Northwestern

Northwestern University Feinberg School of Medicine

Department of Medical Social Sciences

# Third Coast CFAR: Core Services in Data and Computational Sciences

## Measurement in Behavioral HIV Research

**Patrick Janulis**

Assistant Professor

Third Coast CFAR

CENTER FOR AIDS RESEARCH IN CHICAGO

Northwestern

Institute for Sexual and Gender Minority Health and Wellbeing

CONNECT Complex Systems and Health Disparities Research Program

# Core Services in Data and Computational Sciences

- Traditional
  - Design and analysis planning
  - Power analysis

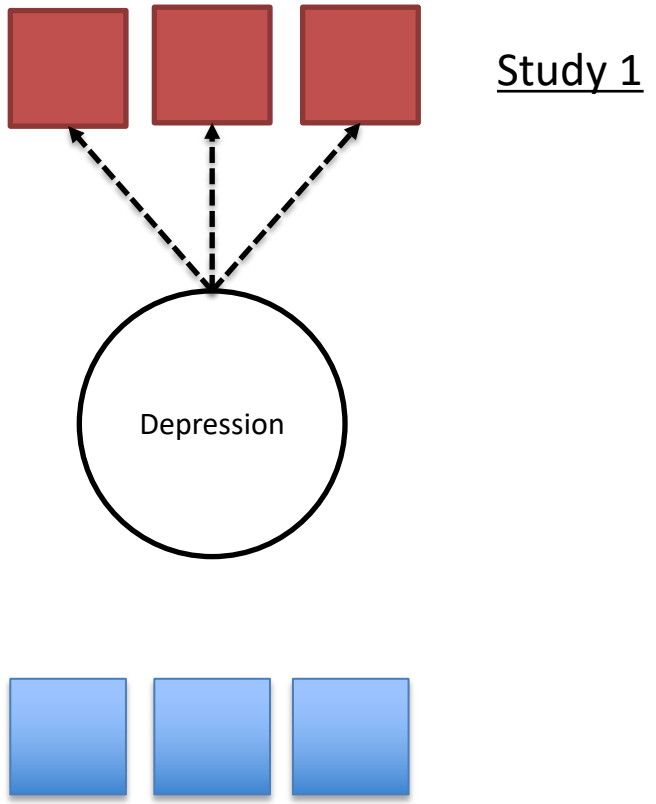
- Advanced
  - ***Psychometrics***
  - Social network analysis
  - Geographic information systems (GIS)
  - Agent-based modeling (ABMs)
  - Machine learning / data science
  - High performance computing

# Measurement in Behavioral HIV research

- Multiple groups at risk for HIV (e.g., PWID, MSM)
- Studies often focus on single group or subgroup
- Share common pathways and risk factors for transmission
- **Difficult to identify common and unique risk factors across groups without unified measurement**

# Psychometrics in Behavioral HIV research

- Data harmonization across studies limited by measurement differences
- Difference scales, phrasing, response options, or data collection methods
- Psychometrics (IRT) can be used to convert scores to translate across questionnaires
- Commonly used for comparing depression: CESD, PHQ9, and PROMIS



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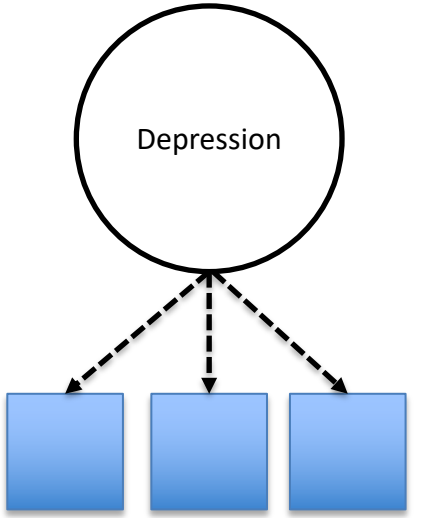
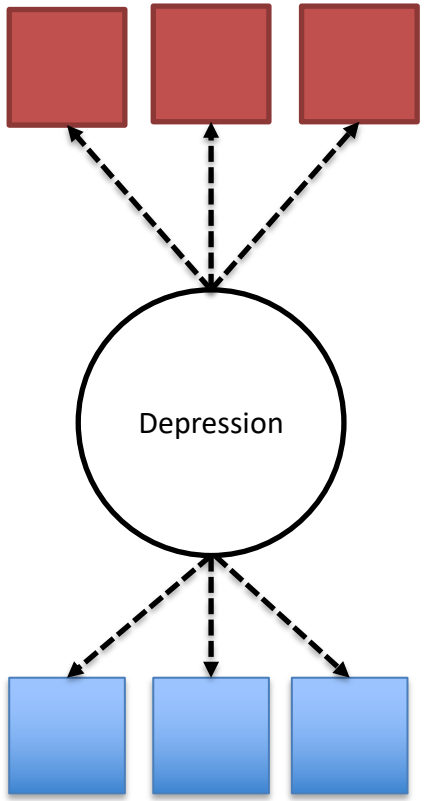


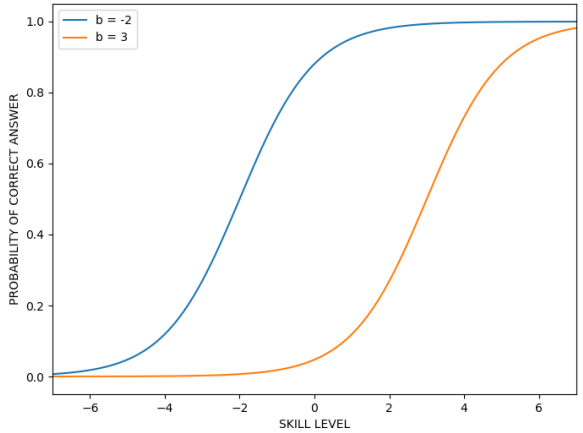

Study 2

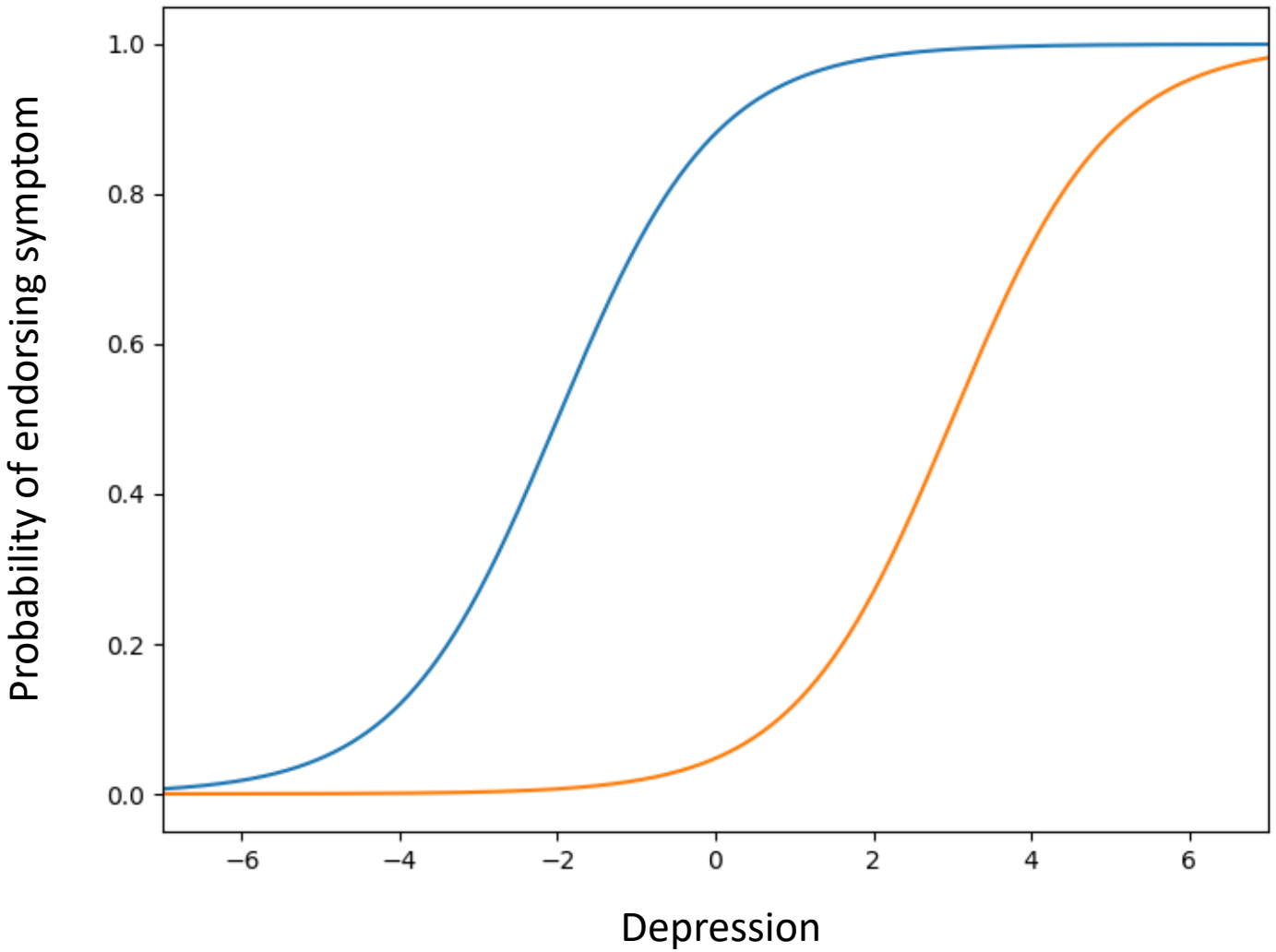
# Psychometrics in Behavioral HIV research

