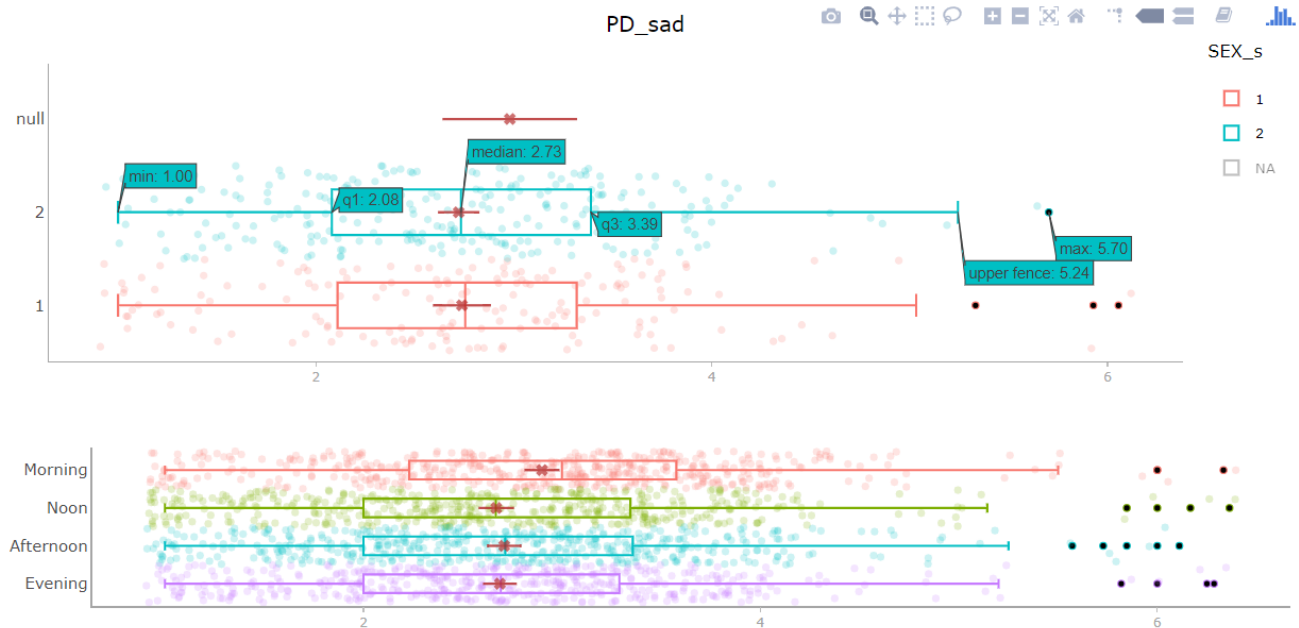
Number of Quantiles:
2 4 10

Random Variable Options

Choose Random Inputs:
☒ Main Var. ☒ Color Var.

Random Vars

Create/Update Plot



Using the App: Aggregate Level Exploratory Visuals

Main Variable Options

Main Variable:

PD_sad

Color Variable Options

Color By:

