



JOHNS HOPKINS

ALACRITY CENTER *for*  
HEALTH & LONGEVITY  
*in* MENTAL ILLNESS

# Systems science modeling for implementation research: An application to tobacco smoking cessation for persons with serious mental illness



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Director, Johns Hopkins NIMH ALACRITY Center

# The Johns Hopkins ALACRITY Center for Health and Longevity in Mental Illness

- ▶ People with serious mental illness die 10-20 years earlier than the overall population, largely driven by high rates of cardiovascular disease and other physical health conditions
- ▶ Through research, training, and community partnerships, the Johns Hopkins ALACRITY Center seeks to speed translation of effective interventions to improve physical health and reduce premature mortality among people with serious mental illness into everyday practice
- ▶ Funded by the National Institute of Mental Health (P50115842)



# ALACRITY Research Projects

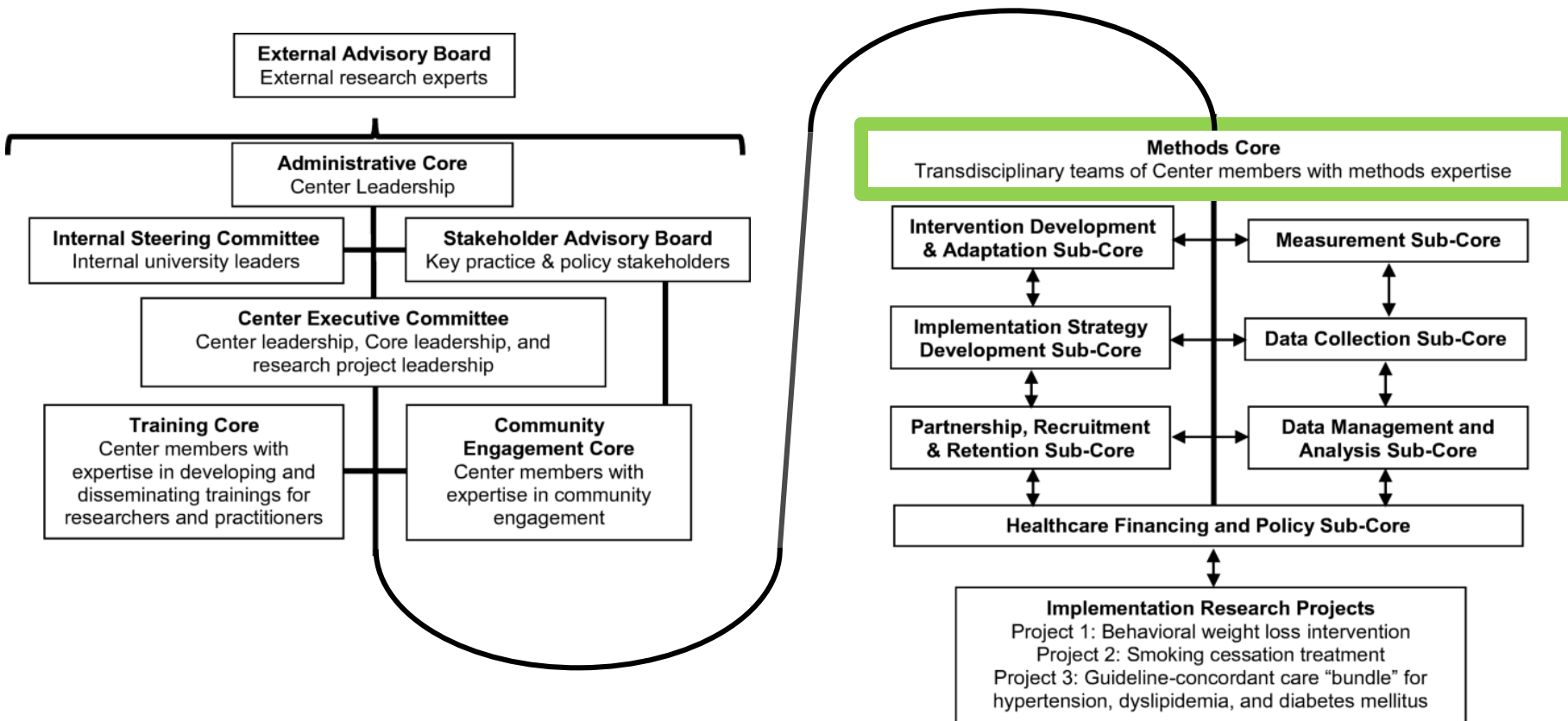
**ACHIEVE-D:** Adapting an evidence-based weight loss intervention and testing strategies to increase implementation in community mental health programs

**IMPACT:** Promoting evidence-based tobacco smoking cessation treatment in community mental health clinics

**RHYTHM:** Using an innovative quality improvement process to increase delivery of evidence-based cardiovascular disease risk factor care in community mental health organizations



# ALACRITY Organizational structure



# ALACRITY Systems Science Core Members

## FACULTY

- ▶ **Gail L. Daumit**, *Division of General Internal Medicine*
- ▶ **Emma E. McGinty**, *Dept Health Policy & Management*
- ▶ **Elizabeth A. Stuart**, *Dept Mental Health*
- ▶ **Nae-Yuh Wang**, *Division of General Internal Medicine*
- ▶ **Tak Igusa**, *Center for Systems Science & Engineering (CSSE)*

## PHD STUDENTS

- ▶ **Wanyu Huang, Todd Chang**, *CSSE*
- ▶ **Tingting Ji**, *Hong Kong Polytechnic University*



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## EBP used in all examples: IDEAL

### A smoking cessation program for persons with serious mental illness

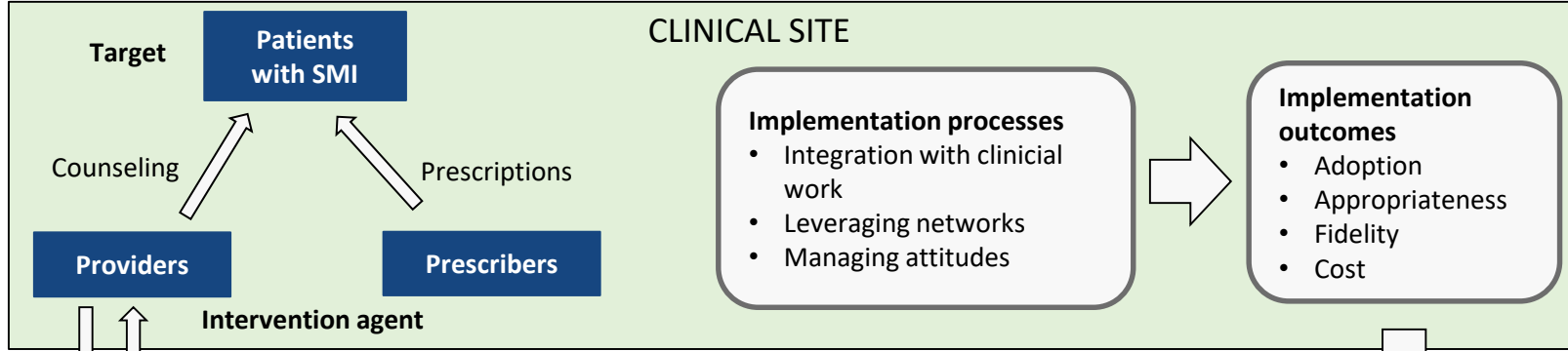
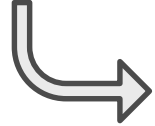
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# Implementation of a smoking cessation intervention

## Conceptual framework based on on **Brown et al (2013)**

### Implementation agency

Training,  
Education,  
Implementation  
guidance



**Payer agent**

Administrative service organization  
(e.g., Optum Maryland)

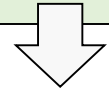


**Policy makers**

State agencies  
(e.g., Behavioral Health  
Administration and Medicaid office)

### Policy options

1. Stepped care therapy or tailored care therapy
2. Fee-for-service or outcome-based reimbursements



**Clinical outcomes**  
Quit rate

# Why systems science?

## STRENGTHS

- ▶ Systems science models can:
  - Simulate implementation processes including multiple interacting components
  - Integrate expert knowledge + data

## WEAKNESSES & MITIGATION STRATEGY

- ▶ High data requirements
  - Rely on parameters from related studies
  - Divulge assumptions
  - Focus on sensitivity studies (what-if scenarios)
- ▶ Complex simulation result
  - Explain in terms of implementation frameworks

