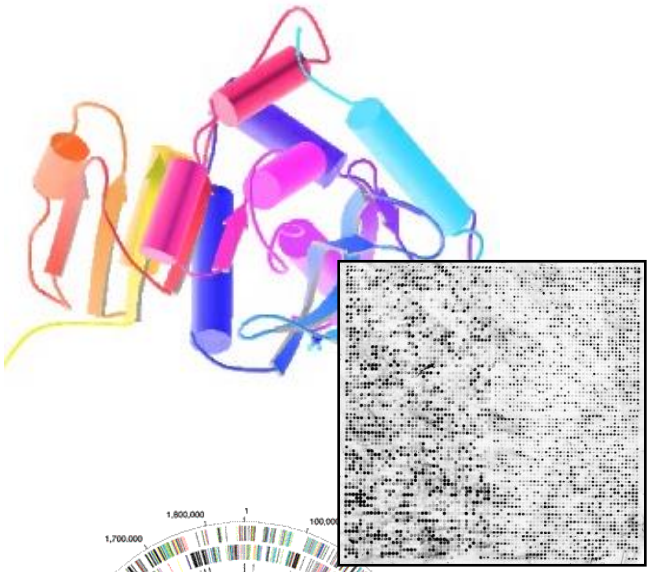
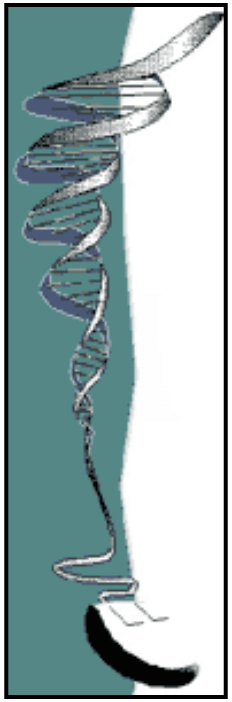
Biomedical Data Science:

Biosensor Analysis



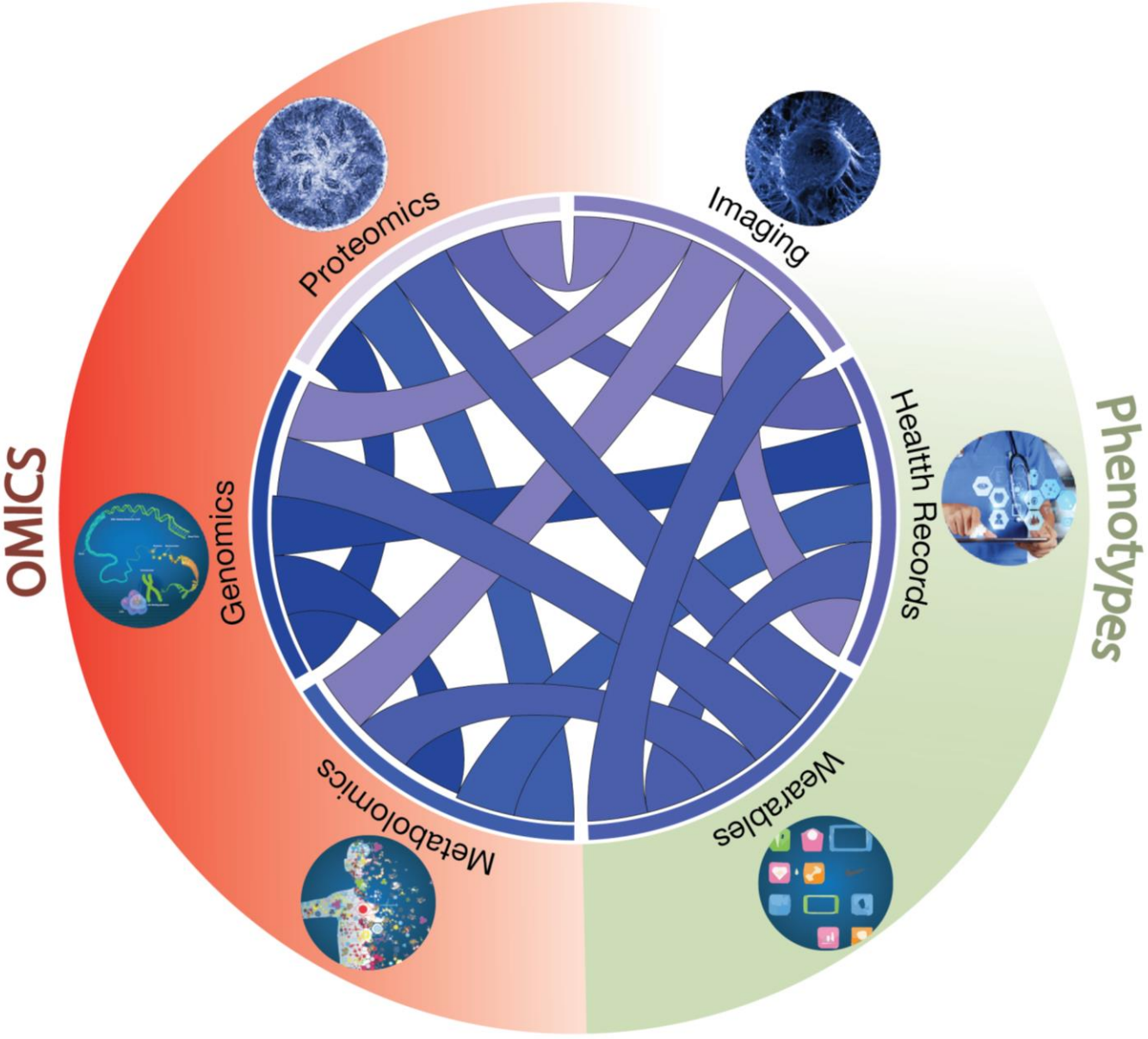


Mark Gerstein, Yale University

gersteinlab.org/courses/452

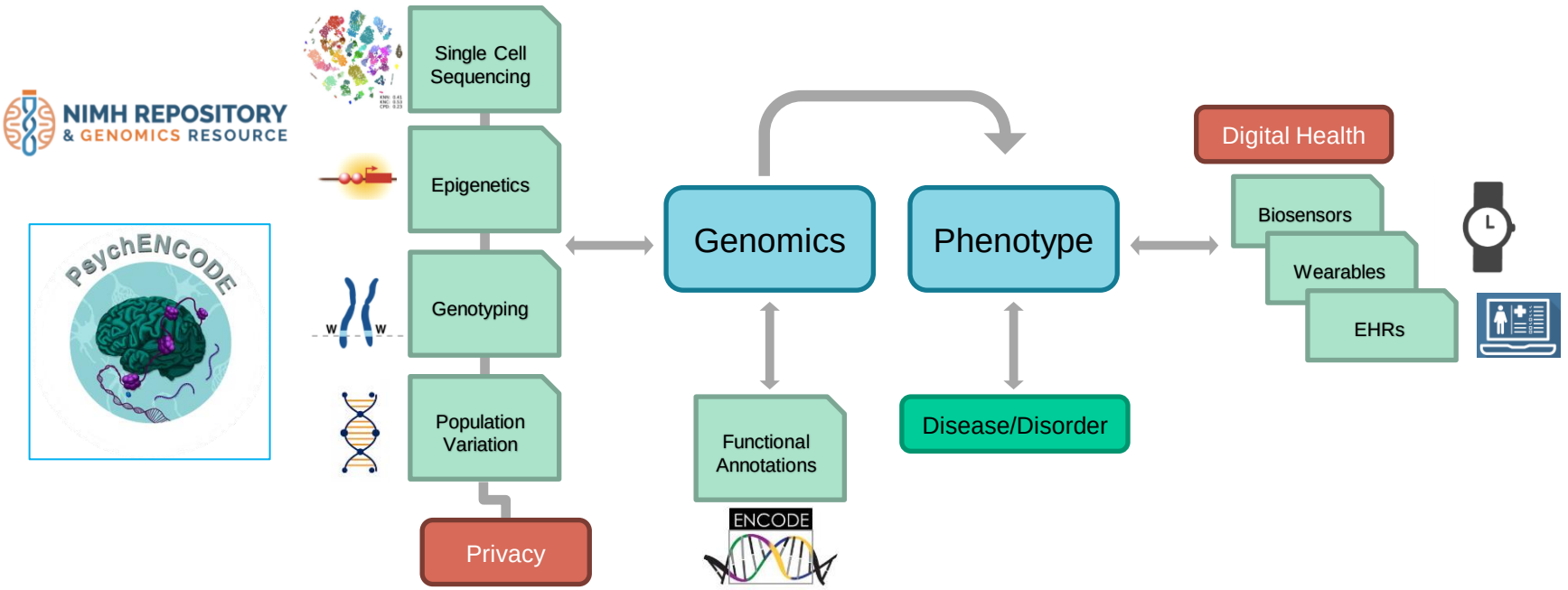
(Last edit in spring ’22. Pack 22m11, which has no counterpart in ‘21.)