PD_Energy

PD_Energy

PD2_diarrhea

PD2_nausea

PD2_vomiting

PD2_alcquan

PD_Beer

PD_Champ

PD_cocktail

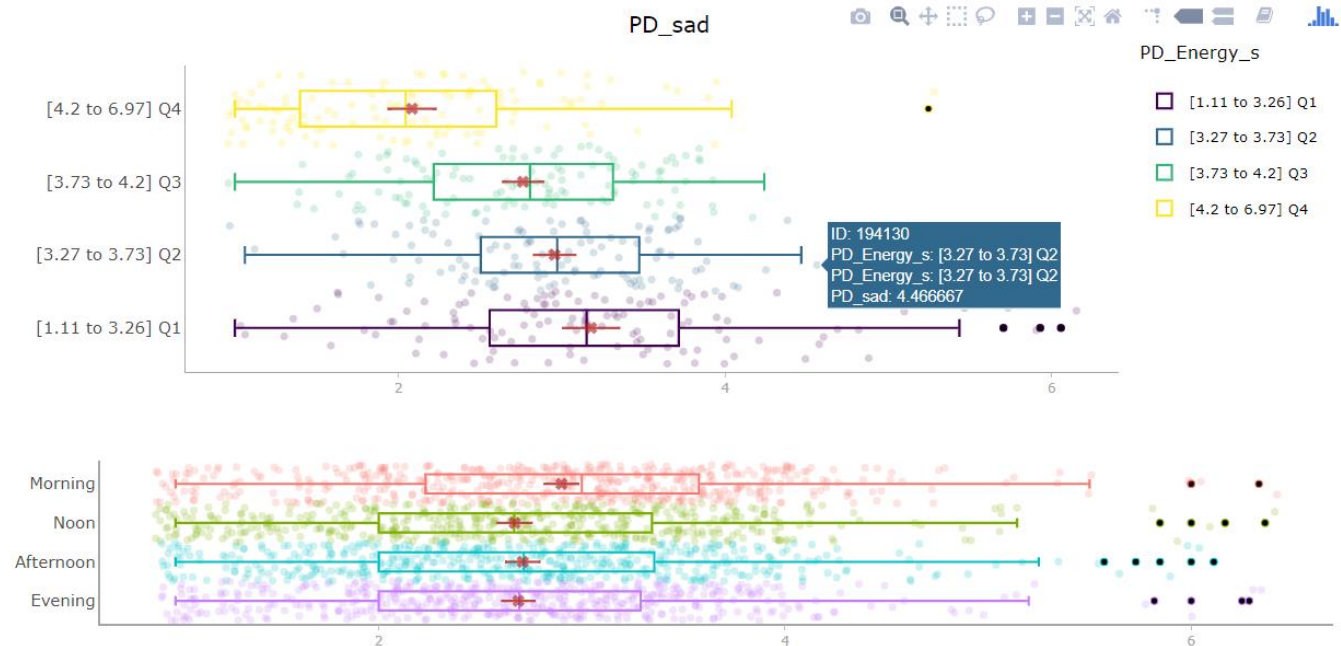
Random Variable Options

Choose Random Inputs:

☒ Main Var. ☒ Color Var.

Random Vars

Create/Update Plot



Using the App: Aggregate Level Exploratory Visuals (scatterplot)

Color Variable Options

Color By:
SEX

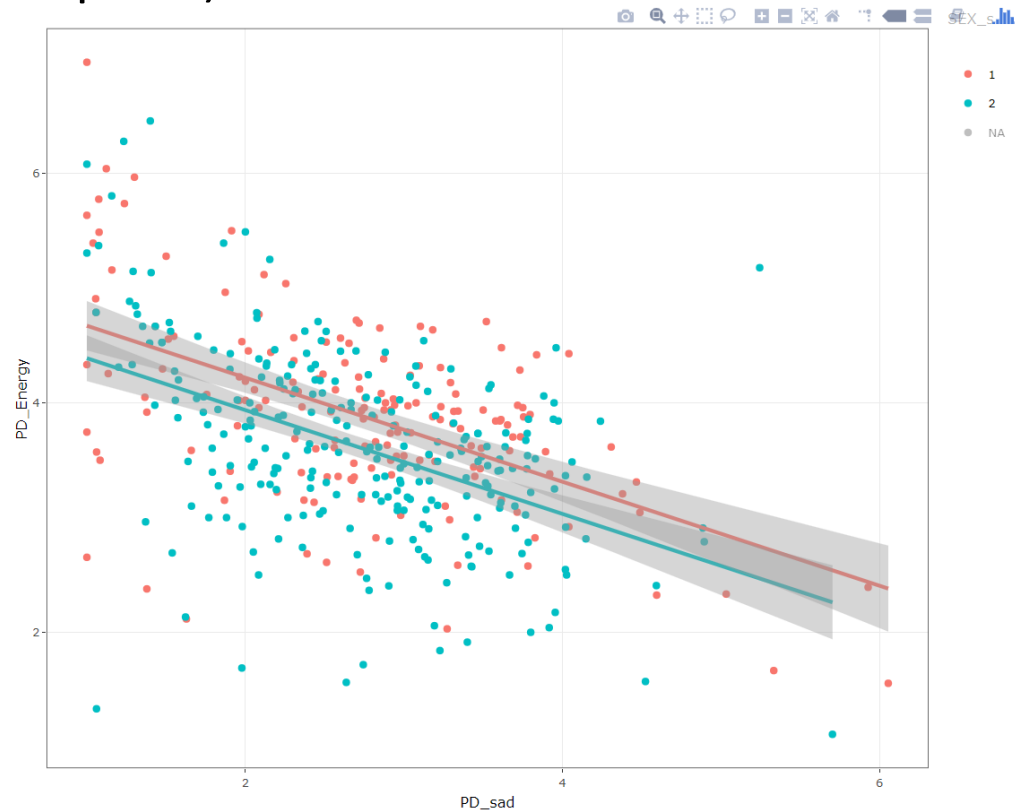
Color Variable Type:
☒ Raw ☐ Subject Normalized