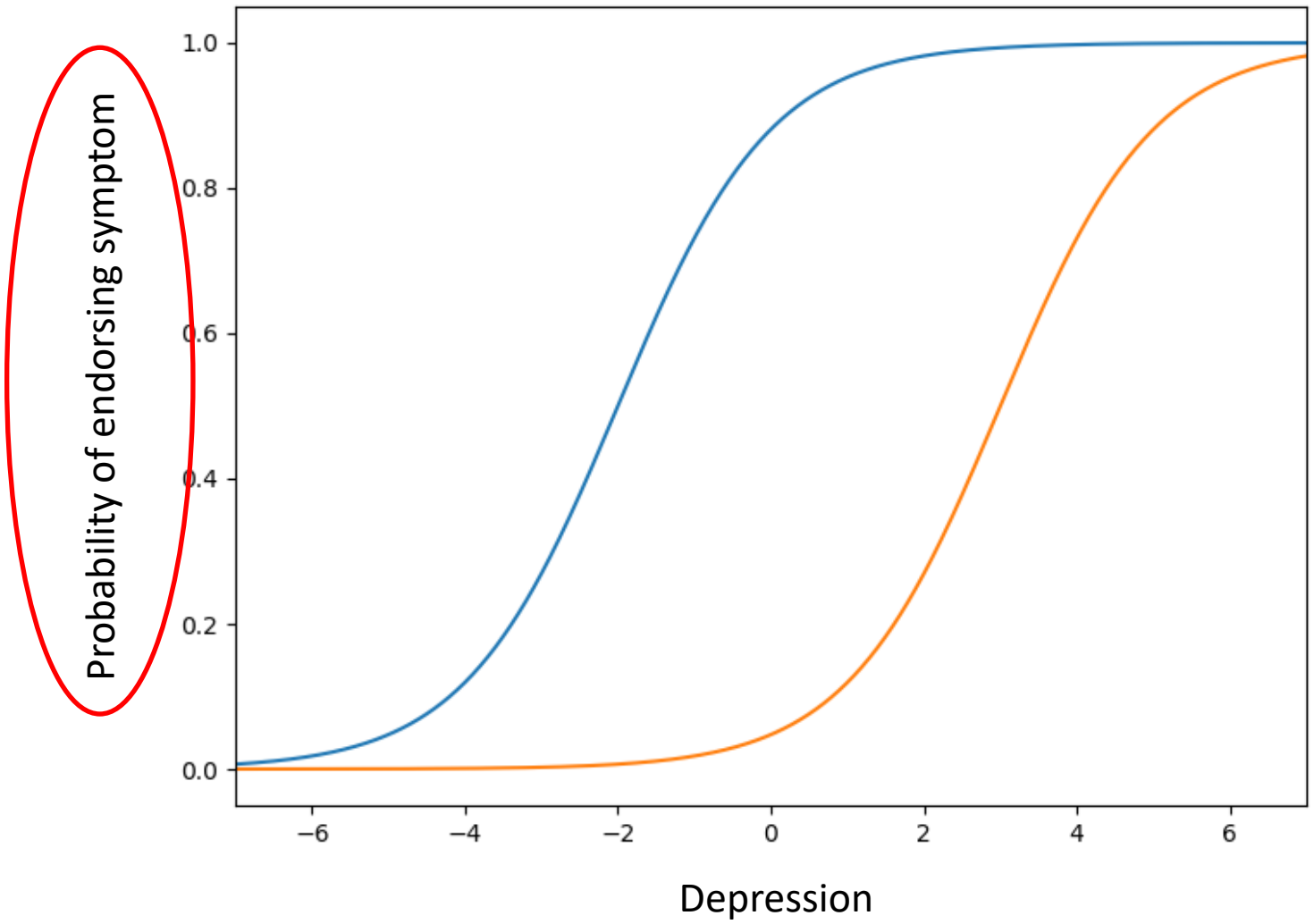
Study 3




$$P(X = 1|\theta, a, b) = \frac{e^{a(\theta-b)}}{1 + e^{a(\theta-b)}}$$




Probability of endorsing symptom
1.0
0.8
0.6
0.4
0.2
0.0
−6
−4
−2
0
2
4
6
Depression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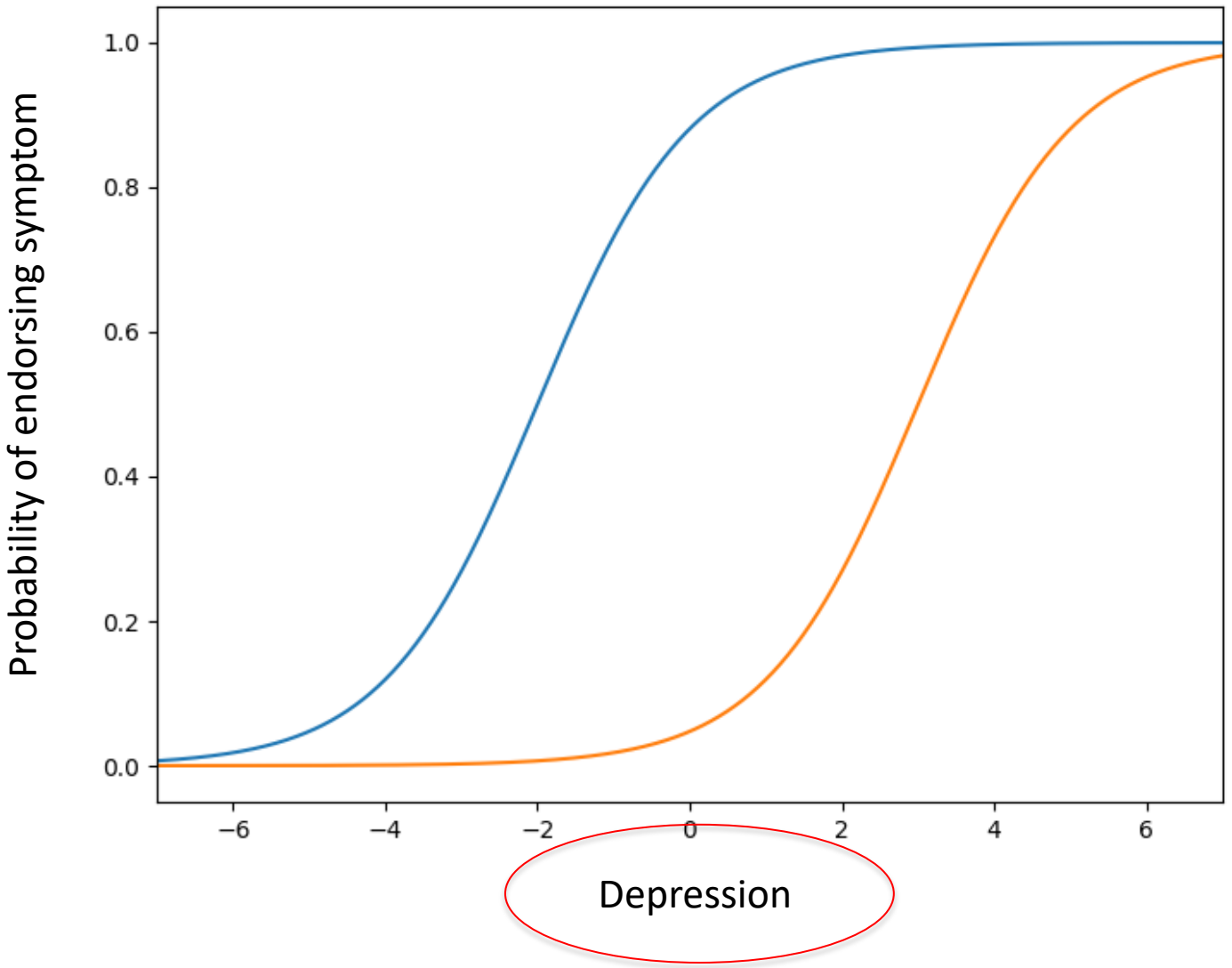
Probability of endorsing symptom