Data Drivers for Biomedical Data Science

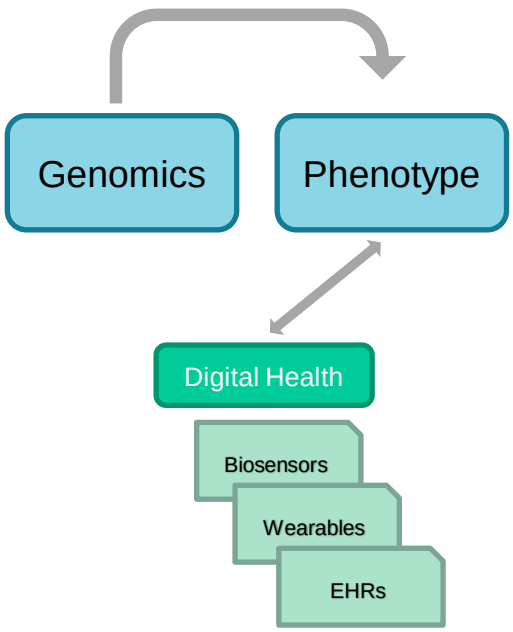


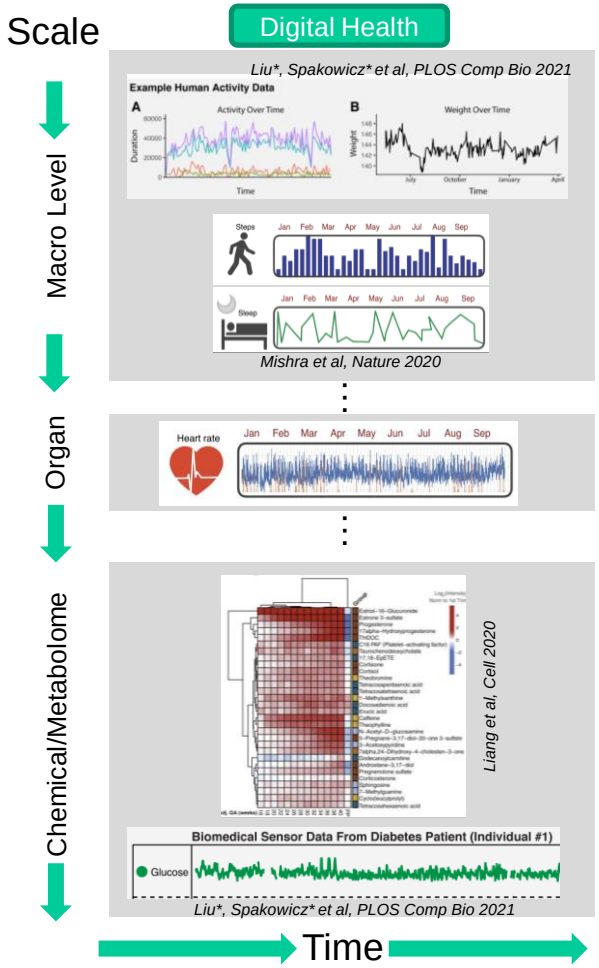
[Navarro et al. GenomeBiol. (’19)]

Genotype-Phenotype Correlations



Deep Phenotyping through Digital Health





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As mobile technology advances rapidly, the global mobile healthcare market is projected to be over 90 billion USD in 2022

(Lee SM, Lee D. Healthcare wearable devices: An analysis of key factors for continuous use intention. Service Business 2020; 12/01;14(4):503–531)

Biosensors

Direct Models of Sensor data

Wearable Sensors in Biomedical and Clinical Research

nature medicine

ARTICLES

https://doi.org/10.1038/s41591-021-01339-0

Check for updates

Wearable sensors enable personalized predictions of clinical laboratory measurements

Jessilyn Dunn[1,2,3,4,5,10] ✉, Lukasz Kidzinski[4,10], Ryan Runge[1,4], Daniel Witt[2,3], Jennifer L. Hicks[4], Sophia Miryam Schüssler-Fiorenza Rose[1,5,6], Xiao Li[1,7], Amir Bahmani[1], Scott L. Delp[4,8], Trevor Hastie[9] ✉ and Michael P. Snyder[1,5] ✉

Predicting Clinical Lab Values from Vitals taken from the Hospital vs Wearables

1) Compare  with

2) Build models of clinical labs

- Electrolytes
- Diabetes
- Cardiovascular disease
- Liver function
- Immune system
- Hematologic