Color Variable Level:
☒ Subject

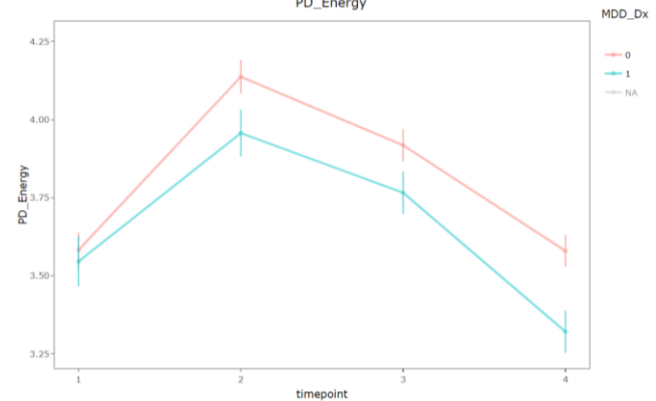
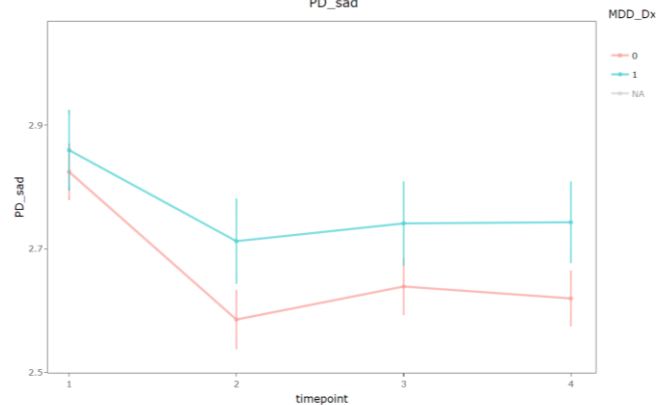
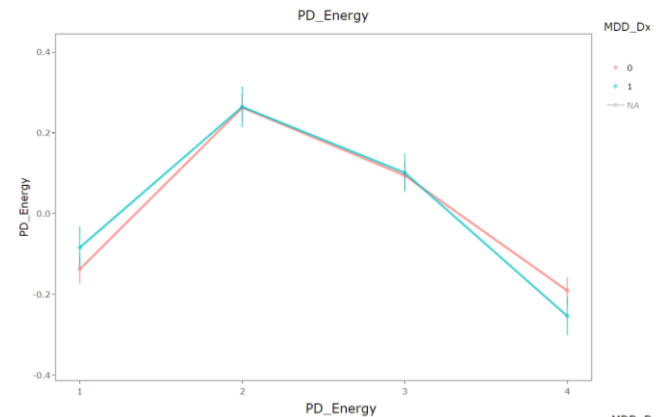
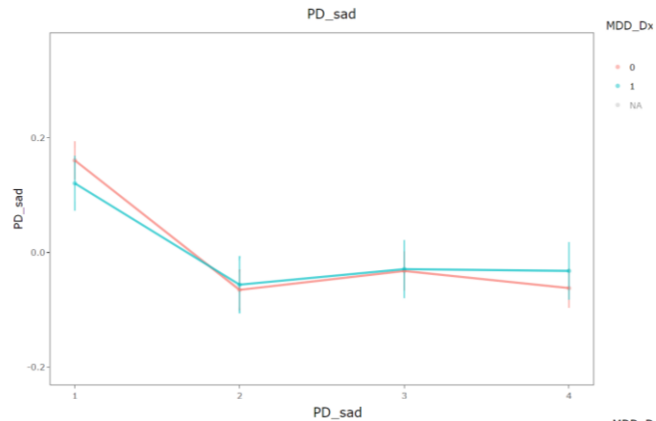
Quantiles:
☒ Auto ☐ On ☐ Off