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0.8
0.6
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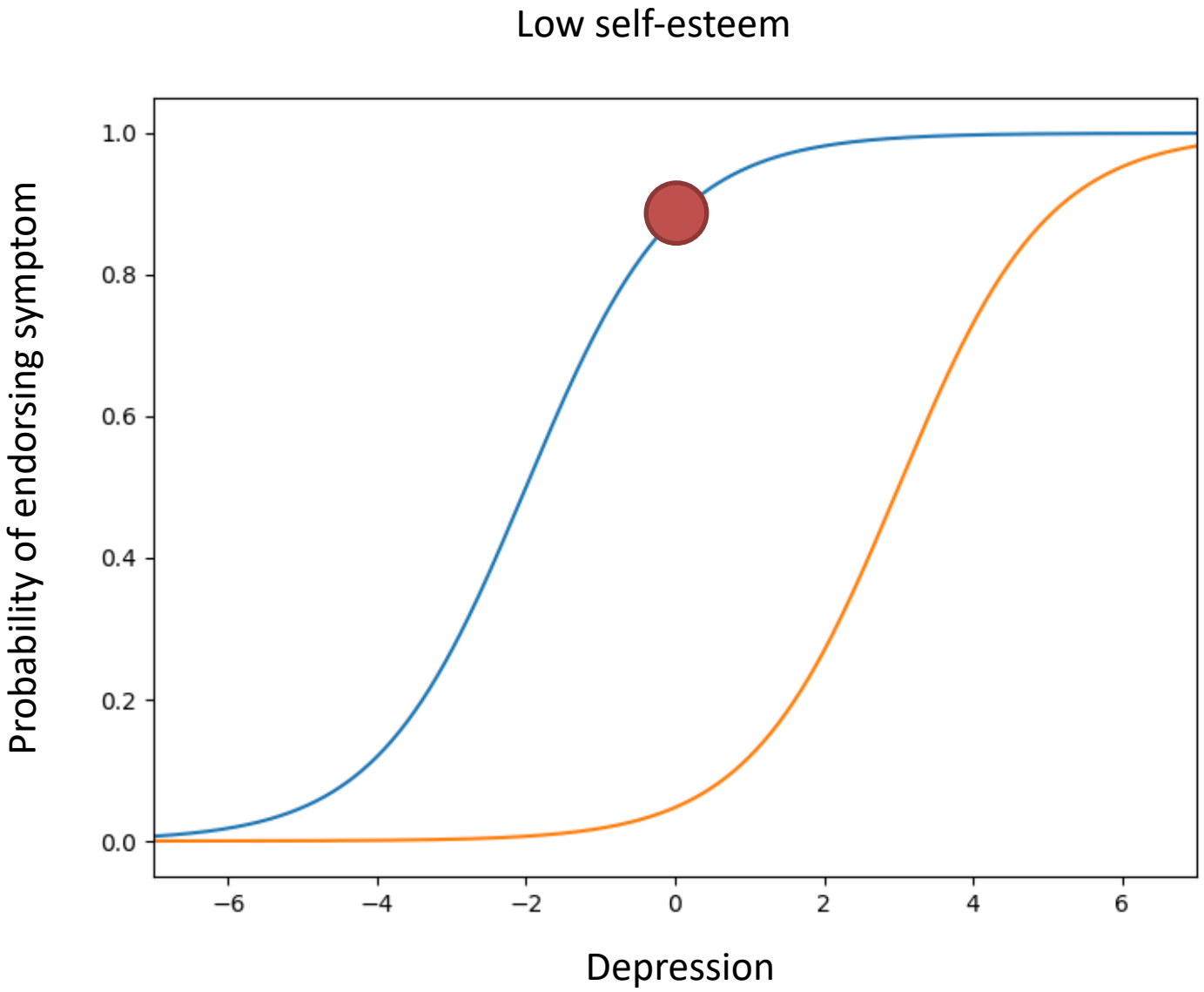
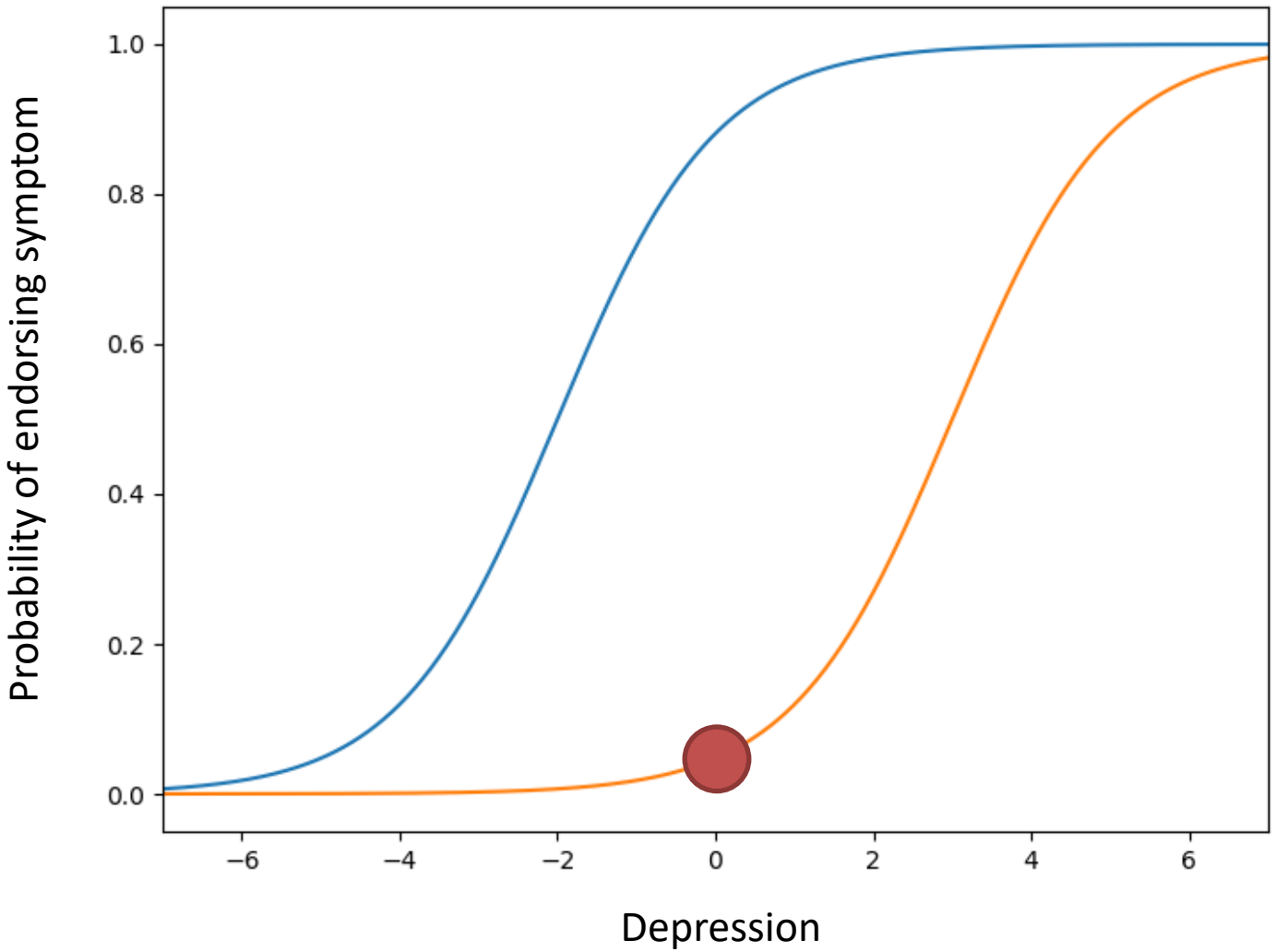
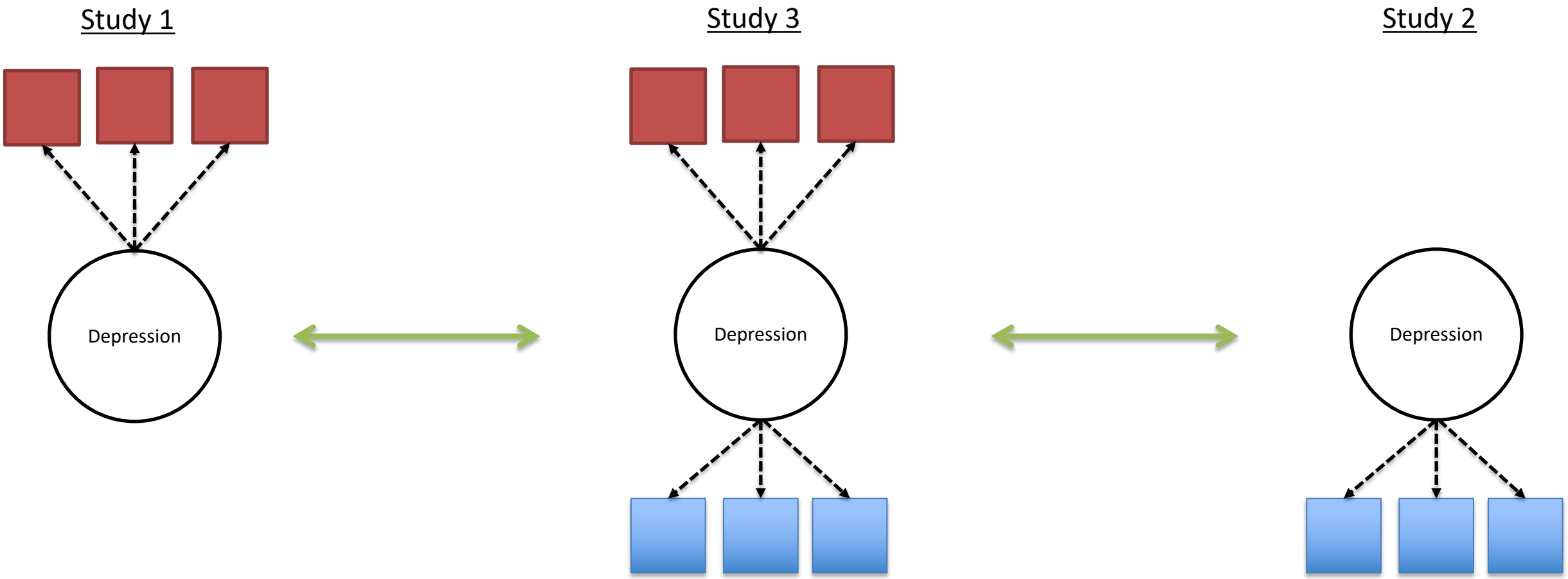
Depression


Low self-esteem
Probability of endorsing symptom
1.0
0.8
0.6
0.4
0.2
0.0
−6
−4
−2
0
2
4
6
Depression