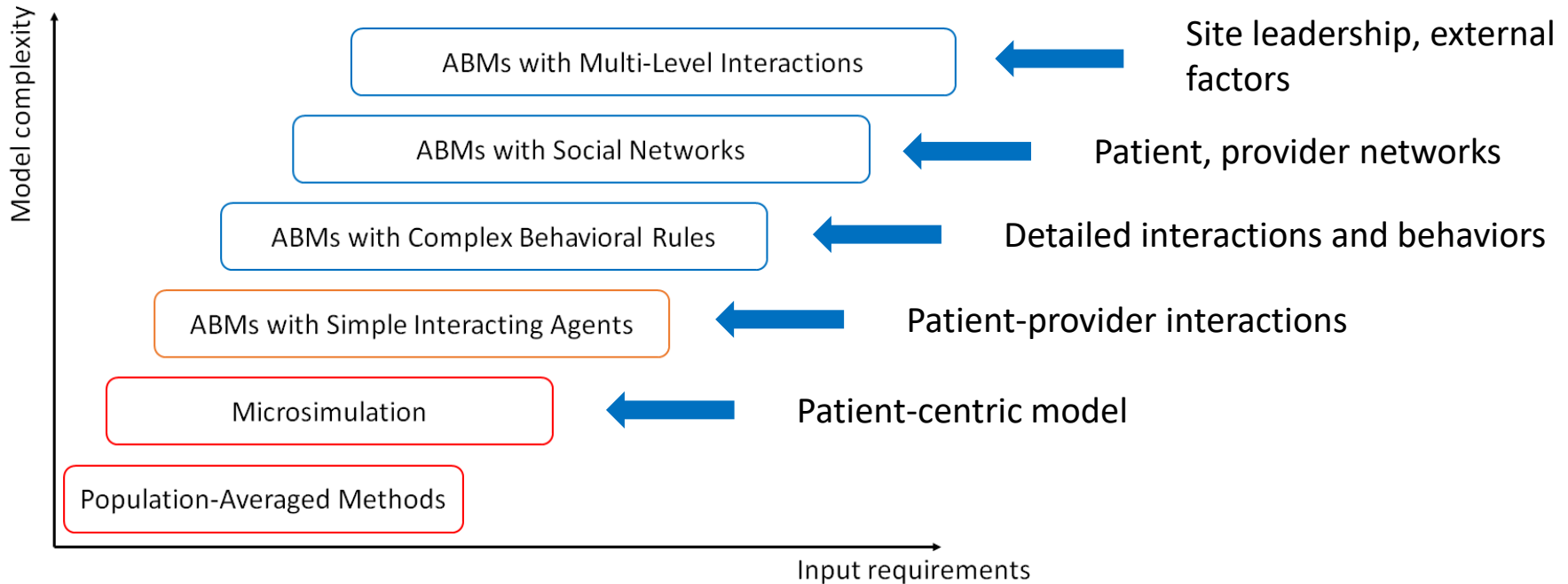




# Stepwise procedure for developing systems science models

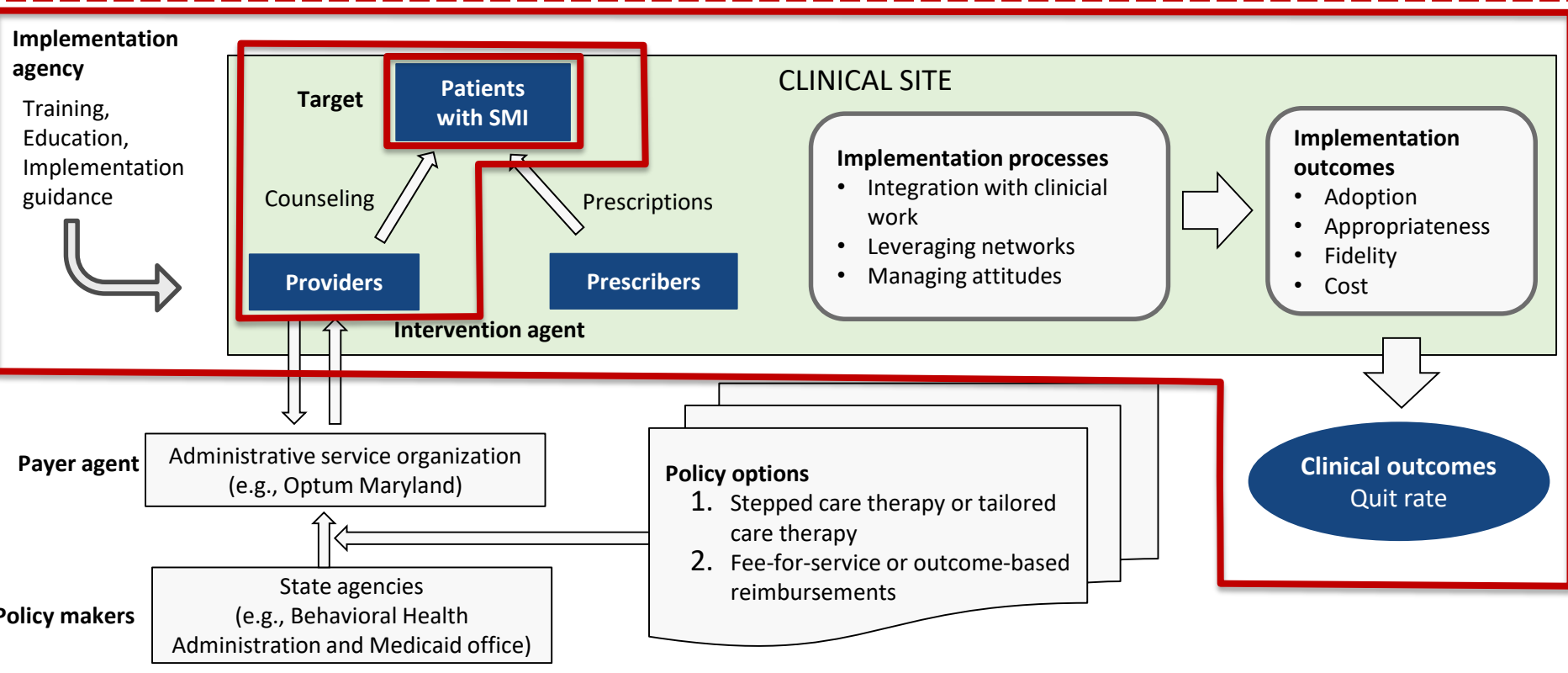
- ▶ Articulate the **research question**
- ▶ Select the **systems science model**
- ▶ **Formulate the model**
- ▶ **Run the model** and explore possible emergent patterns of behavior.
- ▶ Use the **model outputs** to guide implementation plans.

# Model selection



# Implementation of a smoking cessation intervention

## Conceptual framework based on on **Brown et al (2013)**





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## Microsimulation of individual willingness-to-quit transitions in a smoking cessation program

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# Research question

What are the processes within individual patients that should be closely monitored?

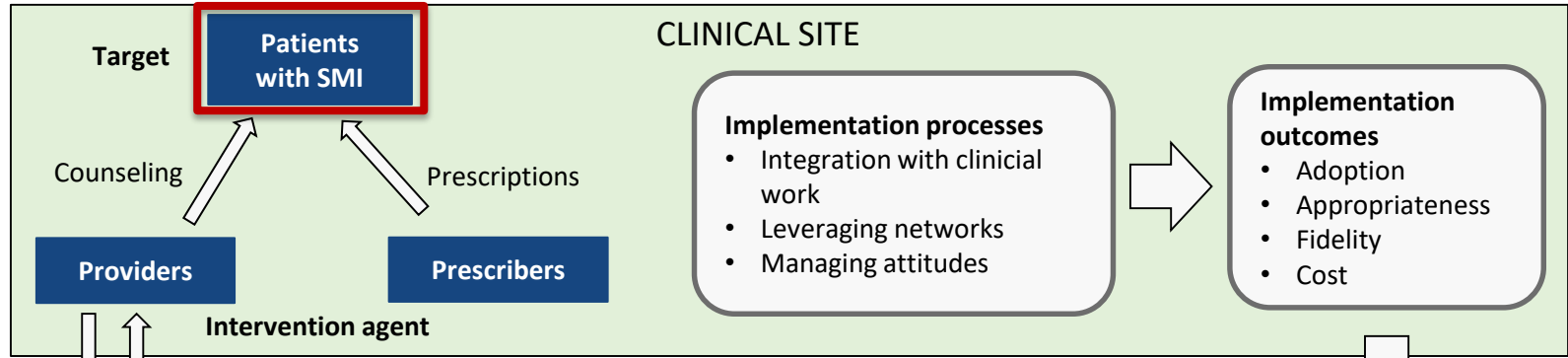


# Implementation of a smoking cessation intervention

## Conceptual framework based on on **Brown et al (2013)**

### Implementation agency

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Administrative service organization  
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### Policy options

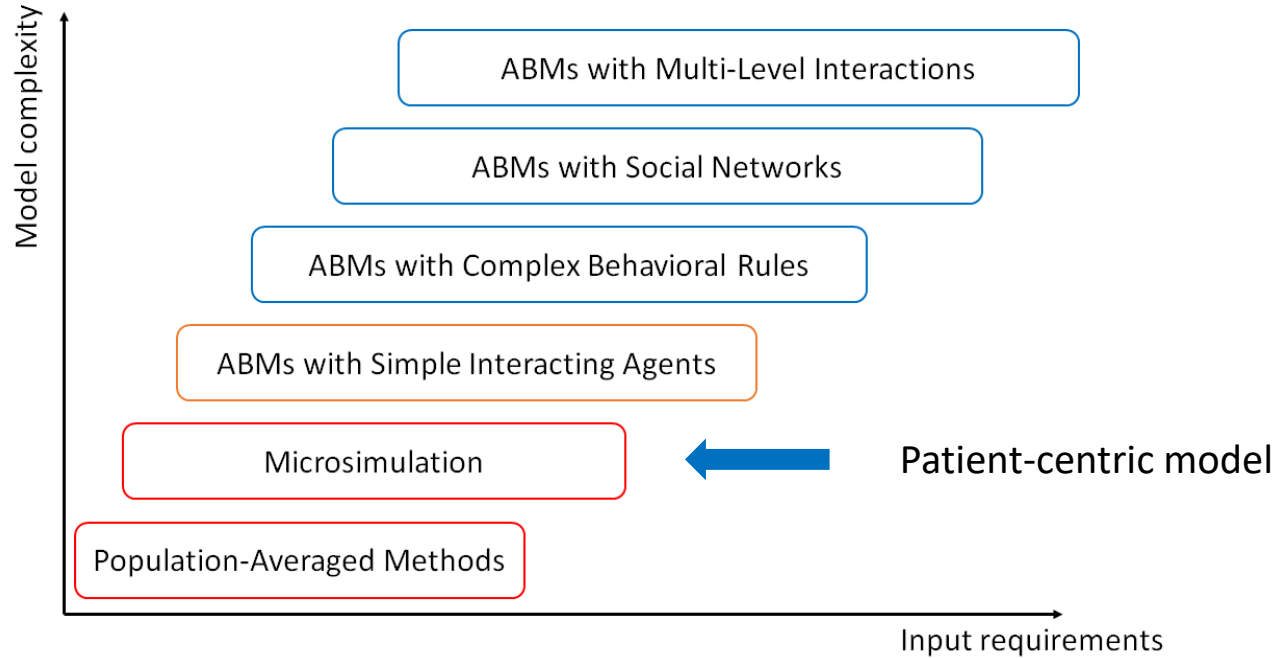
1. Stepped care therapy or tailored care therapy
2. Fee-for-service or outcome-based reimbursements

### Policy makers

State agencies  
(e.g., Behavioral Health  
Administration and Medicaid office)

**Clinical outcomes**  
Quit rate

# Model selection



Huang, et al (2021)

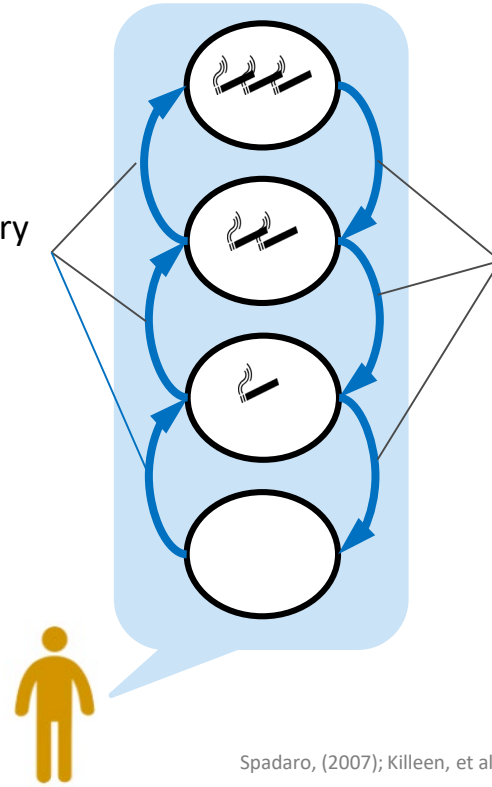
# Model formulation: Levels of willingness-to-quit