Number of Quantiles:
2 4 10

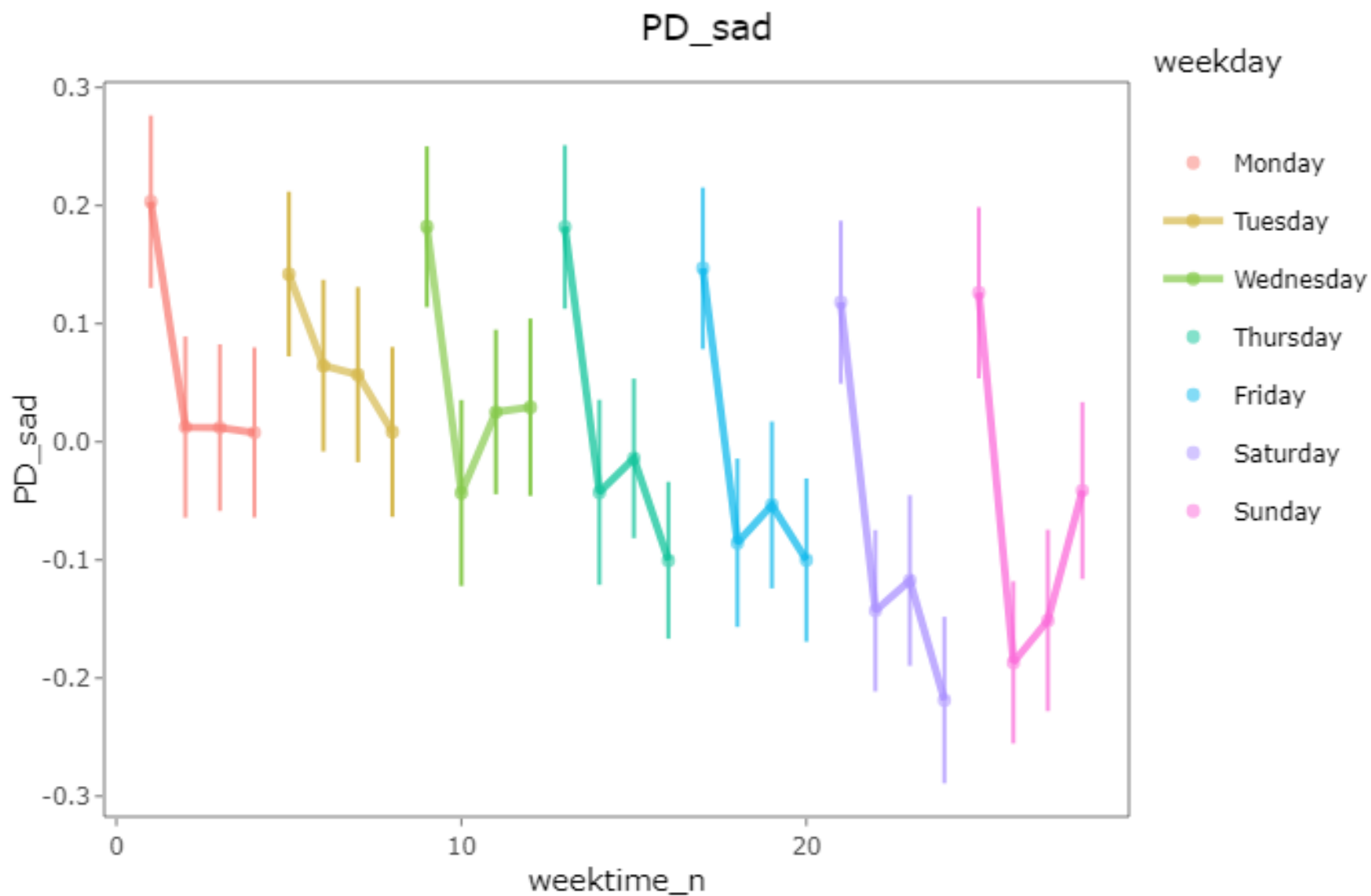
Create/Update Plot



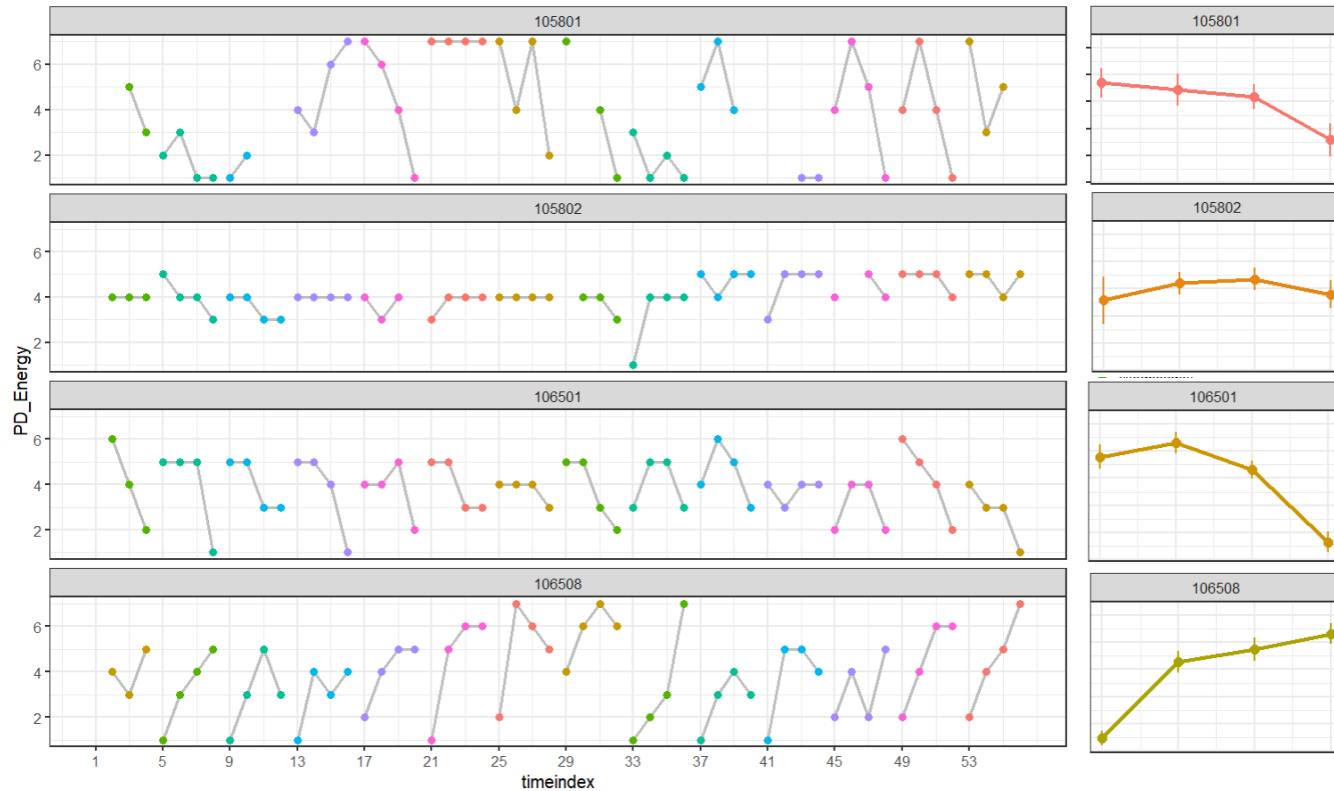
Using the App: Focus on temporal structure (trajectory plot)