Suicidal ideation



# Psychometrics in Behavioral HIV research



# Psychometrics in Behavioral HIV research

AIDS and Behavior
https://doi.org/10.1007/s10461-020-02883-5

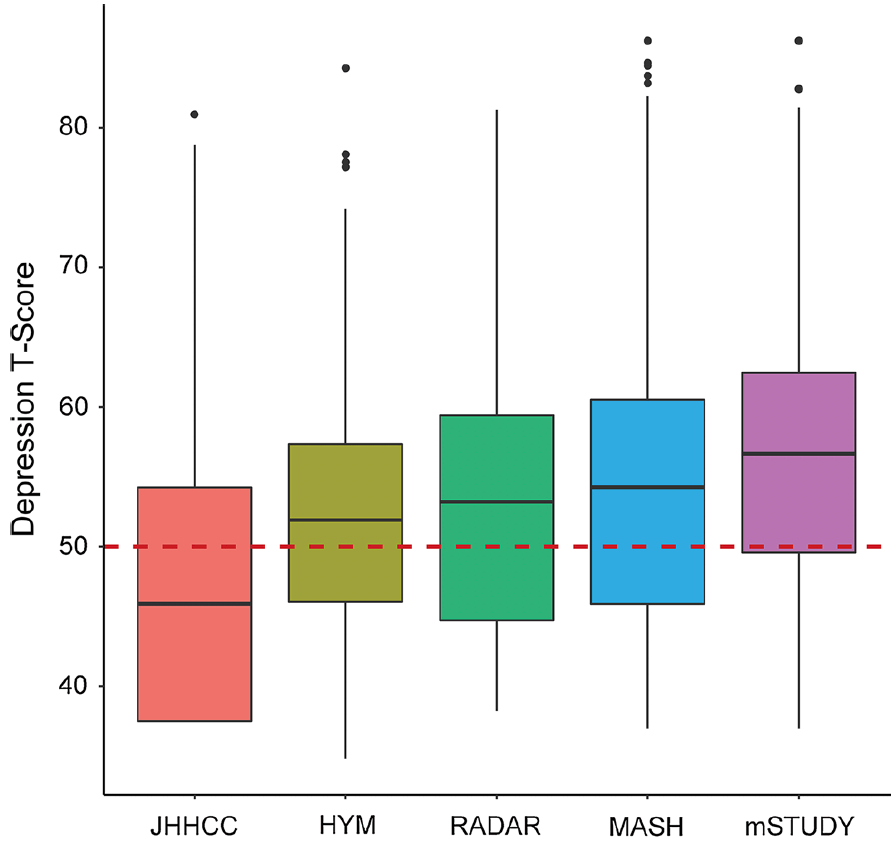
ORIGINAL PAPER

Check for updates

## Psychometric Data Linking Across HIV and Substance Use Cohorts

Benjamin D. Schalet[1] · Patrick Janulis[1,3] · Michele D. Kipke[2] · Brian Mustanski[1,3] · Steven Shoptaw[4] · Richard Moore[5] · Marianna Baum[6] · Soyeon Kim[7] · Suzanne Siminski[7] · Amy Ragsdale[8] · Pamina M. Gorbach[8,9]

C3PNO



# C3PNO and CFAR Supplements

C3PNO

- Alcohol, Smoking, and Substance Involvement Screen Test (ASSIST)
- Administering 2 different versions of ASSIST in three studies to enable comparisons across larger consortium
- Administer both version to 3 cohorts (JHHC, mSTUDY, ACCESS/V-DUS)
- Compare different time-frames, mode of administration (CASI vs. Face-to-face)

Supplement to U24 DA044554


- ASSIST, Drug Abuse Screening Test (DAST-10), and PROMIS Substance use severity
- Position PROMIS measure as common metric
- Administer all 3 measures to 5,000 participants from an online panel study
- Enable comparisons across cohorts and future studies that use only one of these measures

Supplement to P30 AI117943

# HIV Knowledge and CAS

Arch Sex Behav (2018) 47:107–119
https://doi.org/10.1007/s10508-016-0910-4

ORIGINAL PAPER

## Evaluating HIV Knowledge Questionnaires Among Men Who Have Sex with Men: A Multi-Study Item Response Theory Analysis

Patrick Janulis[1] · Michael E. Newcomb[1] · Patrick Sullivan[2] · Brian Mustanski[1]

**Table 2** Items and study

| | Question | % correct | Crew 450 | KIU! 1.0 | TRACK | InvolveMENt | InvolveMENt Pilot | KIU! 2.0 |
|---|---|---|---|---|---|---|---|---|
| 1 | Coughing and sneezing do NOT spread HIV | 83.2 | X | X | X | X | X | |
| 2 | A person can get HIV by sharing a glass of water with someone who has HIV | 90.4 | X | X | X | X | X | |
| 3 | Pulling out the penis before a male climaxes/cums keeps a person from getting HIV | 87.7 | X | X | X | X | X | X |
| 4 | A person can get HIV from having anal sex | 90.9 | X | X | X | | X | X |
| 5 | Showering or washing one's genitals/private parts after sex keeps a person from getting HIV | 88.8 | X | X | X | X | X | |
| 6 | All pregnant females infected with HIV will have babies born with HIV [or AIDS] | 69.1 | X | | X | X | X | |
| 7 | People who have been infected with HIV quickly show serious signs of being infected | 91.4 | X | X | X | X | X | X |
| 8 | There is a vaccine that can stop people (or adults) from getting HIV | 80.5 | X | X | X | X | X | X |
| 9 | People are likely to get HIV by deep kissing, putting their tongue in a partner's mouth, if their partner has HIV [and cuts in their mouth] | 65.4 | X | X | X | X | X | X |
| 10 | It is possible to get HIV when a person gets a tattoo if the equipment is not properly cleaned | 82.7 | X | X | X | | | |
| 11 | Using a latex condom or rubber can lower a person's chance of getting HIV | 93.9 | X | X | X | | | X |
| 12 | A natural skin [lamb skin] condom works better against HIV than does a latex condom | 59.5 | X | X | X | X | X | X |

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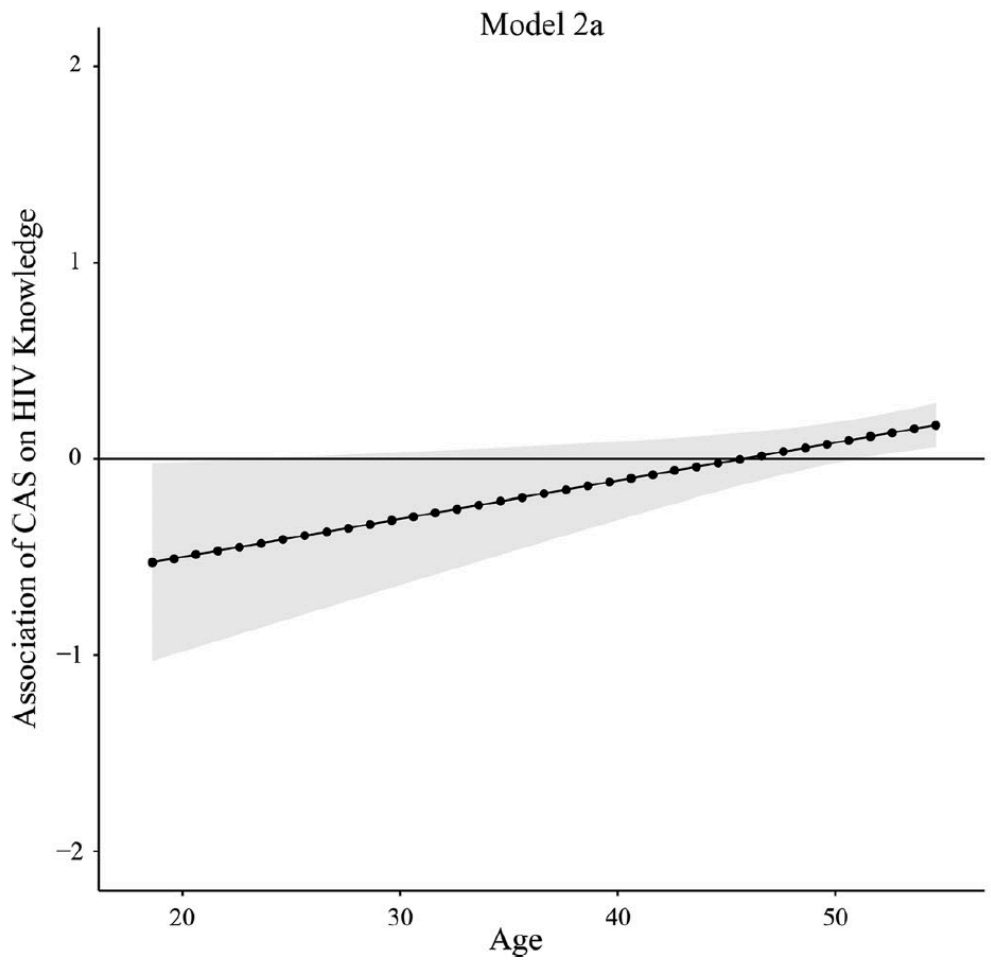

# IRT and Injection Behavior

The American Journal of Drug and Alcohol Abuse

http://informahealthcare.com/ada
ISSN: 0095-2990 (print), 1097-9891 (electronic)

Am J Drug Alcohol Abuse, 2014; 40(2): 143–150
 DOI: 10.3109/00952990.2013.848212

informa healthcare

ORIGINAL ARTICLE

**Improving measurement of injection drug risk behavior using item response theory**

Patrick Janulis, MS

| | Item | |
|---|---|---|
| 6 months | 1 | Used a dirty syringe |
| | 2 | Used a previously used cooker, cotton or risk water |
| | 3 | Shared the same ''works'' |
| 30 days | 4 | Injected in last 30 days |
| | 5 | Shared dirty needles |
| | 6 | Used previously used cooker, cotton or risk water |
| | 7 | Injected with other people |
| | 8 | Shared the same ''works'' |
| | 9 | Give or loan used needles without cleaning |
| Ever | 10 | Share works with HIV+ partner |

Table 3. Male/female model parameters and differential item functioning statistic.

| | | $\beta$ | | | $\alpha$ | | |
|---|---|---|---|---|---|---|---|
| Item | Overall | Male | Female | Uniform | Male | Female | Non-uniform |
| 1 | 0.49 | 0.717 | 0.025 | 0.34 | 13.395 | 5.124 | 0.15 |
| 2 | 5.33 | 0.596 | −0.318 | 4.74* | 3.580 | 4.332 | 0.58 |
| 3 | 2.53 | 0.445 | −0.541 | 2.51 | 6.892 | 20.547 | 0.03 |
| 5 | 3.86 | 0.868 | 0.261 | 1.11 | 4.495 | 6.109 | 2.75 |
| 6 | 9.78** | 0.697 | −0.168 | 7.53** | 14.505 | 3.156 | 2.25 |
| 7 | 0.88 | −0.550 | −0.861 | 0.83 | 1.179 | 1.933 | 0.05 |
| 8 | 10.65** | 0.659 | −0.170 | 3.75 | 34.251 | 4.828 | 6.90** |
| 9 | 1.78 | 1.150 | 0.454 | 0.57 | 1.162 | 1.570 | 1.21 |
| 10 | 0.46 | 4.965 | 4.322 | 0.43 | 0.700 | 0.631 | 0.03 |