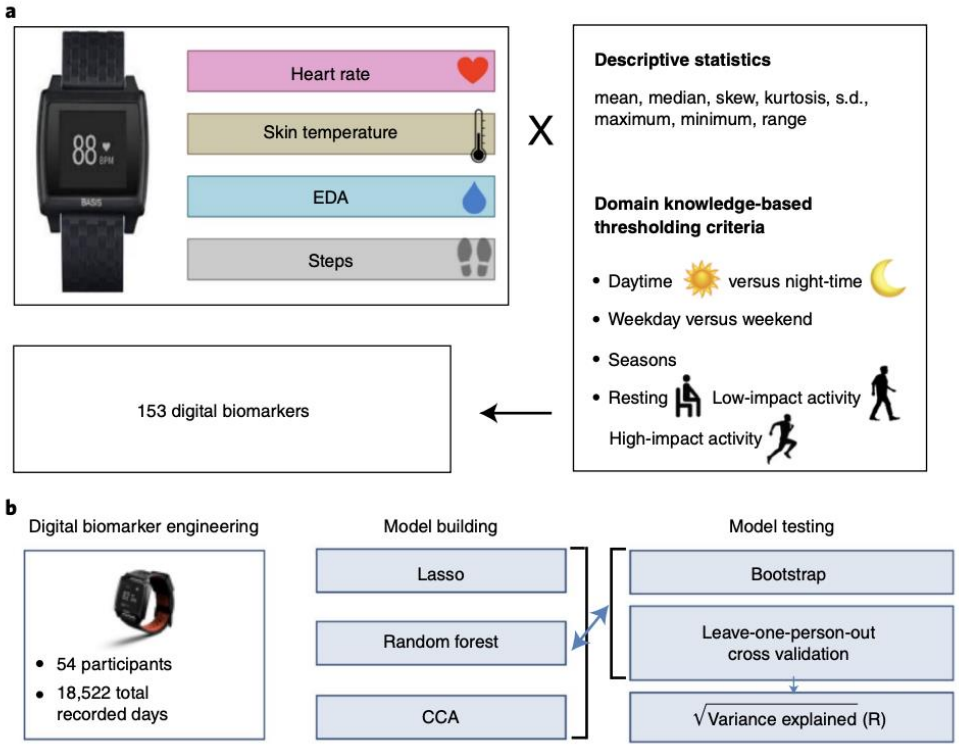
Lab Values to Predict

a

Electrolytes	Ca^{2+} , K^{+} , Cl^{-} , CO_2, Na^{+}, AG
Diabetes	HbA1c, ALB, GLU, UALB, CR, ALCRU
Cardiovascular disease	CHOL, LDLHDL, HDL, CHOLHDL, NHDL, TGL, LDL
Hepatic	ALKP, BUN, ALT, TBIL, AST
Immune system	LYM, LYMAB, MONO, MONOAB, NEUT, NEUTAB, IGM, EOS, EOSAB, BASO, BASOAB, WBC, HSCRP
Hematologic	PLT, GLOB, TP, HGB, HCT, RDW, MCH, MCV, RBC, MCHC

Engineering Wearable Features Used to Predict Clinical Lab Values

Wearable Features



Lab Values to Predict

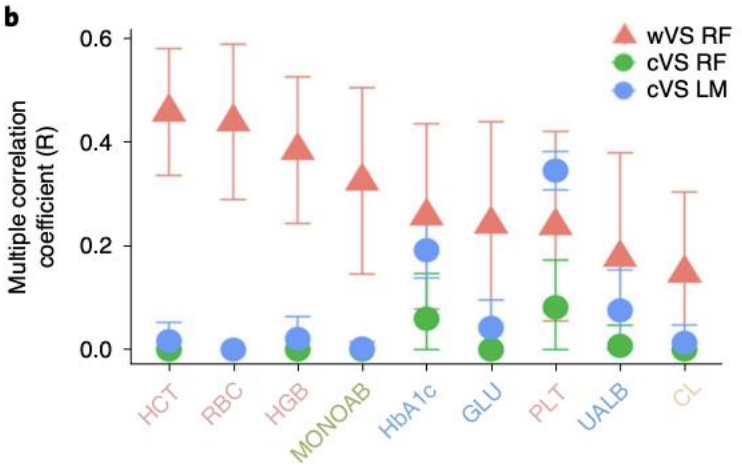
a

Electrolytes	Ca^{2+}, K^+, Cl^-, CO_2, Na^+, AG
Diabetes	HbA1c, ALB, GLU, UALB, CR, ALCRU
Cardiovascular disease	CHOL, LDLHDL, HDL, CHOLHDL, NHDL, TGL, LDL
Hepatic	ALKP, BUN, ALT, TBIL, AST
Immune system	LYM, LYMAB, MONO, MONOAB, NEUT, NEUTAB, IGM, EOS, EOSAB, BASO, BASOAB, WBC, HSCRP
Hematologic	PLT, GLOB, TP, HGB, HCT, RDW, MCH, MCV, RBC, MCHC