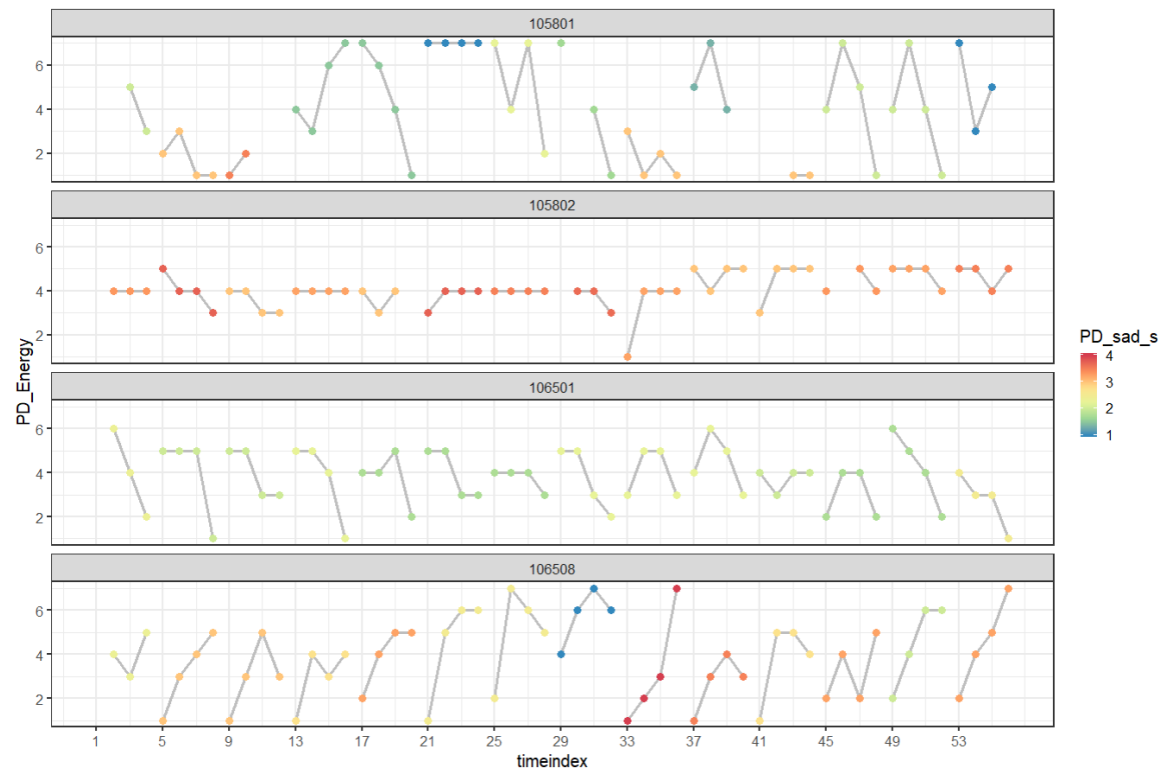
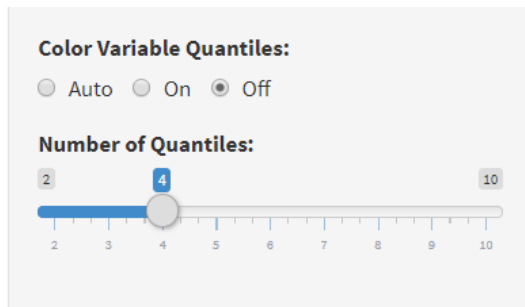
Mood



Using the App: Subject Level Visuals (subject browse)



Using the App: Subject Level Visuals (subject browse)



Important considerations

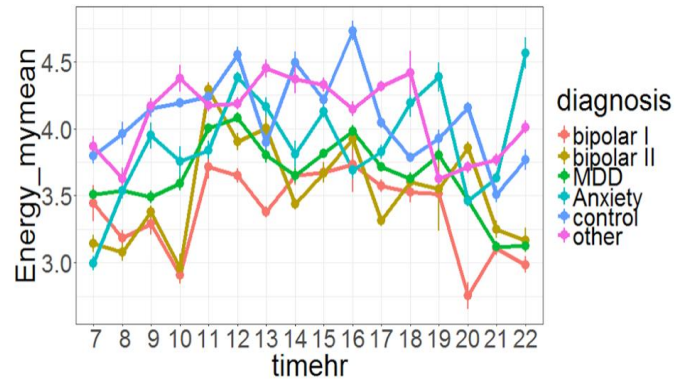
1. Normalization

- Normalize to the subject-specific internal time
- Estimate subject-specific diurnal pattern
- Understand subject-specific weekly pattern
- Do subject-specific normalization of the measurement (subjective scores)