*$p<0.05$, **$p<0.01$

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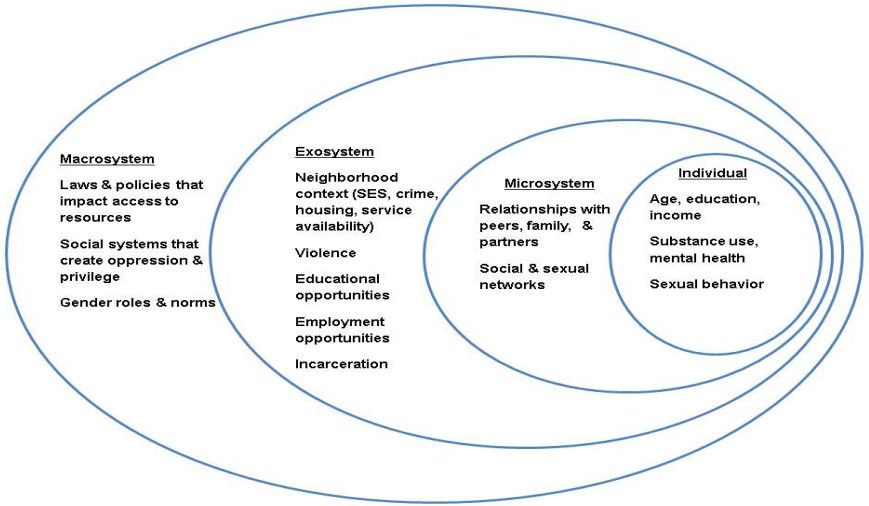
# UNDERSTANDING SOCIO-STRUCTURAL DRIVERS OF HIV TRANSMISSION USING EPIDEMIOLOGY AND SYSTEMS SCIENCE




**ANNA HOTTON, PHD, MPH**

Research Assistant Professor
Department of Medicine
Chicago Center for HIV Elimination
University of Chicago, Chicago IL

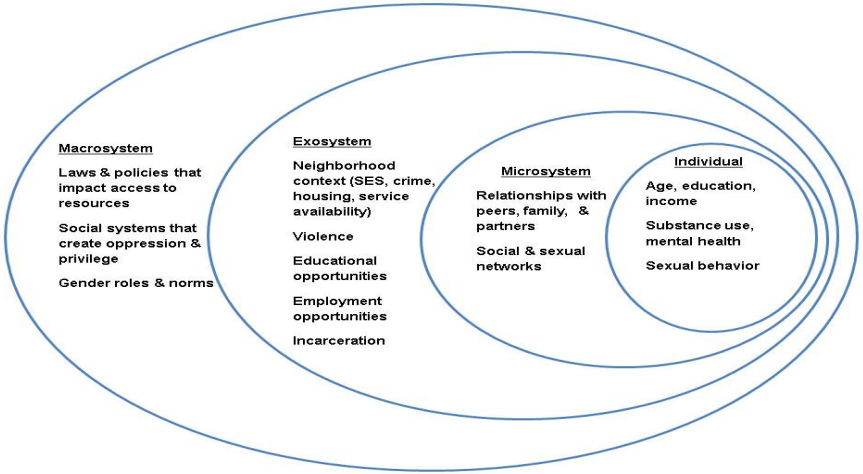
THE UNIVERSITY OF CHICAGO

CCHE The Chicago Center for HIV Elimination

# RESEARCH FOCUS

- Socio-structural & contextual influences
  - Dyad-level factors, serosorting
  - Network influences, environmental context
  - Outcomes: HIV/STI transmission risk, substance use, prevention and care engagement

- Populations disproportionately affected by HIV/STIs
  - MSM, transgender people, people who use drugs




Adapted from Ecological Systems Theory. Source: Bronfenbrenner, U. (1979). *The Ecology of Human Development: Experiments by Nature and Design*. Cambridge, MA: Harvard University Press.

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CCHE

# METHODS

- Applications of quantitative methods in epidemiology and the social sciences
  - Epidemiologic study design, sampling, survey design
  - Causal inference methods
  - Analytic methods for clustered and longitudinal data: multilevel models, survival analysis, network analysis
  - Combining estimates from multiple sources: meta-analysis

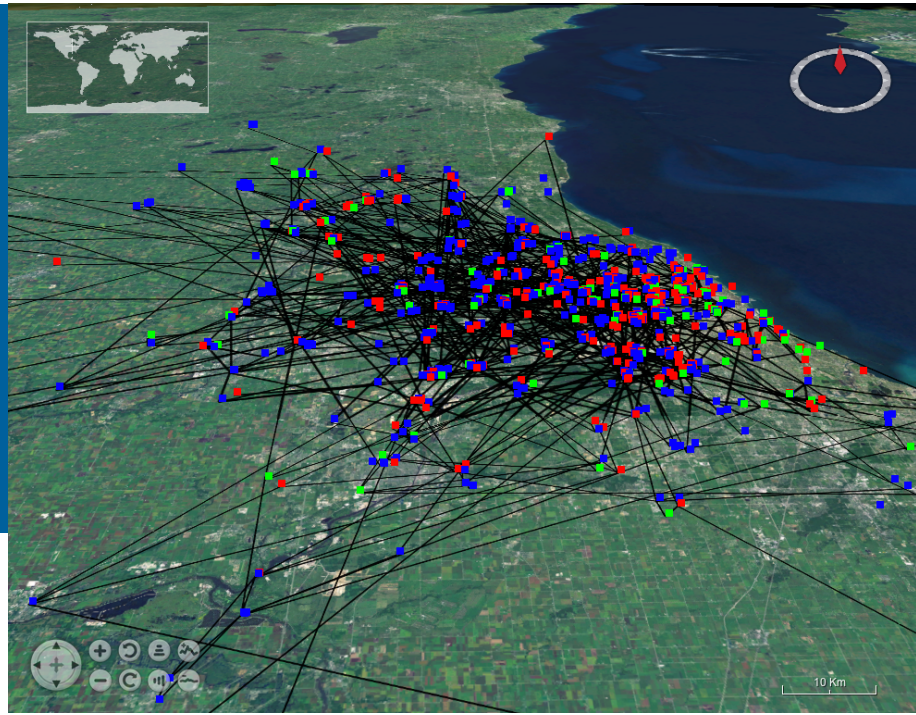
- Applications in systems science
  - Useful for representing complex relationships characterized by: direct and indirect effects, feedback loops, dynamic changes, interference
  - Estimates from traditional epidemiologic analyses can be used as input parameters for agent-based models

# USES OF AGENT-BASED MODELING IN EPIDEMIOLOGY

- Understand mechanisms by which socio-structural factors impact population level health outcomes
  - Can show how patterns at the population level arise from exposures that might not be evident in a single study
  - Conduct counterfactual experiments to evaluate different hypotheses

- Evaluate potential intervention strategies
  - Streamline intervention development process
  - Guidance as to:
    - How interventions can be most effectively focused
    - Optimal combination/sequence of interventions

# AGENT-BASED MODELING AND HIGH-PERFORMANCE COMPUTING FOR PUBLIC HEALTH APPLICATIONS



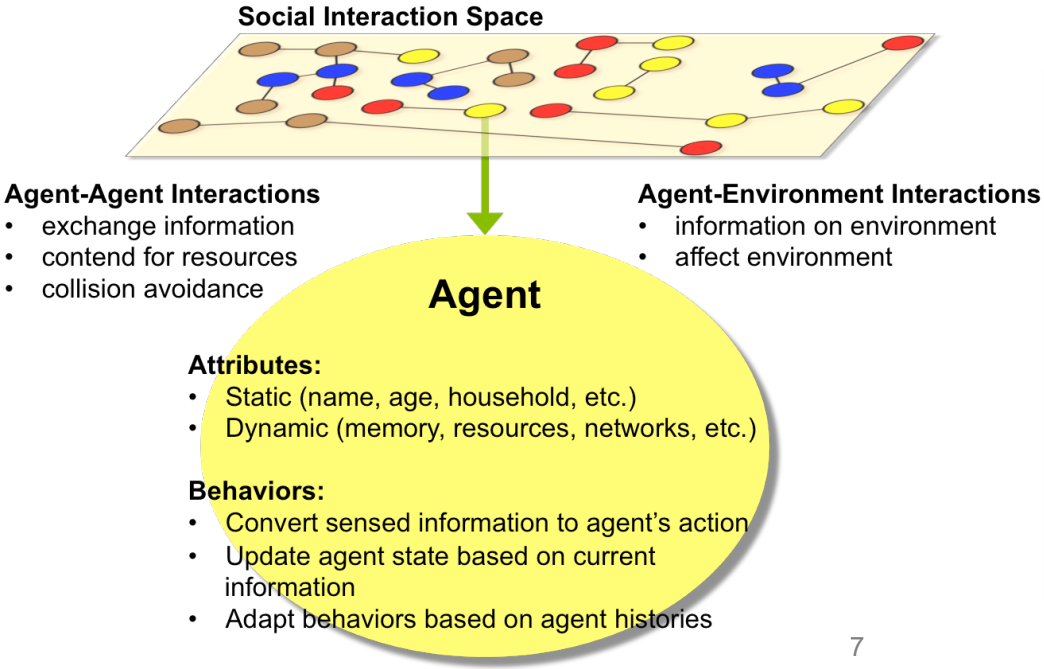

**JONATHAN OZIK, PH.D.**

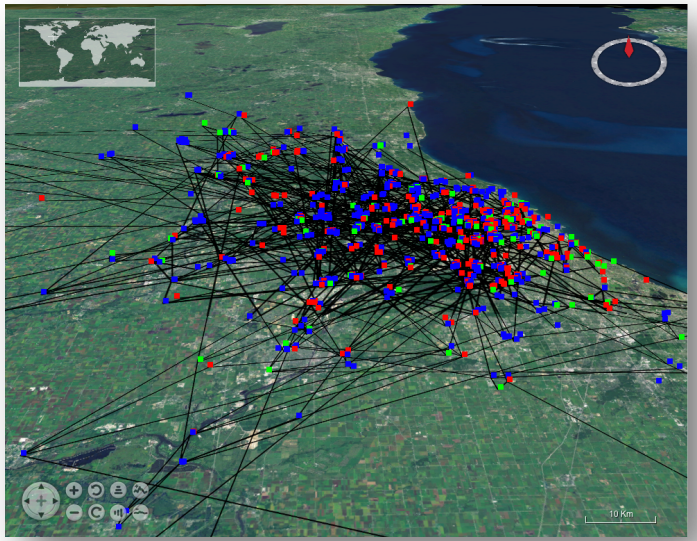
Argonne National Laboratory
University of Chicago