## Microsimulation model

- Markov proces
- Transition probabilities between internal states

## Factors that influences change of smoking status

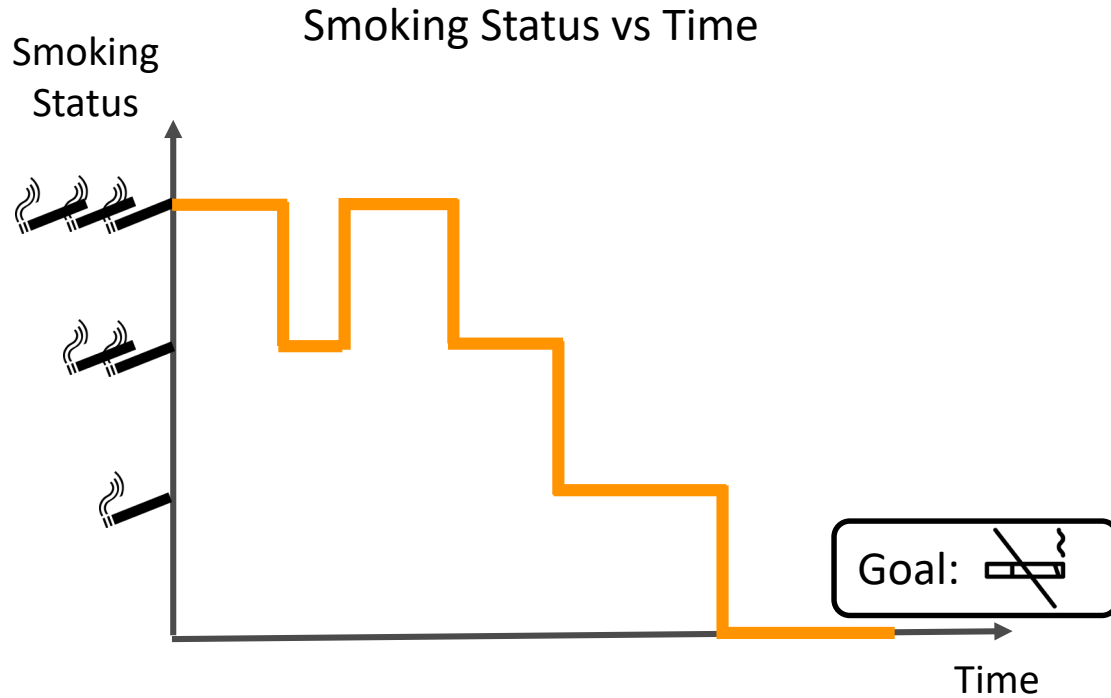
- Smoking history
- Susceptibility



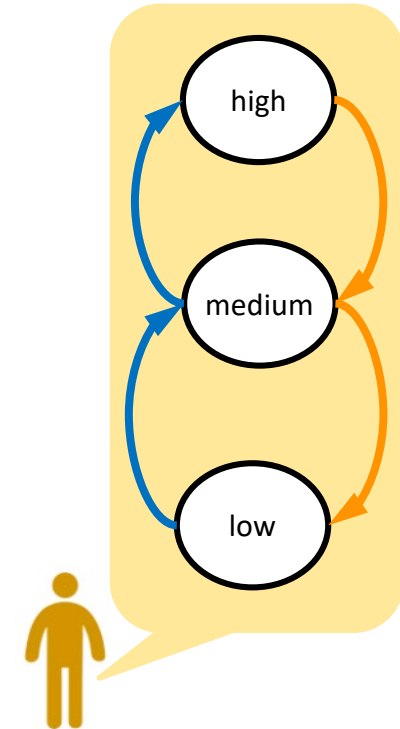
- Willingness to quit
- Peer support
- Pharmacotherapy
- Counseling



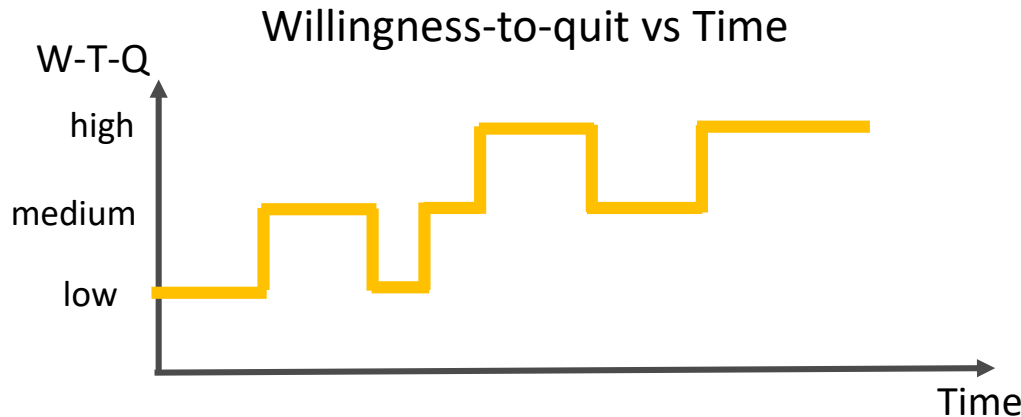
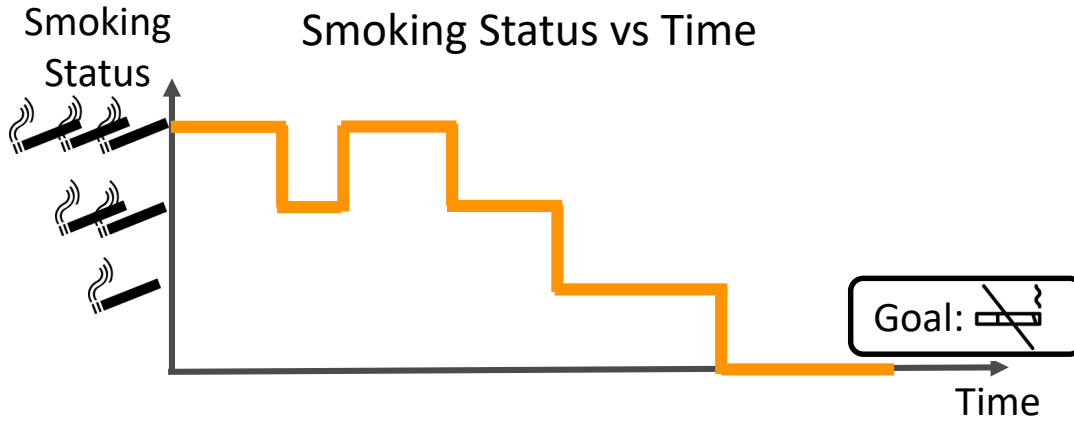
# Markov states



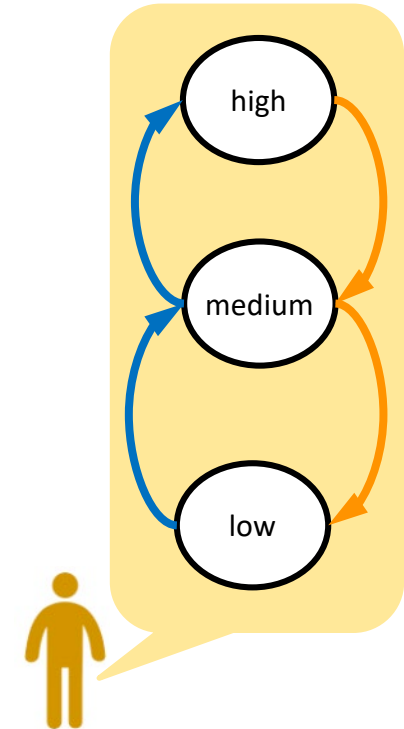
## Markov Transition Map Willingness-to-quit



# Relationships between Markov states and willingness-to-quit



## Markov Transition Map Willingness-to-quit



## MODEL FORMULATION

### Levels of willingness-to-quit

- Markov transition matrix for individual  $i$ 's willingness-to-quit

$$\begin{array}{c} \text{low} \\ \text{medium} \\ \text{high} \end{array} \begin{bmatrix} \text{low} & \text{medium} & \text{high} \\ p_1^i & p_2^i & 1 - p_1^i - p_2^i \\ p_3^i & p_1^i & p_2^i \\ 1 - p_1^i - p_3^i & p_3^i & p_1^i \end{bmatrix}$$

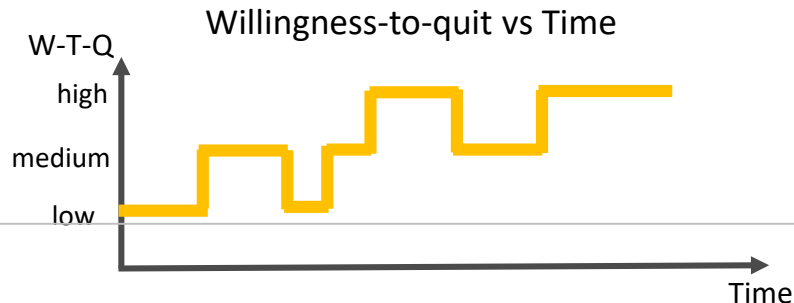
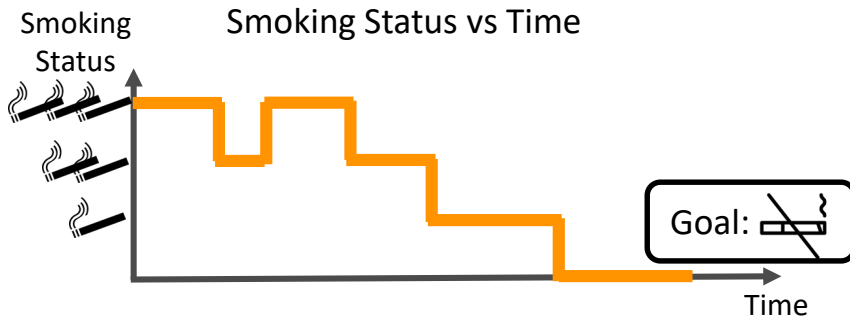
- We assumed that the transition probability is based on baseline covariates  $X_i$  for patient  $i$  using the logit function

$$p_k^i = \frac{1}{1 + \exp(-\beta_{1,k} - \beta_{2,k}X_i)}$$

# Example 1: IDEAL, A smoking cessation program for persons with serious mental illness

## MODEL OUTPUTS

- Explore the associations between lasso-selected variables and agents' abstinent status



| Variables        | $\beta$ |
|------------------|---------|
| Male             | 0.73    |
| Caucasian        | 98.85   |
| Schizophrenia    | -0.80   |
| Bipolar disorder | -1.84   |
| Depression       | 2.08    |
| Employment       | 46.53   |
| BASIS-24 score   | -1.81   |
| Change in w-t-q  | 1.07    |