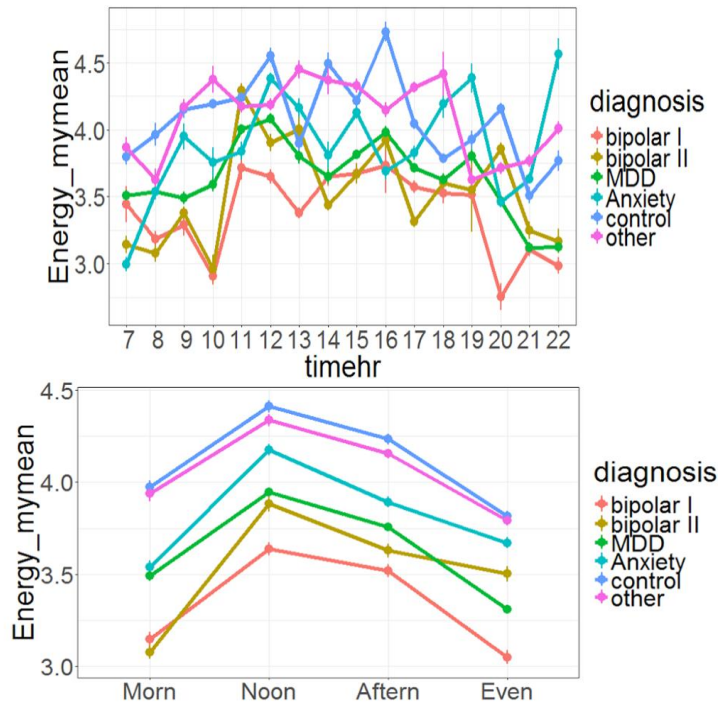
2. Standardization

- Using subject-specific standard deviation
- Using population-level/sample-based references

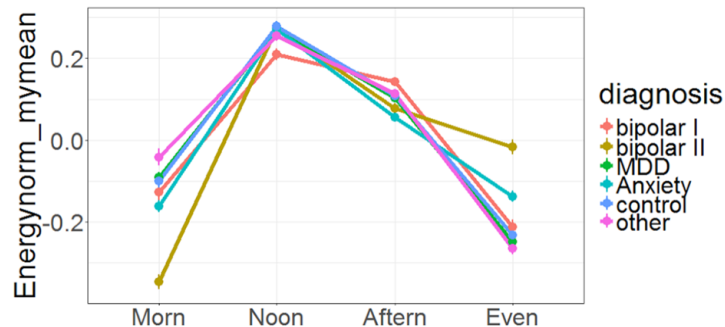
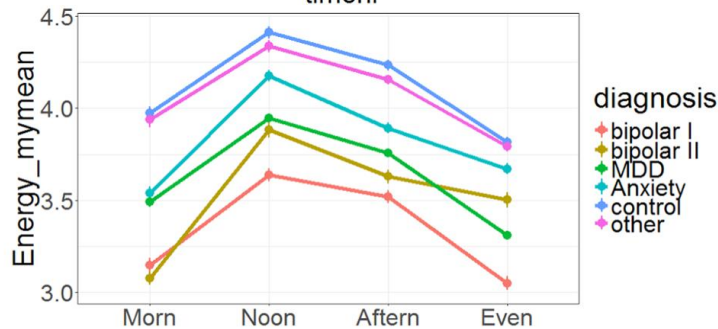
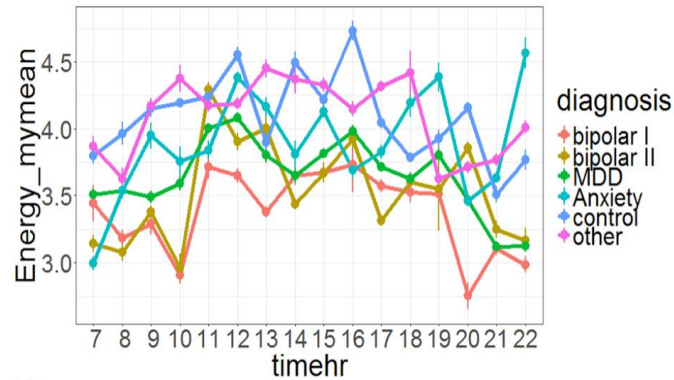
Steps 1 and 2: internal (wake) time and diurnal patterns



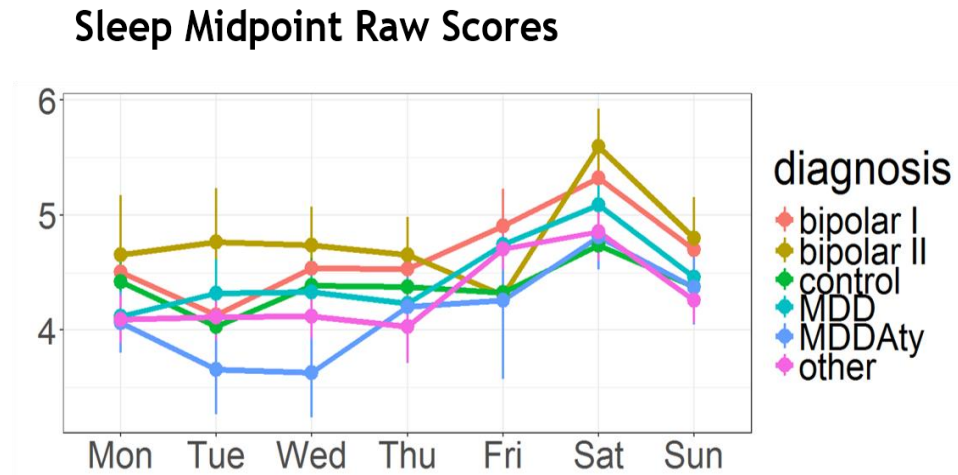
Steps 1 and 2: internal (wake) time and diurnal patterns