# AGENT-BASED MODELING

# AGENT-BASED MODELS (ABMS)

- **Disaggregated description of complex systems:**
  - Method of computing the potential system-level consequences of the behaviors of sets of individuals
  - Effects of interventions can be run with different assumptions



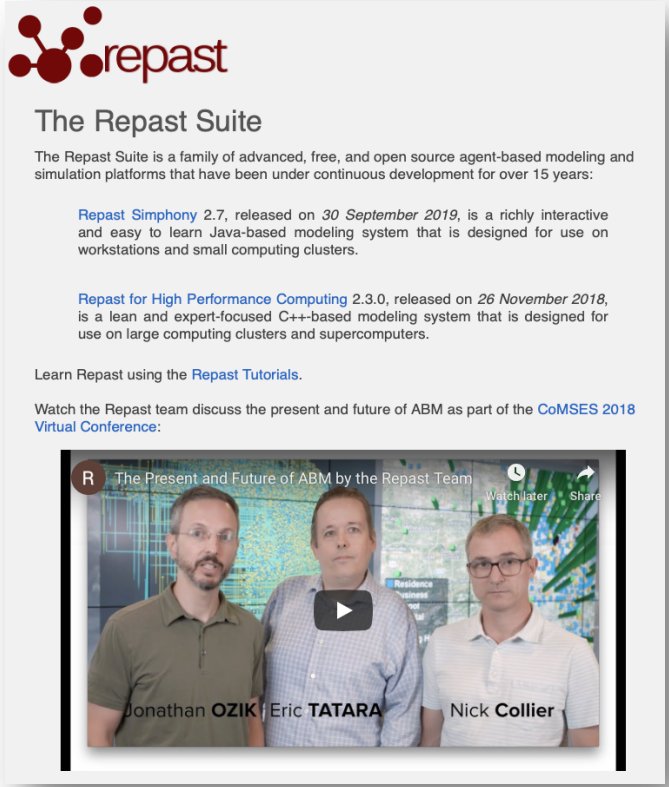
# REPAST ABM TOOLKIT

# REPAST AGENT-BASED MODELING SUITE

repast

**https://repast.github.io**

- Family of advanced, free, and open source agent-based modeling and simulation platforms that have collectively been under continuous development for over 20 years
- Over 200,000 downloads globally
- Developed and maintained at Argonne
- Two flavors of agent-based modeling toolkits
  - Repast Simphony
  - Repast for High Performance Computing (Repast HPC)

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# IN SILICO LABORATORY WITH HIGH-PERFORMANCE COMPUTING

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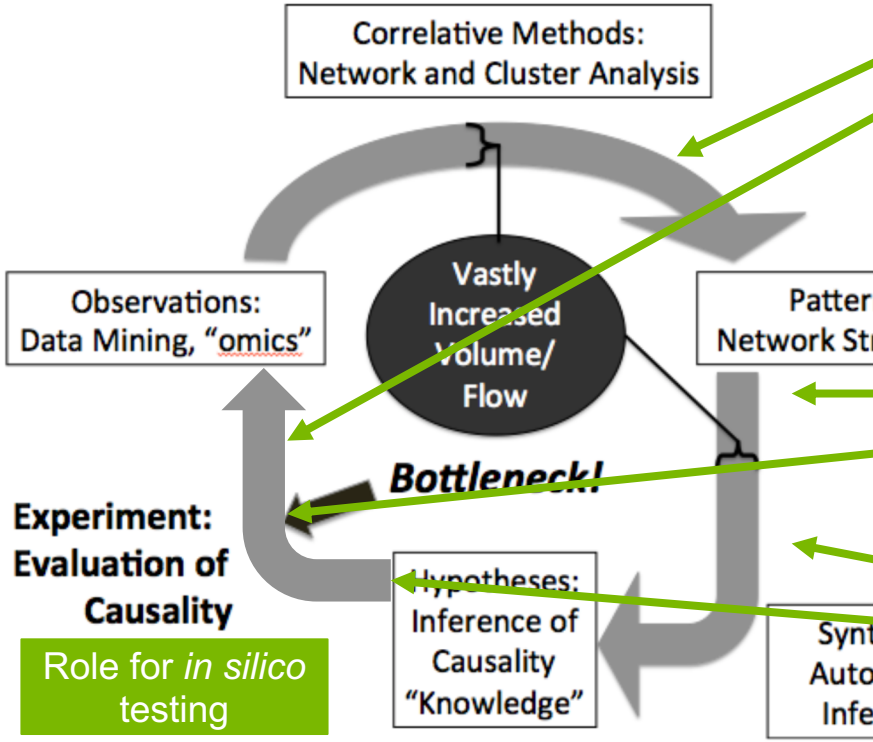
# SCIENTIFIC CYCLE BOTTLENECK






powered by aws

Google Cloud

Left image credit: Gary An, University of Vermont

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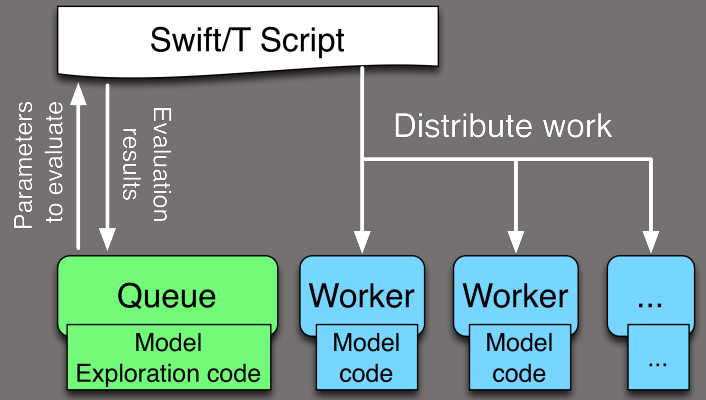
# Extreme-scale Model Exploration with Swift

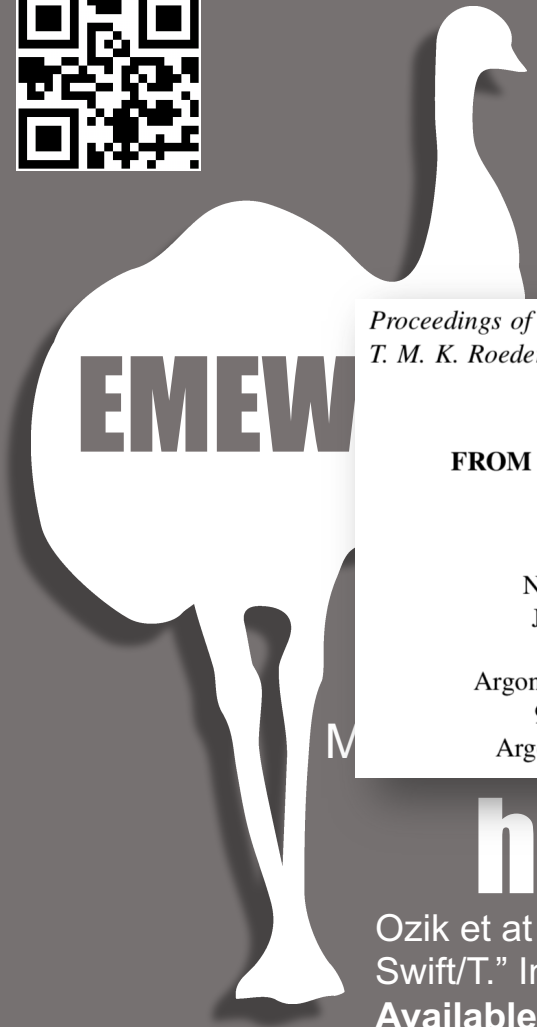
EMEWS




Multi-language ME and models: R, Python, Java, Julia, C++,…

**http://emews.org**

# Extreme-scale Model Exploration with Swift




*Proceedings of the 2016 Winter Simulation Conference*
*T. M. K. Roeder, P. I. Frazier, R. Szechtman, E. Zhou, T. Huschka, and S. E. Chick, eds.*