# References

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## Agent-based simulation of peer influence in smoking cessation intervention program

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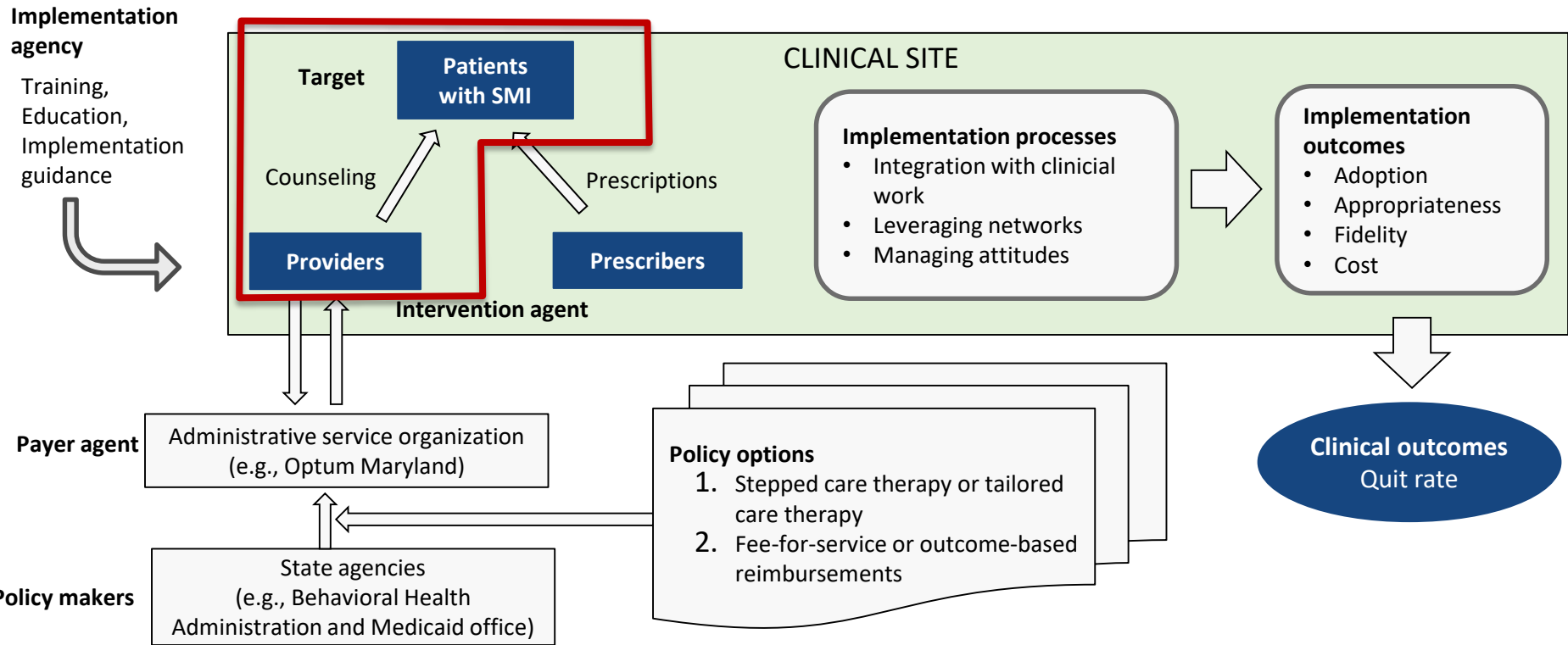
# Research question

Are individual patients affected by peer influence in group sessions?



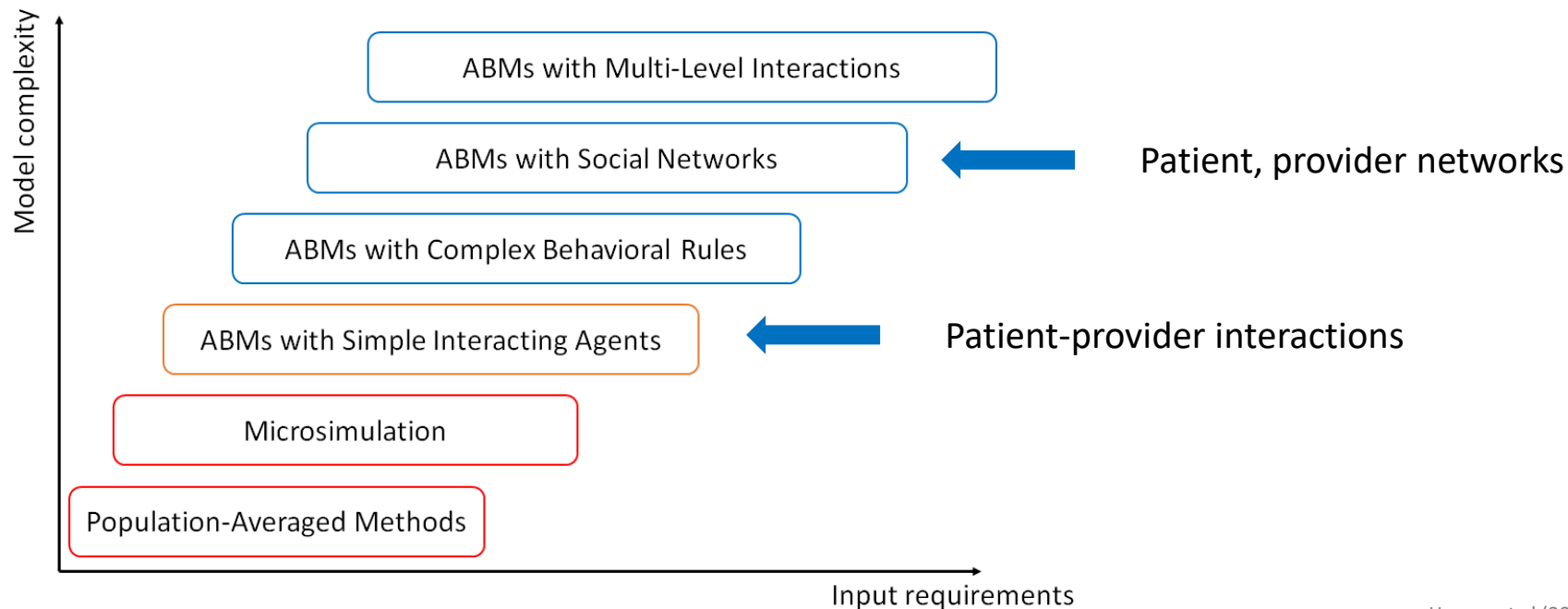
# Implementation of a smoking cessation intervention

## Conceptual framework based on on **Brown et al (2013)**





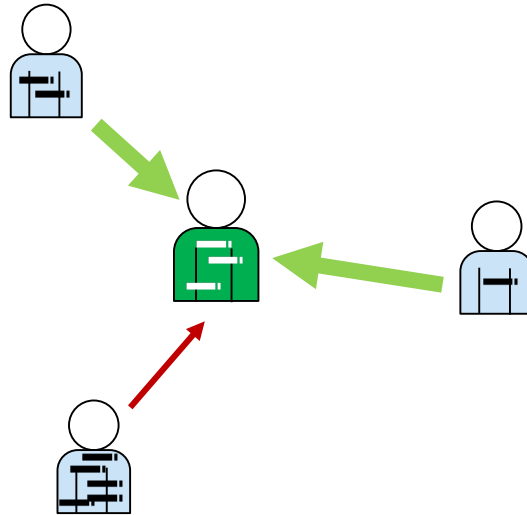
# Model selection



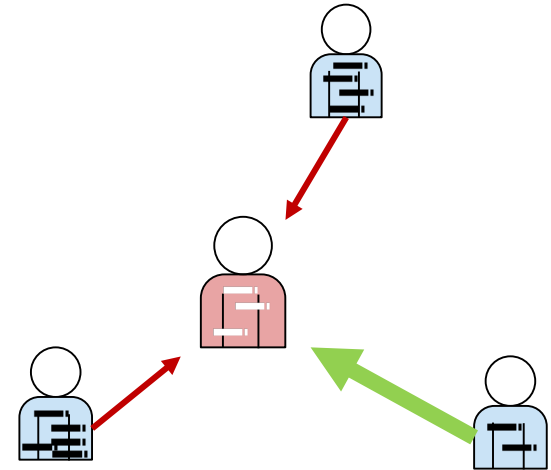
Huang, et al (2021)

# Group counseling sessions

Stronger influence from those who smoke less



Mean effect from peer influence is positive



# Non-linear regression model

$Y_i(t)$  = smoking status of patient  $i$  at time  $t$

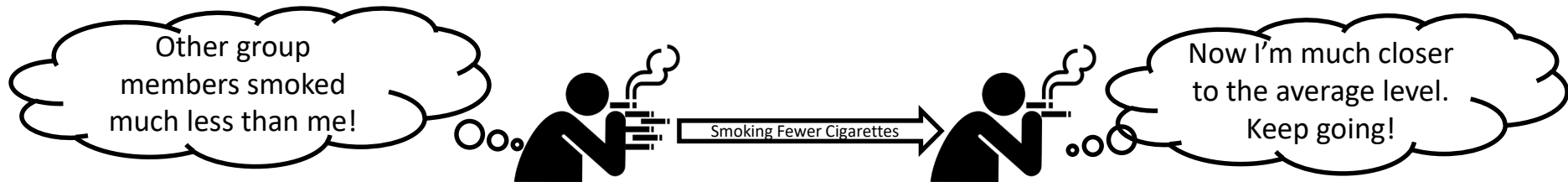
$\bar{Y}(t)$  = group mean

$$Y_i(t + 1) - Y_i(t) = \beta_0 + \beta_{\text{patient below group mean}} * (\bar{Y}(t) - Y_i(t))$$