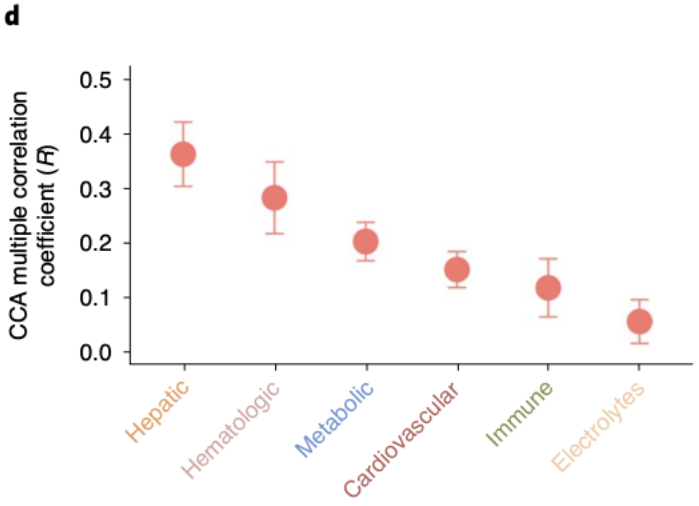
Prediction using Random Forest And Linear model (Lasso)

Correlation of Predicted and Observed Lab Values using Wearable vs Clinical Vital Signs

Comparing predictions between wearables and clinical vital signs



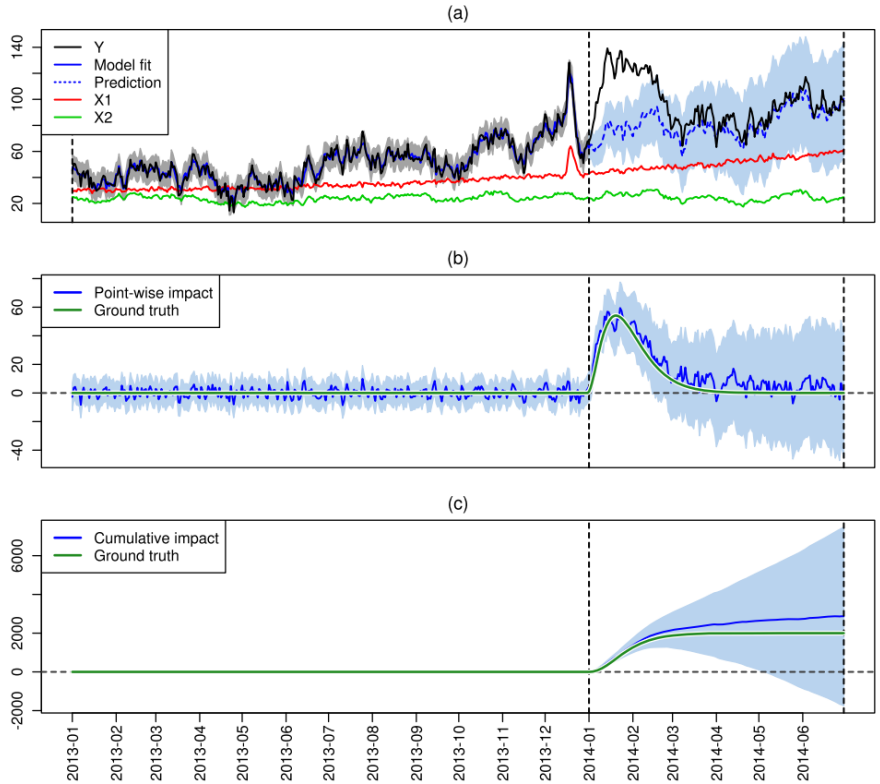
Overall CCA between predicted (wearable) and observed variables within each clinical category