**FROM DESKTOP TO LARGE-SCALE MODEL EXPLORATION WITH SWIFT/T**

Jonathan Ozik
Nicholson T. Collier
Justin M. Wozniak

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Argonne, IL 60439, USA

Carmine Spagnuolo

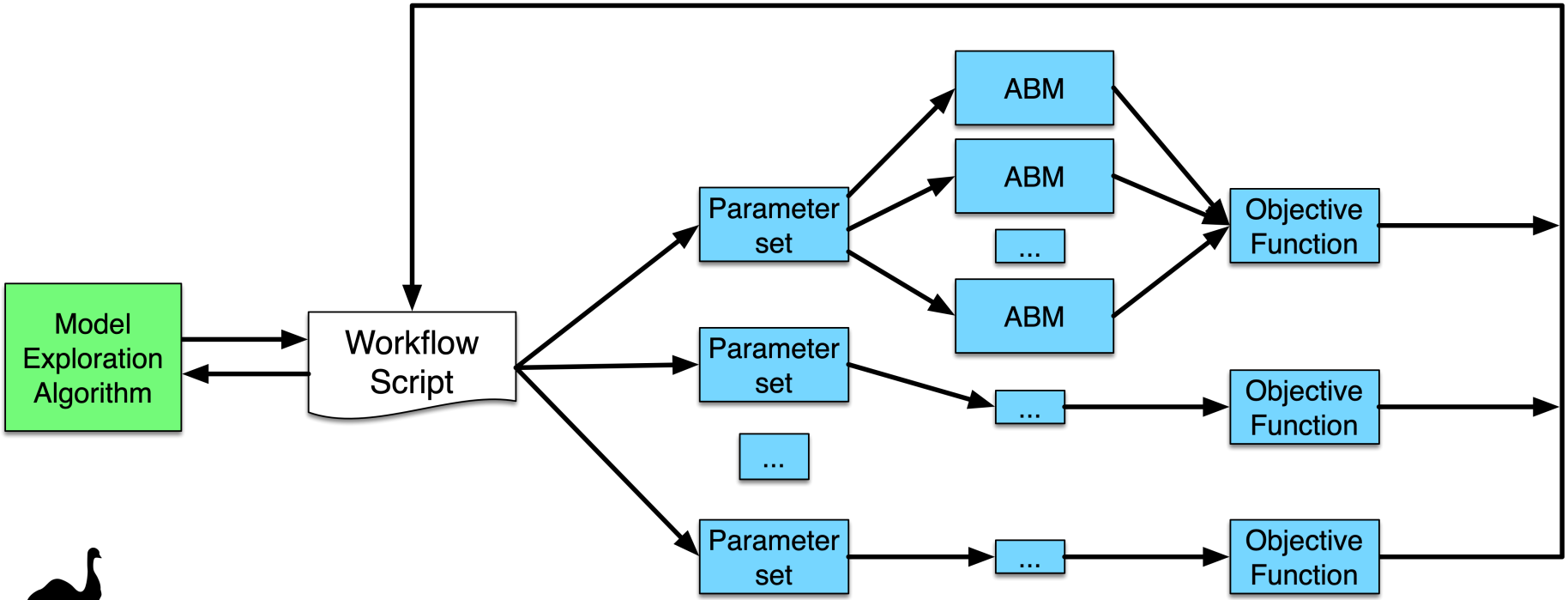
Dipartimento di Informatica, ISISLab
Università degli Studi di Salerno
Via Giovanni Paolo II, 132, 84084 Fisciano SA
Salerno, ITALY

M ++,...

# http://emews.org

Ozik et at al. 2016. “From Desktop to Large-Scale Model Exploration with Swift/T.” In *Proc. Winter Simulation Conference*.
**Available at:** https://www.informs-sim.org/wsc16papers/019.pdf

# High-performance Model Exploration Workflows




EMEWS

swift



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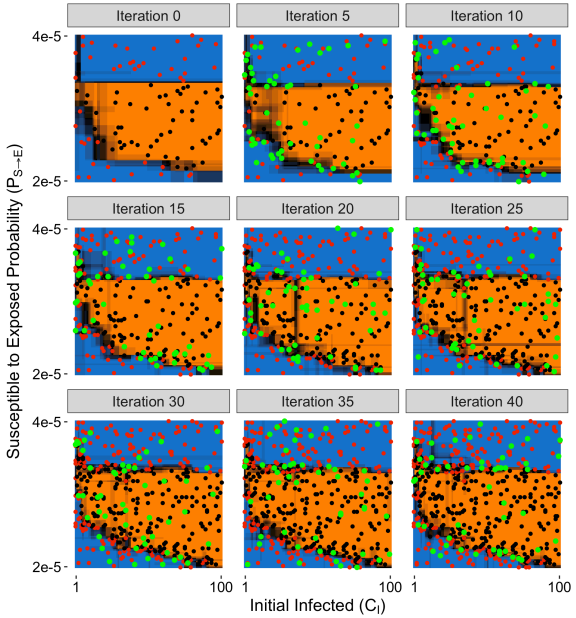
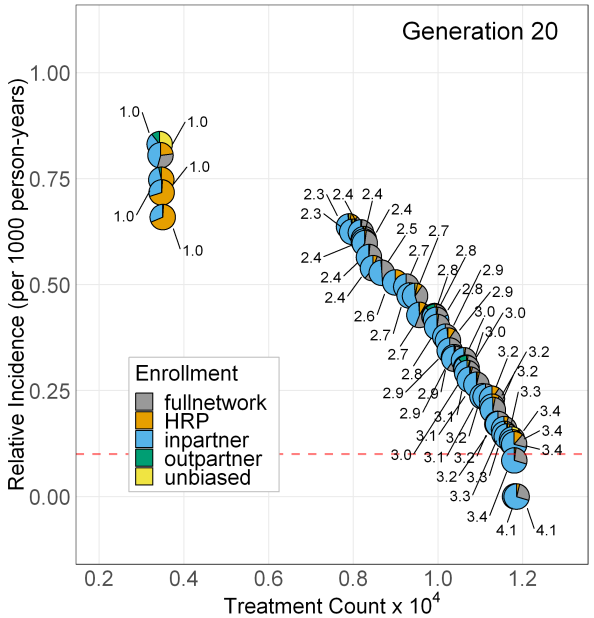
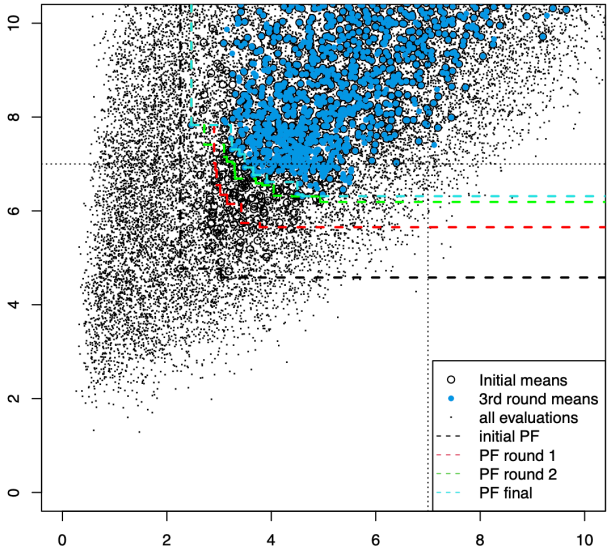
# Model Exploration




Active Learning of Viable Regions*




Multi-objective Optimization**




Bayesian Optimization***


* Ozik, Jonathan, Nicholson T. Collier, Justin M. Wozniak, Charles M. Macal, and Gary An. 2018. “Extreme-Scale Dynamic Exploration of a Distributed Agent-Based Model With the EMEWS Framework.” IEEE Transactions on Computational Social Systems 5 (3): 884–95. https://doi.org/10.1109/TCSS.2018.2859189.

** Tatara, Eric, Nicholson T. Collier, Jonathan Ozik, Alexander Gutfraind, Scott J. Cotler, Harel Dahari, Marian Major, and Basmattee Boodram. 2019. “Multi-Objective Model Exploration of Hepatitis C Elimination in an Agent-Based Model of People Who Inject Drugs.” In 2019 Winter Simulation Conference (WSC), 1008–19. https://doi.org/10.1109/WSC40007.2019.9004747.

*** Ozik, Jonathan, Nicholson T. Collier, Justin M. Wozniak, Charles M. Macal, and Mickaël Binois. under review. “A Population Data-driven Workflow for Covid-19 Modeling and Learning.” Gordon Bell Special Prize for HPC-Based COVID-19 Research, Supercomputing 2020.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# BUILDING AGENT-BASED MODELS OF RACIALIZED JUSTICE SYSTEMS (BARS)

THE UNIVERSITY OF CHICAGO

CCHE The Chicago Center for HIV Elimination

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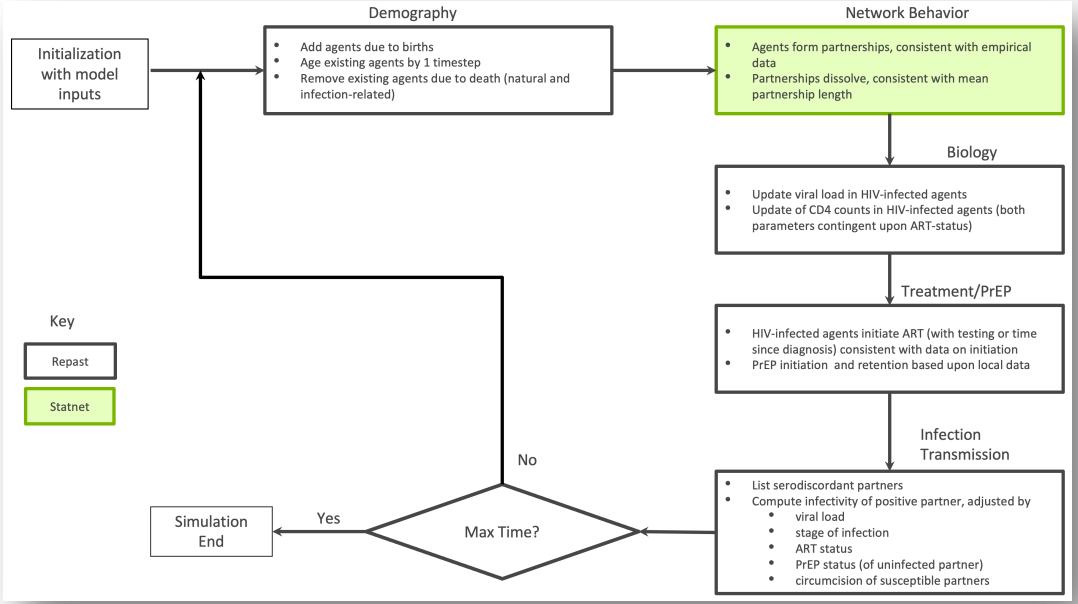
# BARS HIV MODEL