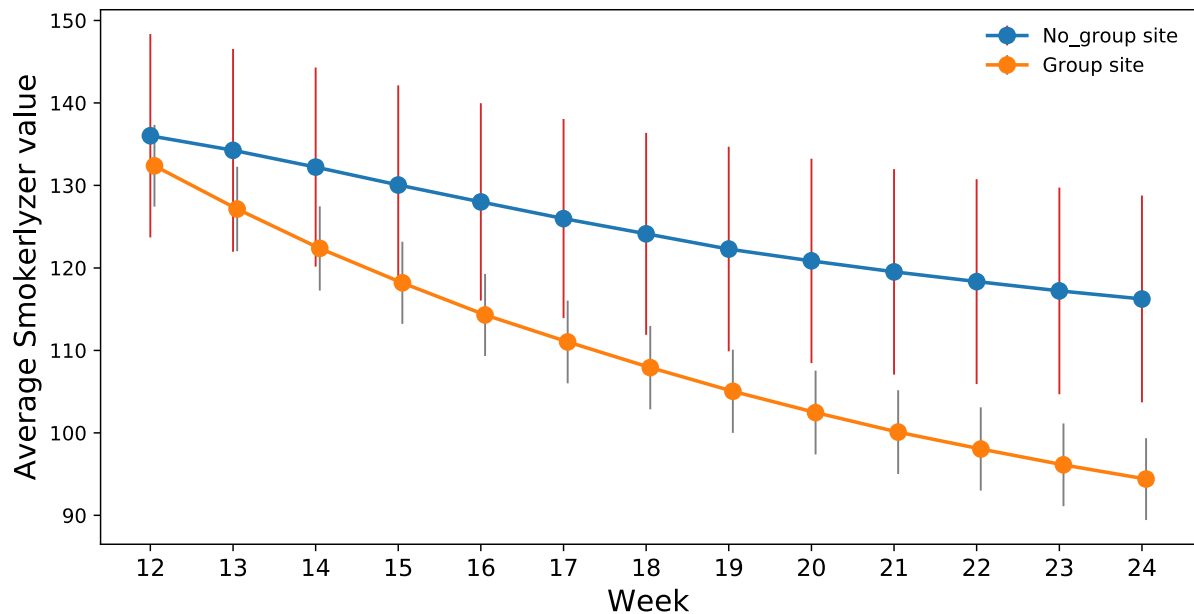
$$Y_i(t + 1) - Y_i(t) = \beta_0 + \beta_{\text{patient above group mean}} * (\bar{Y}(t) - Y_i(t))$$

# Regression coefficients for group effects

| Group session type              | Group effects                         |                                       |
|---------------------------------|---------------------------------------|---------------------------------------|
|                                 | Individual <b>below</b> group average | Individual <b>above</b> group average |
| Overall (N=1184)                | 0.0821                                | 0.288                                 |
| Motivational Enhancement (N=93) | 0.154                                 | 0.390                                 |
| Smoking Cessation (N=862)       | -0.0127                               | 0.246                                 |
| Relapse Prevention (N=229)      | -0.0184                               | 0.499                                 |



# Simulation of smoking cessation program with and without group sessions

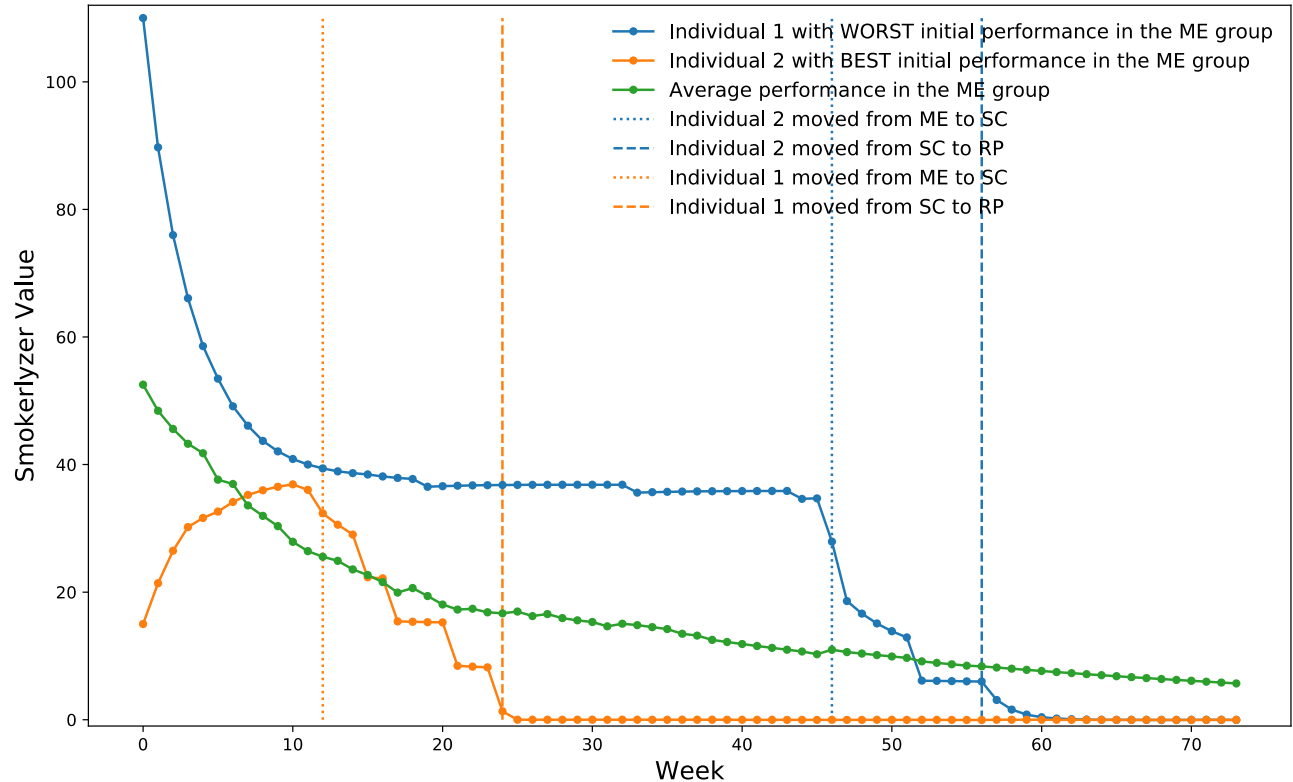


# Simulations including transitions between group session types

Multiple groups



Assignment to improve site performance



# References

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## Agent-based simulation of implementation barriers and strategies

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# Research question

How do implementation strategies affect site processes?

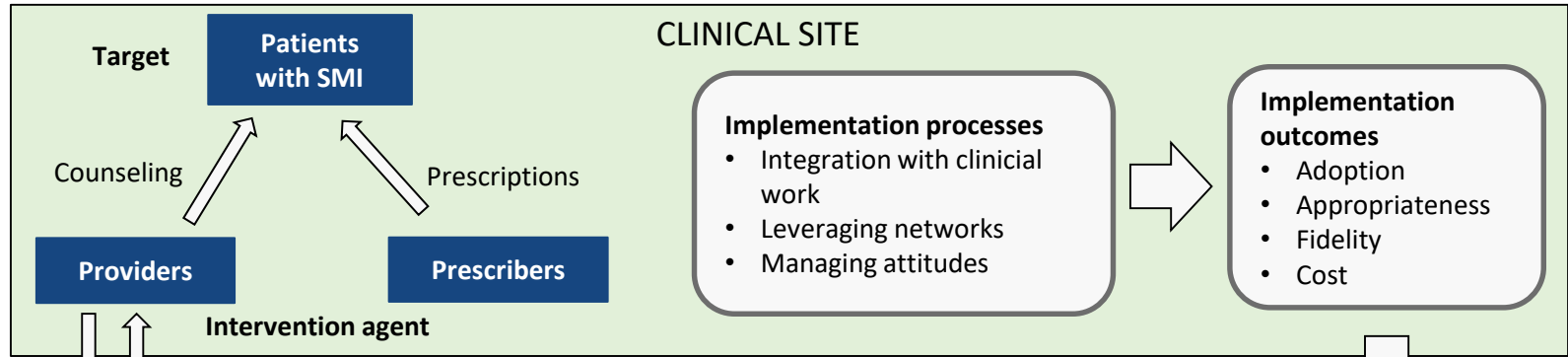


# Implementation of a smoking cessation intervention

## Conceptual framework based on on **Brown et al (2013)**

### Implementation agency

Training,  
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guidance



### Payer agent

Administrative service organization  
(e.g., Optum Maryland)



State agencies  
(e.g., Behavioral Health  
Administration and Medicaid office)

### Policy makers

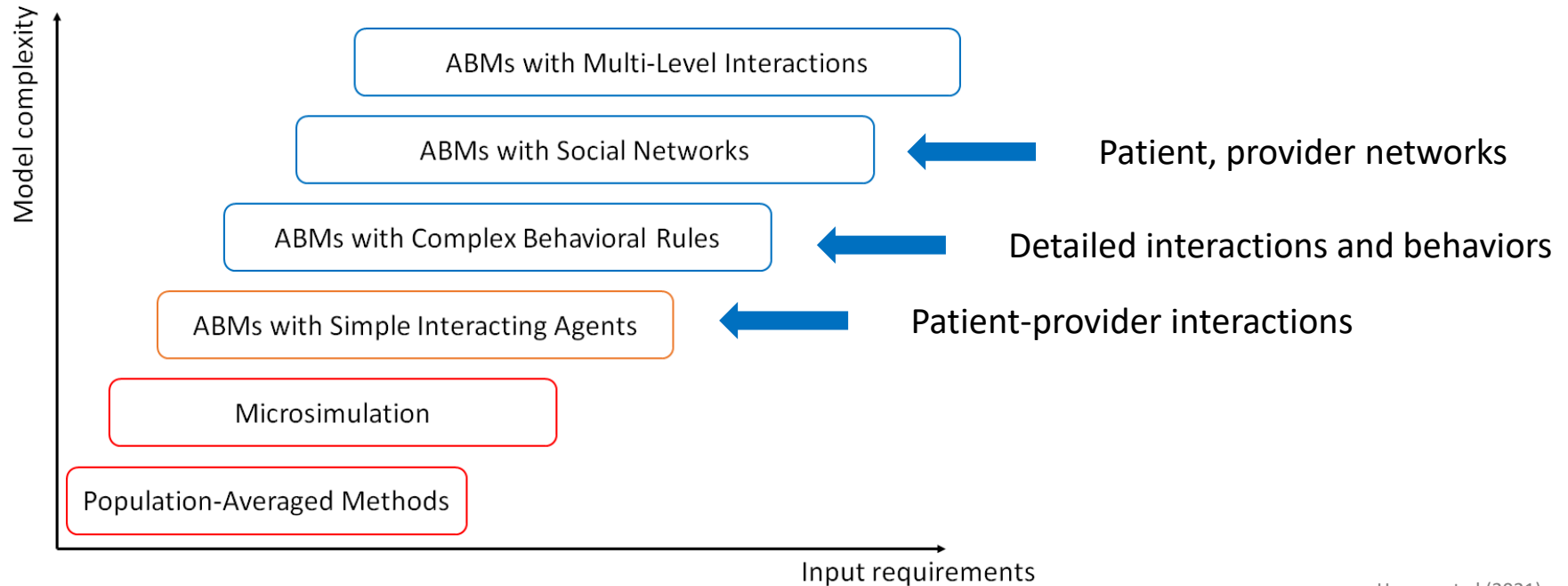
State agencies  
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### Policy options