Biosensors

Analysis of the Impact of an Intervention

Bayesian Structural Time Series and Causal Impact

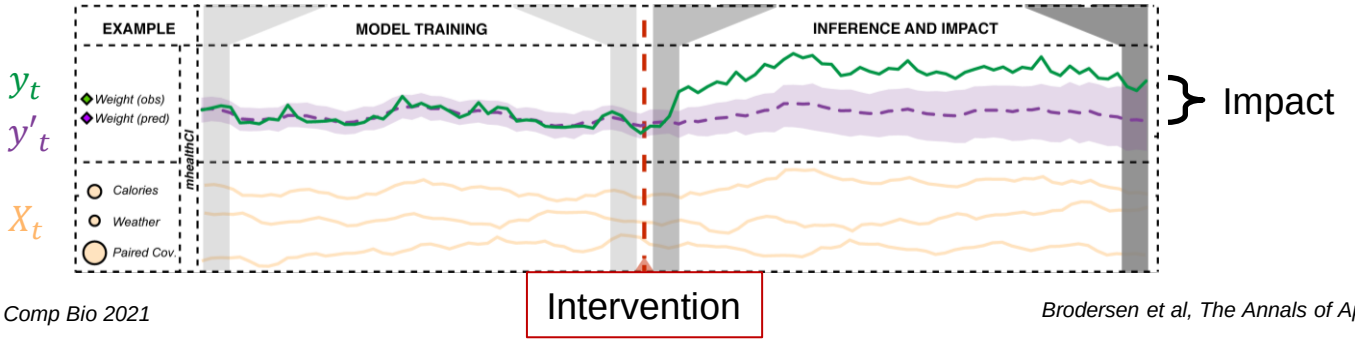


Brodersen et al

Bayesian Structural Time Series and Causal Impact

- Understanding the causal effect of an intervention as measured by biosensors
- As an example:
  - y_t : weight (observed)
  - y'_t : weight (predicted)
  - S_t : latent state variable
  - X_t : Covariates (calories, weather, etc.)

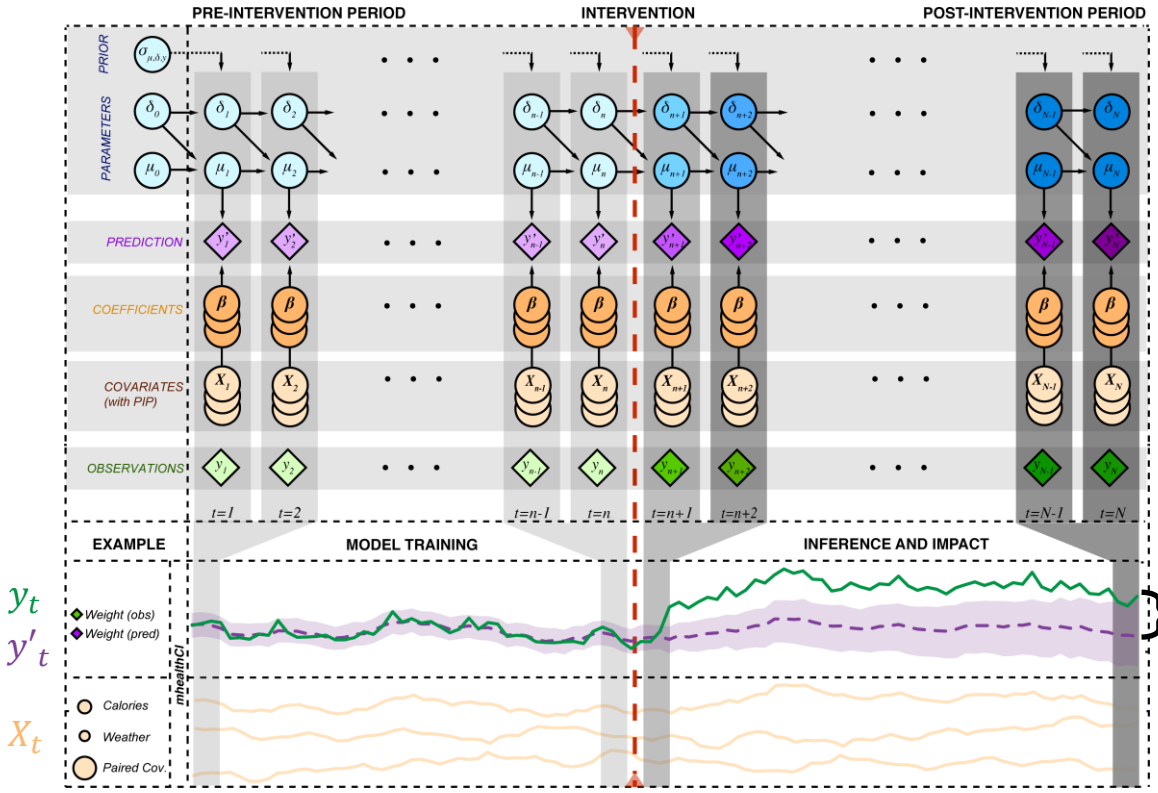
$$y_t = S_t + X_t\beta$$



Liu, Spakowicz* et al, PLOS Comp Bio 2021*

Brodersen et al, The Annals of App. Stat. 2015

Using a Bayesian Structural Time Series Framework for Modeling Biosensor Data to Evaluate Interventions



y_t

y'_t

X_t

$$y'_t = \mu_t + X_t\beta + e_t, e_t \sim N(0, \sigma_e^2)$$
$$\mu_{t+1} = \mu_t + \delta_t, \delta_t \sim N(0, \sigma_\delta^2)$$