- Combines ABM and network (ERGM) modeling
- Incorporates empirical data on micro-level behaviors and sexual network structure to aggregate population-level outcomes
- Includes processes that impact transmission, including demography, biology, ART, PrEP
- Impact of justice involvement on sexual networks and HIV prevention/care continuums




NIH/National Institute On Drug Abuse (R01DA039934): PIs John Schneider (UC), and Nina Harawa (UCLA), Kayo Fujimoto (UT Houston)

# INTERSECTION OF HIV AND CRIMINAL JUSTICE INVOLVEMENT

- Black MSM are disproportionately impacted by HIV and criminal justice involvement
  - Frequent cycling between communities and criminal justice settings

- CJI can impact:
  - Social and sexual network stability
  - Employment and housing opportunities
  - Access to medical care
    - Resulting in cycles of socioeconomic marginalization and HIV transmission

- Agent-based models can be used to:
  - Provide insights to understand processes that drive HIV transmission
  - Evaluate interventions

# HYPOTHESIZED MECHANISMS BY WHICH JUSTICE INVOLVEMENT IMPACTS HIV TRANSMISSION

- Disruption in the HIV prevention and care continuum due to changes in post-incarceration ART and PrEP engagement
- Impact of incarceration and release on partners of those with CJI due to altered tie formation and dissolution in sexual networks
- ABM can uncover emergent dynamics resulting from the intersection of CJI-related changes in network composition and HIV prevention/care continuum engagement

# BARS HIV MODEL POPULATION AND DATA SOURCES

- Model population: 10,000 agents representing Black MSM ages 18-34 in the city of Chicago

- Data sources: Parameter values for sexual networks and behaviors and HIV/PrEP care continuum engagement  were estimated from a population-based cohort of young Black MSM in Chicago (uConnect), calibration to local HIV surveillance estimates

# MODEL COMPONENTS AND PARAMETER VALUES

| Process/component | Description | Parameter values |
|---|---|---|
| **Demography** | | |
| Arrivals | Agents enter model at constant rate at age 18 | Constant |
| Aging | Advance agent age by 1 unit per time step (day) | Increase by 1 unit per day |
| Departures | Due to age-specific all-cause mortality, HIV-related mortality, and deterministically due to aging out of model at age 35 | Age-specific mortality rates for Chicago |
| **Networks & Behaviors** | | |
| Mean partnership duration | Based on empirical data, specific to partnership type (main/casual) | Main: 512 days<br>Casual: 160 days |
| Momentary degree distribution | Distribution of number of sexual partnerships on a given day | Main: 0 (60%), 1 (38%), 2 (1%)<br>Casual: 0 (61%), 1 (32%), 2 (7%) |
| Partnership formation | Occurs at rate consistent with empirical data on momentary degree distribution for main and casual partnerships | Derived |
| Partnership dissolution | Occurs at rate determined by mean partnership duration for main and casual partnerships | Derived |
| Frequency of anal intercourse (AI) | Based on empirical data, specific to partnership type (main/casual) | Main: 0.189<br>Casual: 0.053 |
| Condom use for AI in serodiscordant partnerships | Based on empirical data, specific to partnership type (main/casual) | Main: never: 26.1%; rarely: 4.7%; sometimes: 8.1%; usually: 8.7%; always: 52.3%.<br>Casual: never: 28.1%; rarely:1.4%; sometimes: 4.3%; usually: 5.4%; always: 60.7% |
| **Transmission between serodiscordant partners** | Dependent on condom use, viral load & stage of infection (HIV positive), PrEP use (HIV negative) | Derived |
| Infectivity multiplier based on viremia | Increase in infectivity corresponding to one unit increase in log viral RNA | 2.89 |

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# MODEL COMPONENTS AND PARAMETER VALUES

| Process/component | Description | Parameter values |
|---|---|---|
| **Biology** | | |
| CD4 in uninfected | | 916 cells/μl |
| CD4 decline in HIV-infected but untreated individuals | | As per a linear model |
| **Acute & chronic stage duration among HIV +** | Acute stage duration | Infection to peak viremia: 45 days<br>Peak viremia to viral set point: 45 days |
| | Chronic stage duration | 3550 days |
| | Late stage (AIDS) duration | 728 days |
| **Viremia & viral set point** | Level of Peak Viremia | 6.17 log |
| | Viral set point | 4.2 log |
| | Max. late stage viremia | 5.05 log |
| Viral load/CD4 evolution after ART initiation(HIV +) | Dependent on time since infection and ART use | CD4 count recovers by 15 cells/μl every month until first of pre-infection level or 3 years<br>Viral load among ART initiated declines to 200 copies/ml in 30 days |
| **HIV prevention/care continuum** | | |
| HIV testing | Age-specific annual testing frequencies among HIV negative/undiagnosed | Age <26: 7.8% never test<br>Age ≥ 26: 2.3% never test |
| ART initiation | Based on local data on frequency and timing of ART initiation after positive diagnosis | 0-1week (16.7%);1week-1month (29.8%); 1-3months (16.0%); 3-6 months(9.2%); 6months-1year (12.9%); 1-2years (8.4%); 3-5years (6.9%) |
| ART adherence | Dependent on ART use, time-varying | Never: 10%, Sometimes: 30%, Usually: 28%, Always: 32% |
| Viral suppression | Dependent on ART use, time-varying | Derived from ART adherence |
| **PrEP uptake and retention** | | |
| Initiation of PrEP | Based on local data on age-specific prevalence of PrEP use among young Black MSM | Age <26: 12.7%<br>Age ≥ 26: 14.7% |
| Duration/frequency of PrEP use | Based on local data on mean duration of PrEP retention | 1 year (on average) |
| PrEP adherence | Based on data from national demonstration projects | Non-adherence: 0 pills/week (21.1%); low adherence: <2 pills/week (7.0%), moderate adherence: 2–3 pills/week (10.0%), and high adherence: 4+ pills/week (61.9%) |

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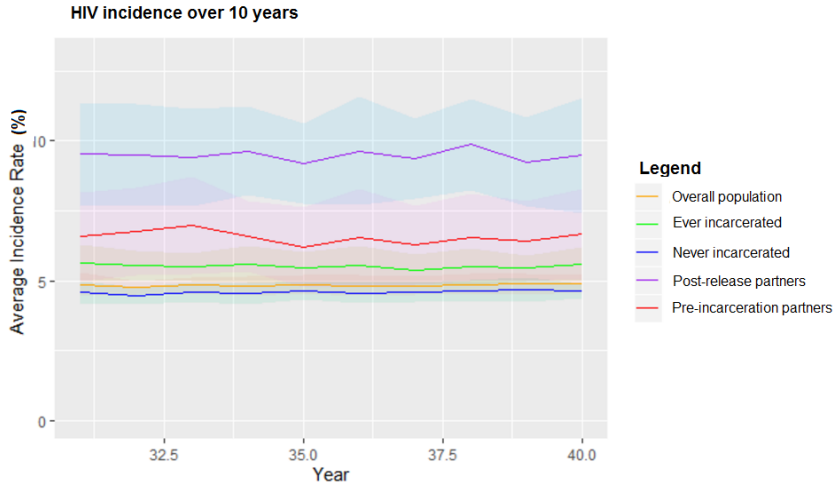
# ABM EXPERIMENTS

- Quantify the impact of criminal justice involvement:
  - Population level HIV incidence
  - HIV incidence among justice involved individuals and their networks

- Evaluate interventions to reduce the impact of justice involvement on HIV transmission in different sub-populations
  - Examples:
    - Reduce post-release disruption in HIV/PrEP care (e.g., interventions to facilitate care engagement by reducing insurance, housing, or employment barriers)
    - Focused or enhanced PrEP and ART interventions for justice involved individuals and their networks

# MODEL RESULTS

- HIV incidence is higher among ever vs. never incarcerated
- HIV incidence is higher among partners of those released from jail (~9.5%) and those incarcerated (~6.25%) than HIV incidence in the general population (~5%)
- Partners of those with recent CJI history have elevated HIV incidence
  - May be priority candidates for PrEP interventions




- Suggests need for interventions to increase ART and viral suppression among HIV-positive individuals with CJI *and* increase PrEP/ART use in their networks

# CFAR BCRT RESOURCES

- Anna Hotton:
  - Methods in Epidemiology and Biostatistics
    - Epidemiologic study design, sampling, survey design
    - Causal inference methods
    - Analytic methods for clustered and longitudinal data
    - Meta-analysis
- Jonathan Ozik:
  - Agent-based modeling
    - Model design
    - Modeling toolkits and implementation
  - High-performance computing
    - High-performance ABM
    - Use of high-performance computing for model exploration (of ABMs or other modeling methods)
- AH + JO:
  - Interdisciplinary collaborations between ABM and epidemiologists/clinicians/social scientists
  - Complex systems modeling of HIV and other associated topic areas
- Agent-based, network and complex systems modeling:
  - Can generate useful insights to understand complex processes that pose challenges to traditional epidemiologic and statistical methods
  - Is useful for contexts not conducive to traditional study designs (e.g., justice settings) and for evaluating interventions that would be logistically challenging or infeasible to implement in the real world
  - Modeling can identify priority subpopulations for intervention focus

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