Steps 1 and 2: internal (wake) time and diurnal patterns

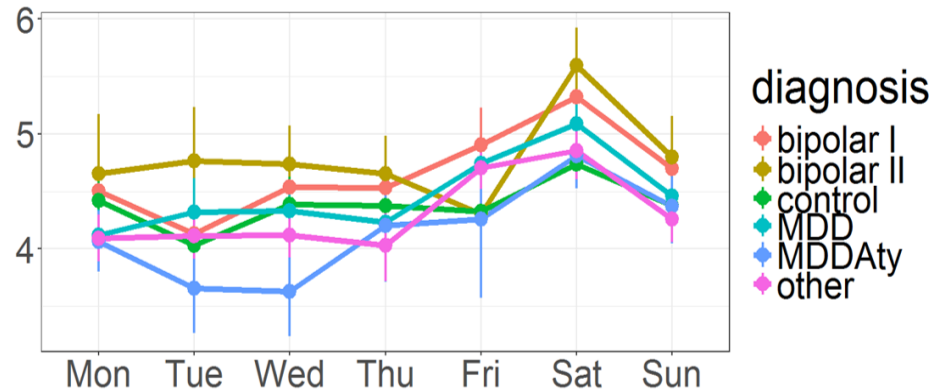


Step 3: Subject-specific weekly patterns

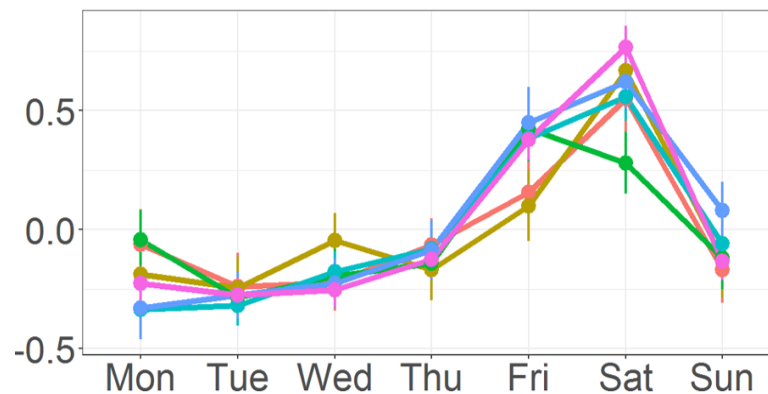


Step 3: Subject-specific weekly patterns

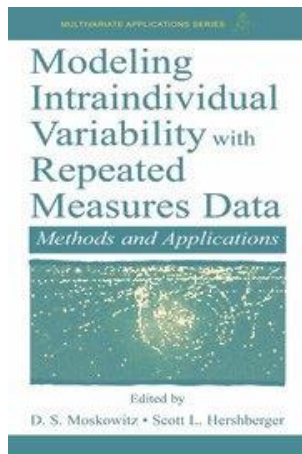
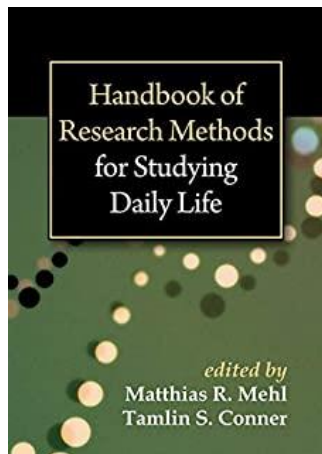
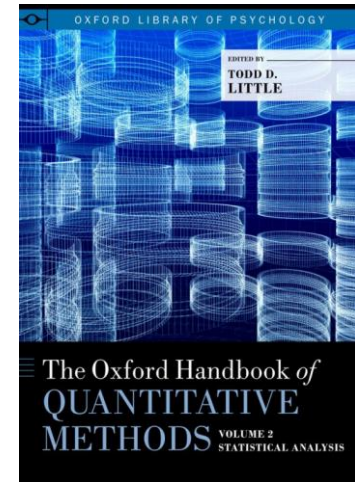
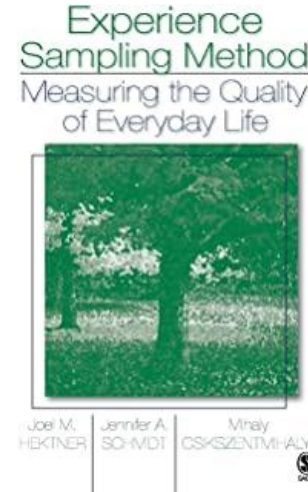
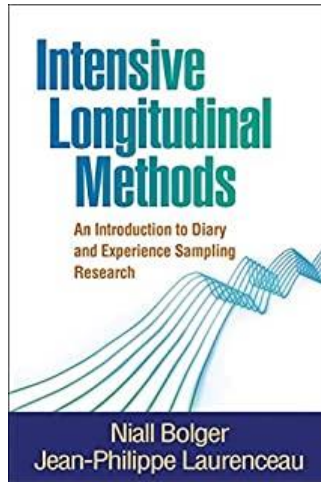
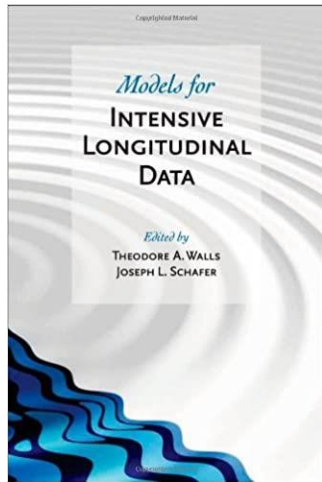
Sleep Midpoint Raw Scores