- y_t : weight
- X_t : Covariates (calories, weather, etc.)
- e_t : error term
- μ_t : local level (unobserved trend)
- δ_t : slope

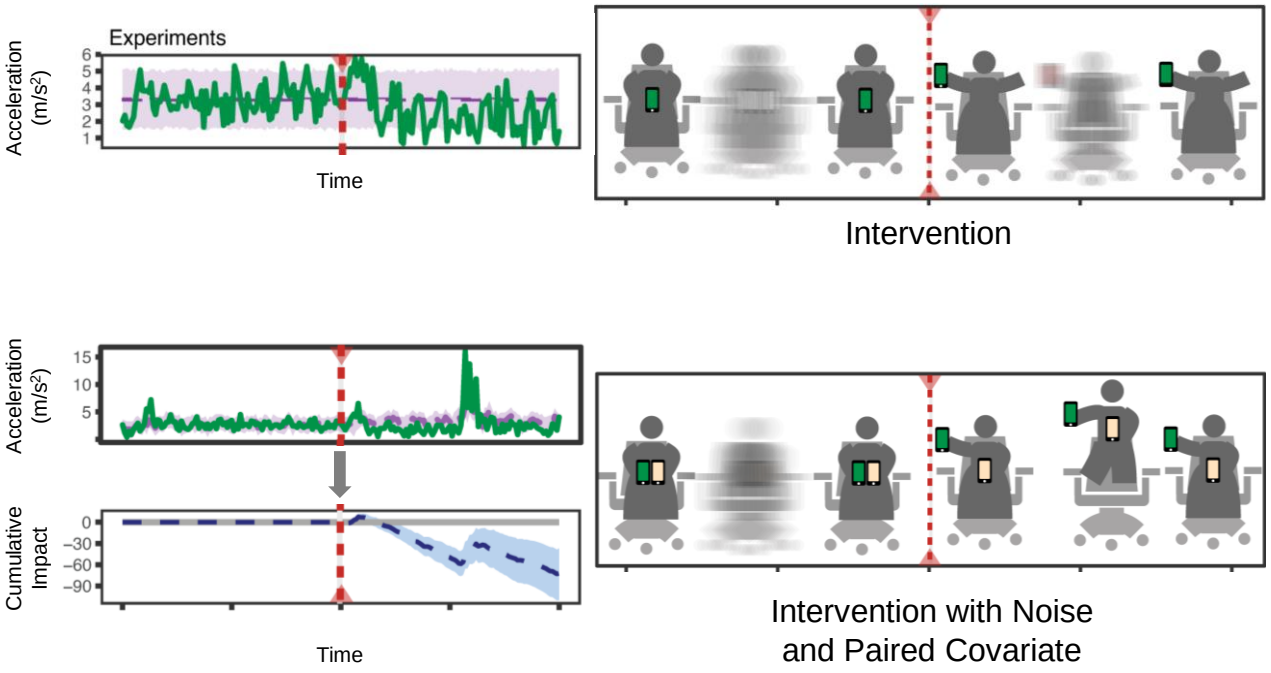
$$P(y'_{n+1:N} | y_{1:n})$$

} Impact

Liu, Spakowicz* et al, PLOS Comp Bio 2021*

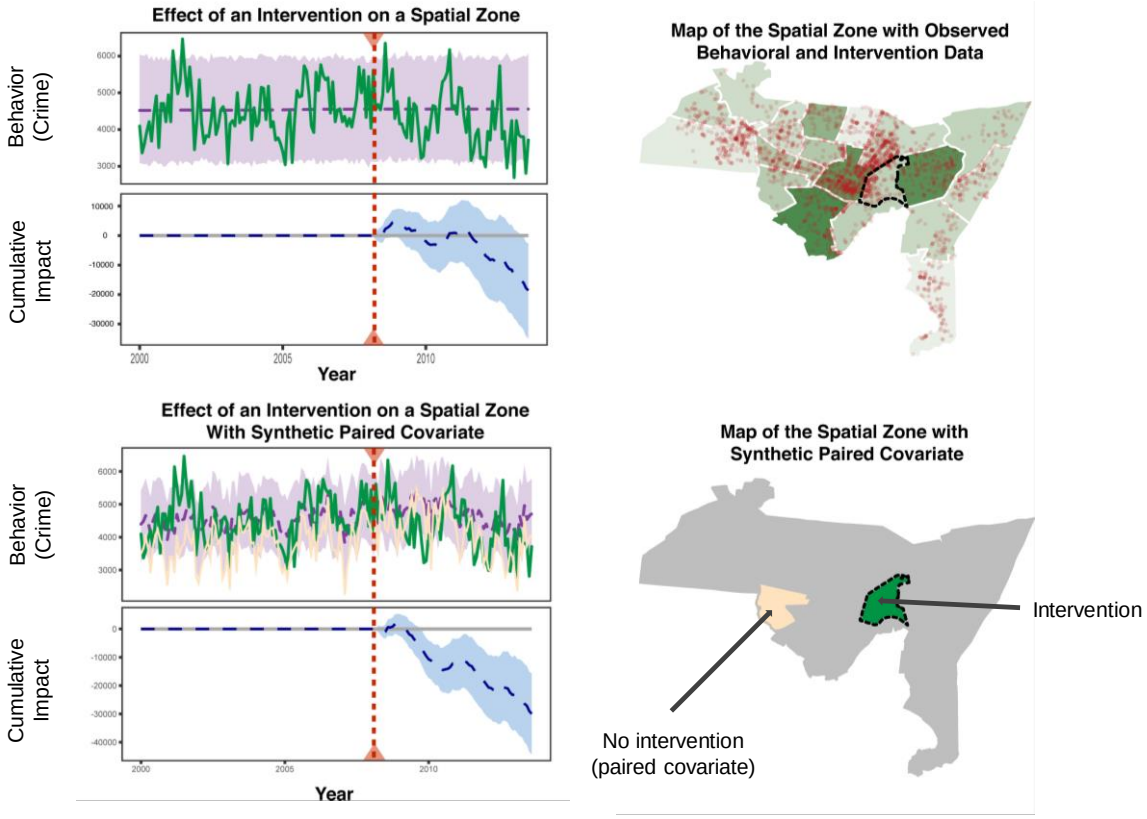
Brodersen et al, The Annals of App. Stat. 2015