1. Stepped care therapy or tailored care therapy
2. Fee-for-service or outcome-based reimbursements

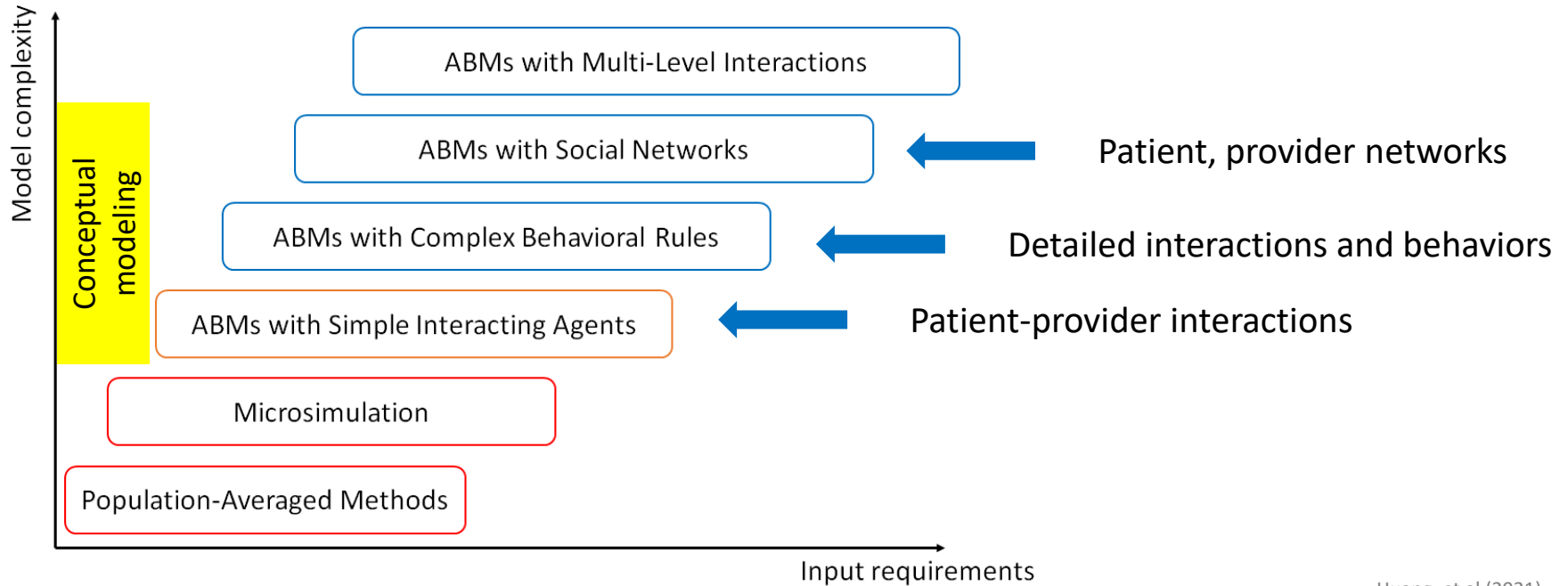
**Clinical outcomes**  
Quit rate

# Model selection



Huang, et al (2021)

# Model selection



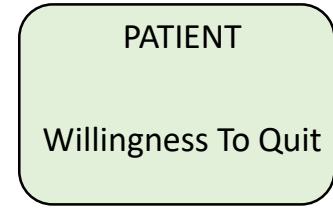
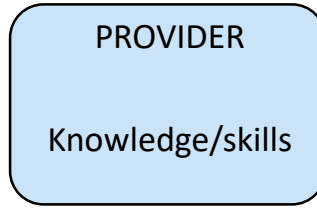
Huang, et al (2021)

# Links between determinants, implementation strategies, and implementation outcomes (Lewis, et al. 2021)

| Determinant                   | Implementation strategy   | Mechanism                                 | Implementation outcome                                |
|-------------------------------|---|---|---|
| Provider knowledge deficit    | Education (provision of information)  | Awareness-building, knowledge-acquisition | Feasibility, acceptability, appropriateness, adoption |
| Provider skill deficit        | Training (teaching and practice with corrective feedback)                           | Skill acquisition, refinement, mastery    | Fidelity to EBP                                       |
| Provider view EBP unfavorably | Audit and feedback provision of descriptive social norms indicating peer use of EBP | Social pressure/norms                     | Adoption  |
| Competing clinical demands    | Leadership training   | Growing leadership support/perseverance   | Adoption, sustainability                              |

# Training

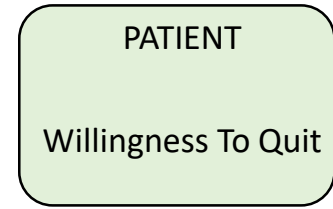
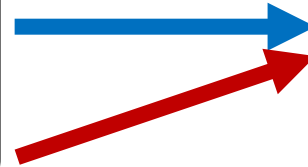
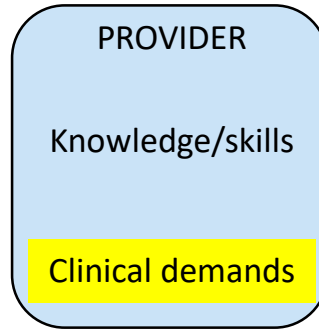
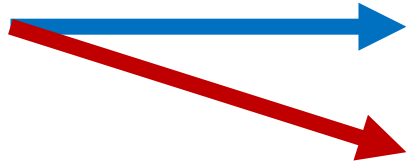
Training



| Determinant       | Implementation strategy | Mechanism             | Implementation outcome |
|-------------------|-------------------------|-----------------------|------------------------|
| Knowledge deficit | Education               | Awareness-building    | Acceptability          |
| Skill deficit     | Training                | Skill acquisition     | Fidelity to EBP        |
| Unfavorable view  | Audit and feedback      | Social pressure/norms | Adoption               |
| Clinical demands  | Leadership training     | Leadership support    | Sustainability         |

# Clinical demands

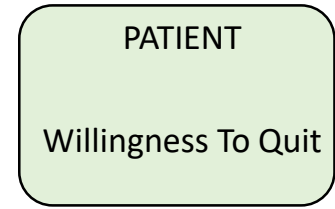
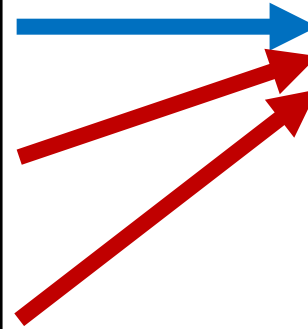
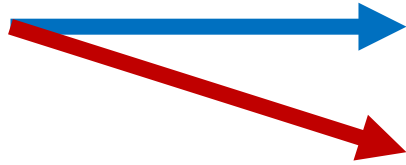
Training



| Determinant       | Implementation strategy | Mechanism             | Implementation outcome |
|-------------------|-------------------------|-----------------------|------------------------|
| Knowledge deficit | Education               | Awareness-building    | Acceptability          |
| Skill deficit     | Training                | Skill acquisition     | Fidelity to EBP        |
| Unfavorable view  | Audit and feedback      | Social pressure/norms | Adoption               |
| Clinical demands  | Leadership training     | Leadership support    | Sustainability         |

# View of the EBP

Training

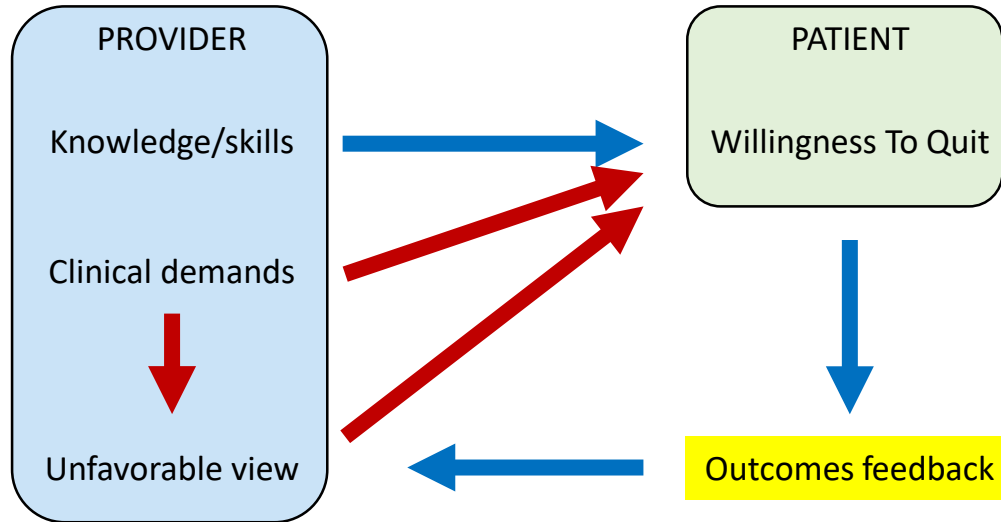


| Determinant       | Implementation strategy | Mechanism             | Implementation outcome |
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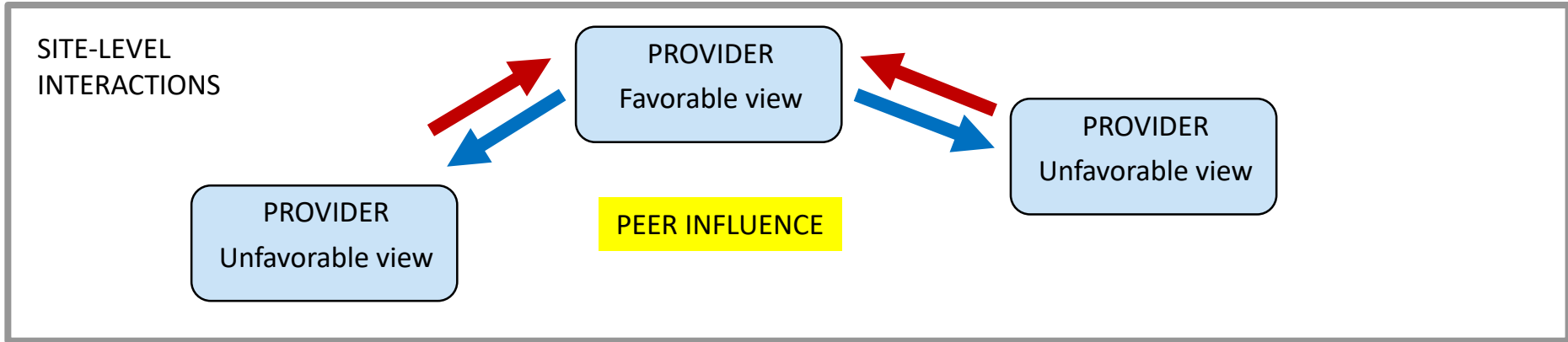
# Outcomes feedback