Sleep Midpoint Normalized



Literature



- https://jruwaard.github.io/aph_ema_handbook/
- <https://statmodel.com/> (M-plus)
- <https://www.methodology.psu.edu/ra/>

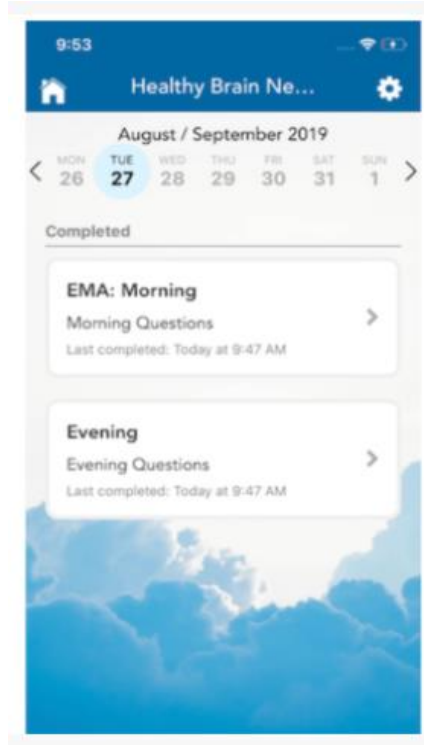
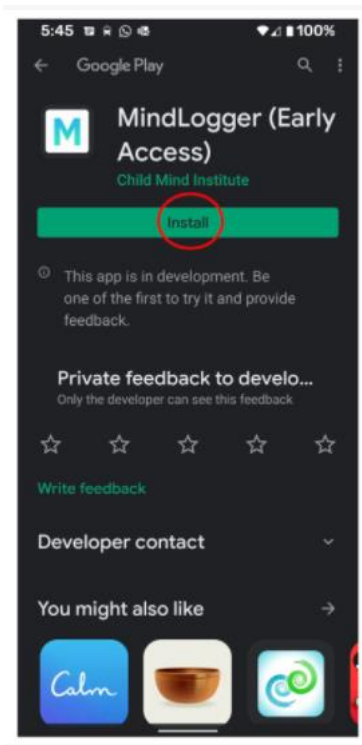
Modelling Software

- **lme4** and **nlme**: linear and nonlinear mixed effects models
- **refund**: functional data models
- **qgraph**: network visualization and analysis
- **lavaan**: growth curve models, structural equation models
- **dynr**: discrete and continuous time dynamic models

- **M-Plus**: dynamic structural equation modelling, growth curve models (bayesian)

App developers

- <https://mindlogger.org/> (iOS and Android, free)



App developers

- <https://mindlogger.org/> (iOS and Android, free)
- https://jruwaard.github.io/aph_ema_handbook/ema-instruments-catalogue.htm

MindLogger

data collection platform

The image displays five screenshots of the MindLogger app interface, arranged in two rows. The first row shows three screens from the 'MindLogger NIMH-EMA applet': 1. A sleep duration screen with an icon of a person sleeping and a clock, asking 'About how many hours did you actually sleep?' with radio button options: 'less than 30 minutes', '30 minutes', '1 hour', '1.5 hours', and '2 hours'. 2. A drink consumption screen asking 'Since you woke up, did you drink:' with checkboxes for 'water', 'milk', 'a caffeinated beverage (like coffee/tea/soda etc.)', 'an alcoholic beverage (wine/beer/liquor etc.)', 'a beverage containing sugar like juice or caffeine-free soda', and 'another type of drink:'. 3. A social context screen asking 'Who is with you at this moment?' with checkboxes for 'no one', 'family member', 'partner/boyfriend/girlfriend', 'friend', 'colleague or classmate', 'stranger', and 'a pet'. The second row shows two screens from the 'MindLogger DBT applet': 4. A sadness scale screen with a tree icon and a slider from 0 to 5. 5. An anger scale screen with a clock icon and a slider from 0 to 5. The final screen on the right is a mindfulness skills check screen with a brain icon, asking 'Please check the Mindfulness skills you used today:' with checkboxes for 'Wise Mind', 'Observe: Just notice without reacting', and 'Describe words on labels'. Each screen has a 'Back' button at the bottom, and the last screen has a 'Skip' button.

MindLogger NIMH-EMA applet

MindLogger DBT applet

- **Thank you!**