Simple Ex of Performance on Biosensor Data



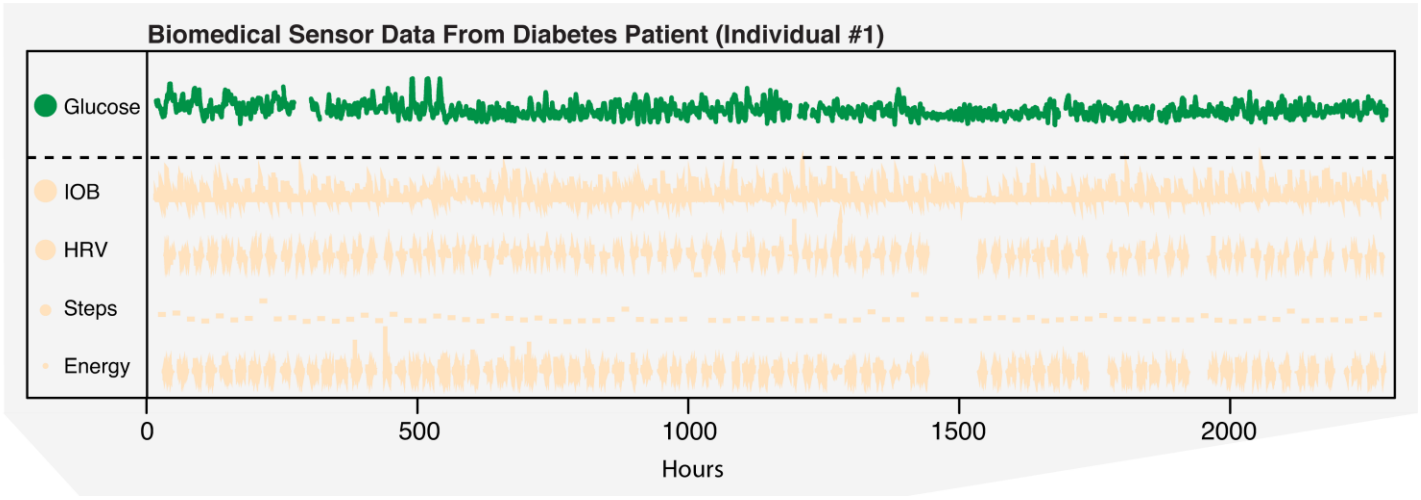
Liu, Spakowicz* et al, PLOS Comp Bio 2021*

Analyzing Behavioral Sensor Data using Paired and Spatial Covariates



Liu, Spakowicz* et al, PLOS Comp Bio 2021*

Collecting Biosensor and Wearable Data from Diabetes Patients



Evaluating The Efficacy of Exercise Regimens in Diabetes Patients