Training



| Determinant       | Implementation strategy | Mechanism             | Implementation outcome |
|-------------------|-------------------------|-----------------------|------------------------|
| Knowledge deficit | Education               | Awareness-building    | Acceptability          |
| Skill deficit     | Training                | Skill acquisition     | Fidelity to EBP        |
| Unfavorable view  | Audit and feedback      | Social pressure/norms | Adoption               |
| Clinical demands  | Leadership training     | Leadership support    | Sustainability         |

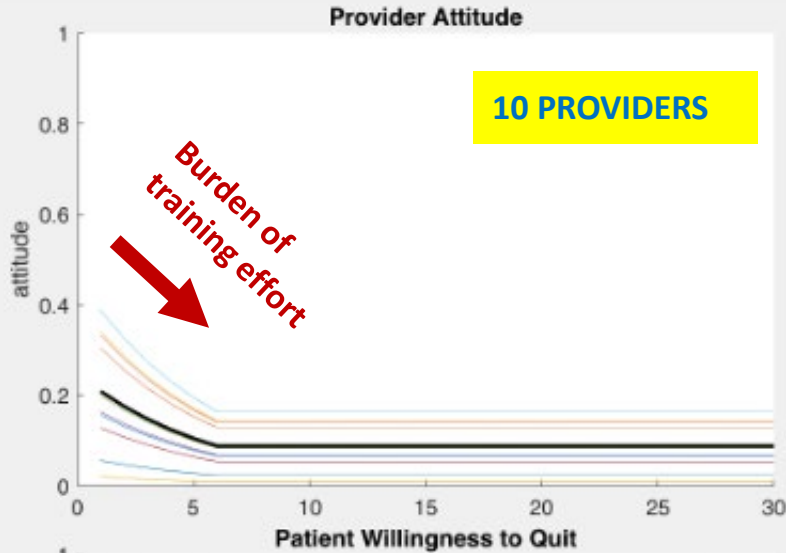
# Peer Influence



| Determinant       | Implementation strategy | Mechanism             | Implementation outcome |
|-------------------|-------------------------|-----------------------|------------------------|
| Knowledge deficit | Education               | Awareness-building    | Acceptability          |
| Skill deficit     | Training                | Skill acquisition     | Fidelity to EBP        |
| Unfavorable view  | Audit and feedback      | Social pressure/norms | Adoption               |
| Clinical demands  | Leadership training     | Leadership support    | Sustainability         |

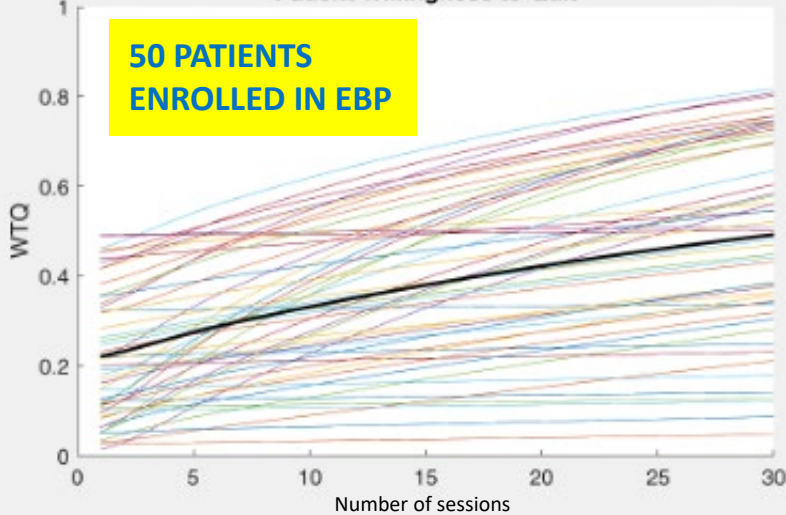
# Agent-Based Simulation

Initial attitudes towards the EBP



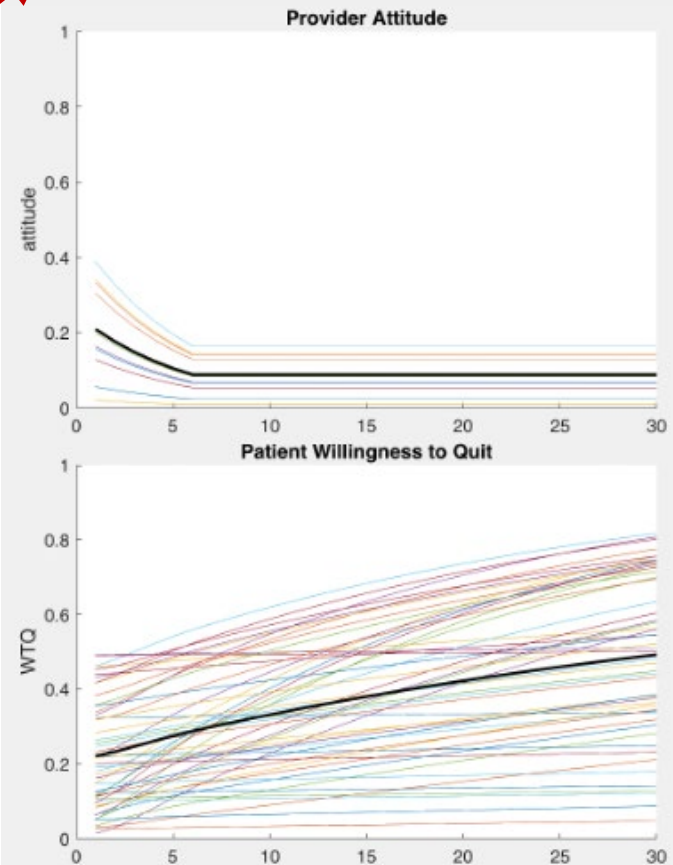
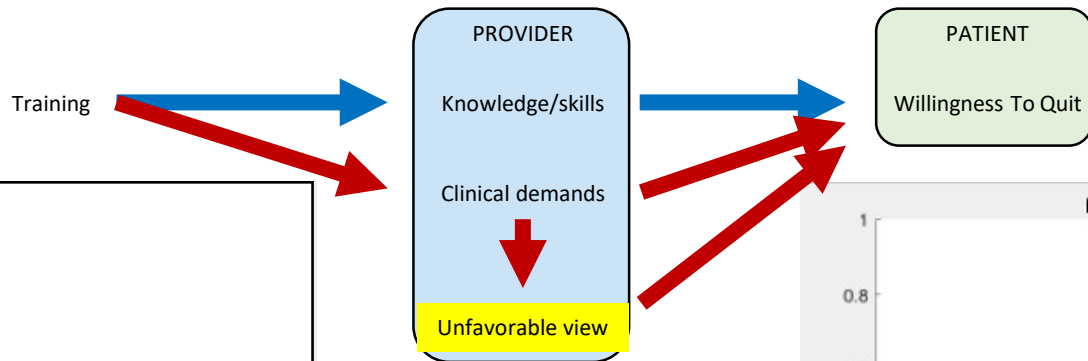
Attitudes towards the EBP after 30 sessions

Initial willingness to quit



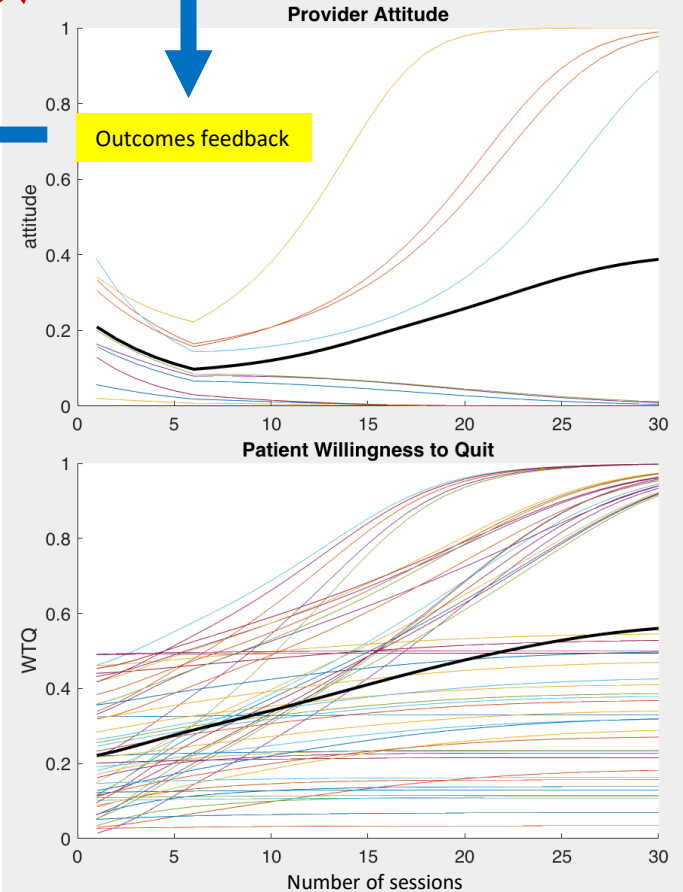
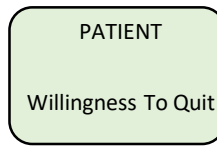
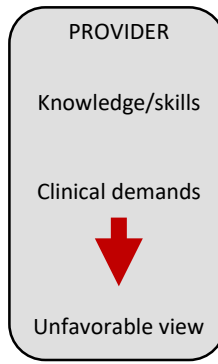
Final willingness to quit

# Training



# Outcomes feedback

Training



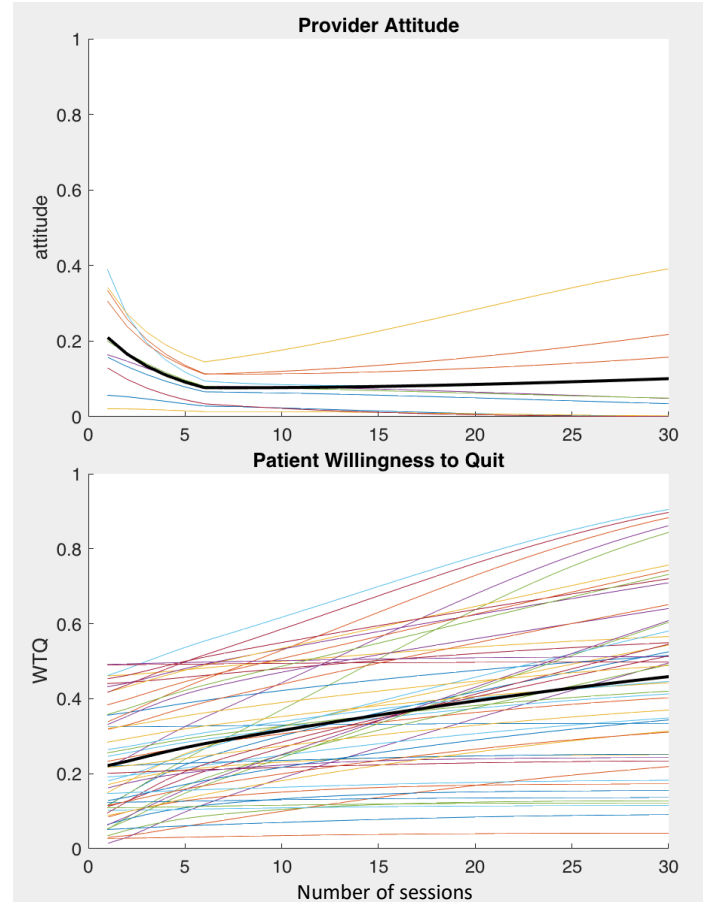
# Peer Influence

PROVIDER  
Unfavorable view

PROVIDER  
Favorable view

PROVIDER  
Unfavorable view

PEER  
INFLUENCE



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JOHNS HOPKINS

BLOOMBERG SCHOOL  
*of* PUBLIC HEALTH

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## Agent-based simulation of the impacts of Medicaid policies

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# Research question

What are the impacts of Medicaid policies on the implementation of a smoking cessation intervention?

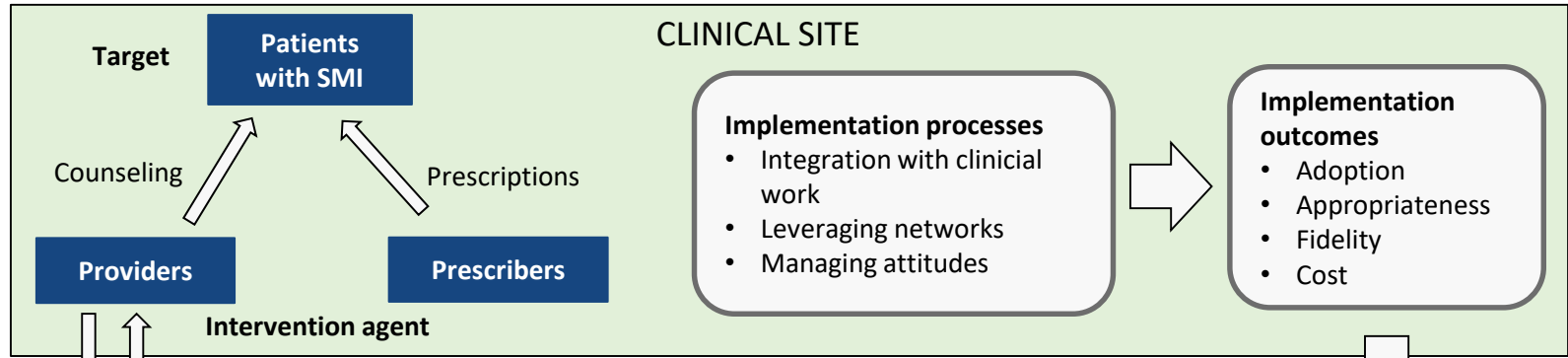
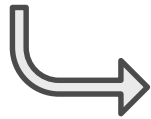


# Implementation of a smoking cessation intervention

## Conceptual framework based on on **Brown et al (2013)**

### Implementation agency

Training,  
Education,  
Implementation  
guidance



### Payer agent

Administrative service organization  
(e.g., Optum Maryland)



### Policy options

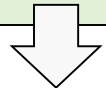
1. Stepped care therapy or tailored care therapy
2. Fee-for-service or outcome-based reimbursements

### Policy makers

State agencies  
(e.g., Behavioral Health  
Administration and Medicaid office)

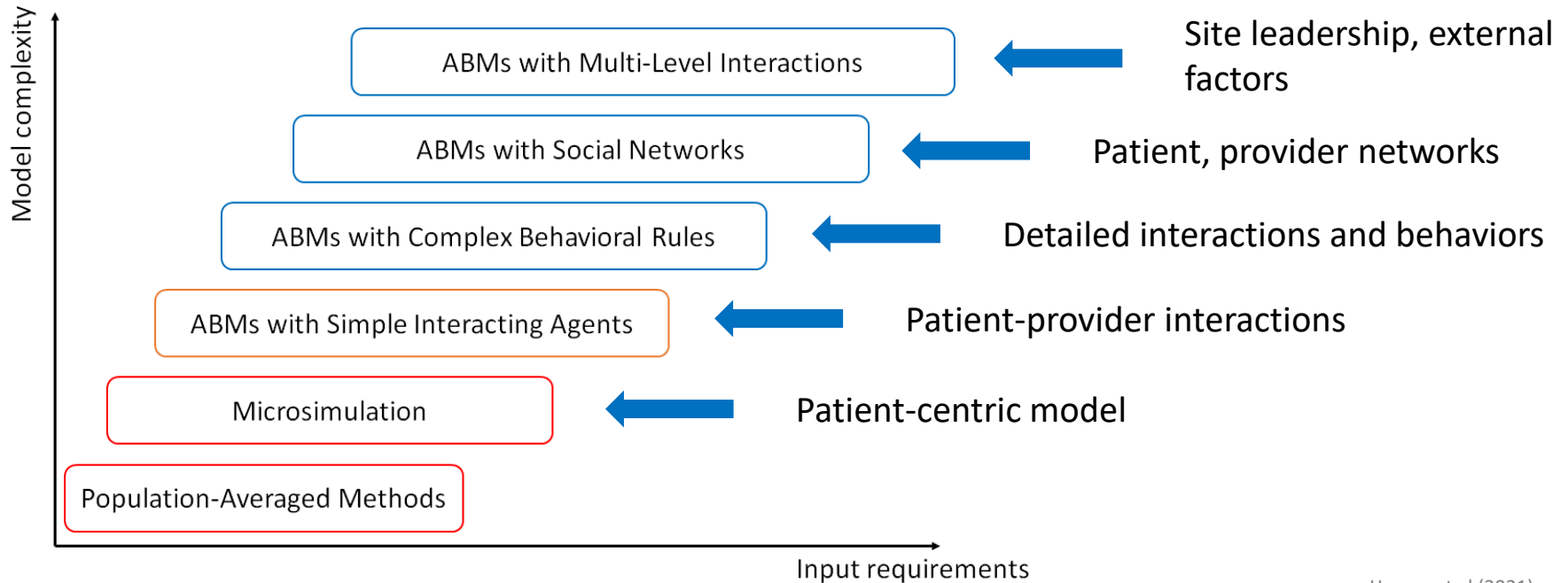


**Clinical outcomes**  
Quit rate



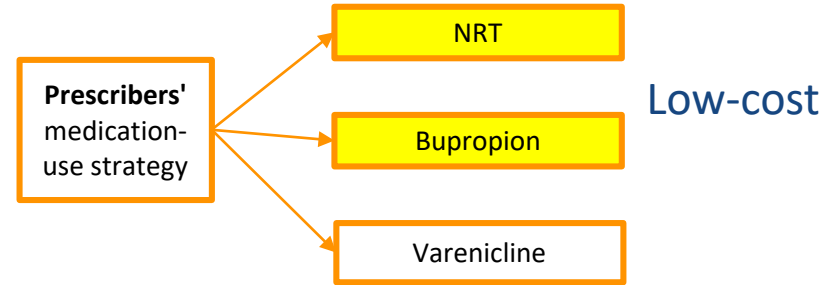
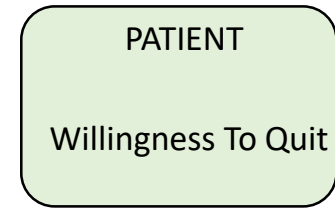
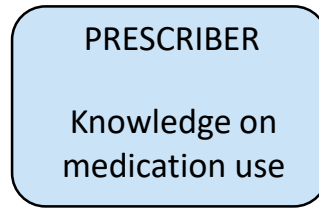
# Example 3: TIRUMPH, A smoking cessation program for persons with serious mental illness - Medicaid policies

## MODEL SELECTION



# Stepped therapy

Stepped therapy

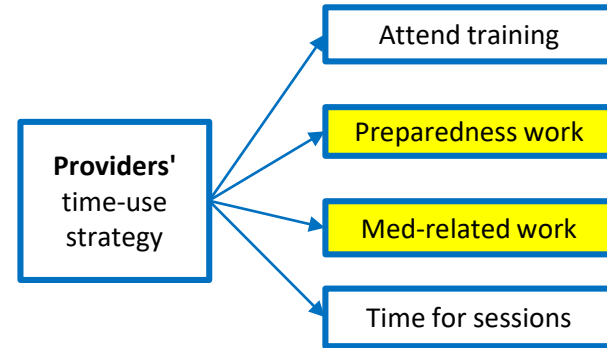
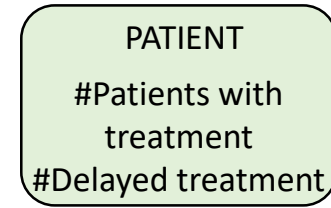
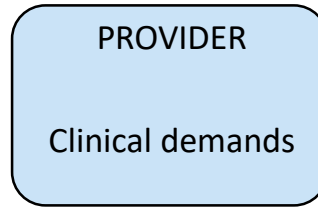


| Determinant       | Implementation strategy | Mechanism             | Implementation outcome         |
|-------------------|-------------------------|-----------------------|--------------------------------|
| Knowledge deficit | Education               | Awareness-building    | Appropriateness, acceptability |
| Skill deficit     | Training                | Skill acquisition     | Fidelity to EBP                |
| Unfavorable view  | Audit and feedback      | Social pressure/norms | Adoption                       |
| Clinical demands  | Leadership training     | Leadership support    | Sustainability                 |

Use low-cost medication first, if fail, then may use high-cost medication

# Tailored therapy

Tailored therapy

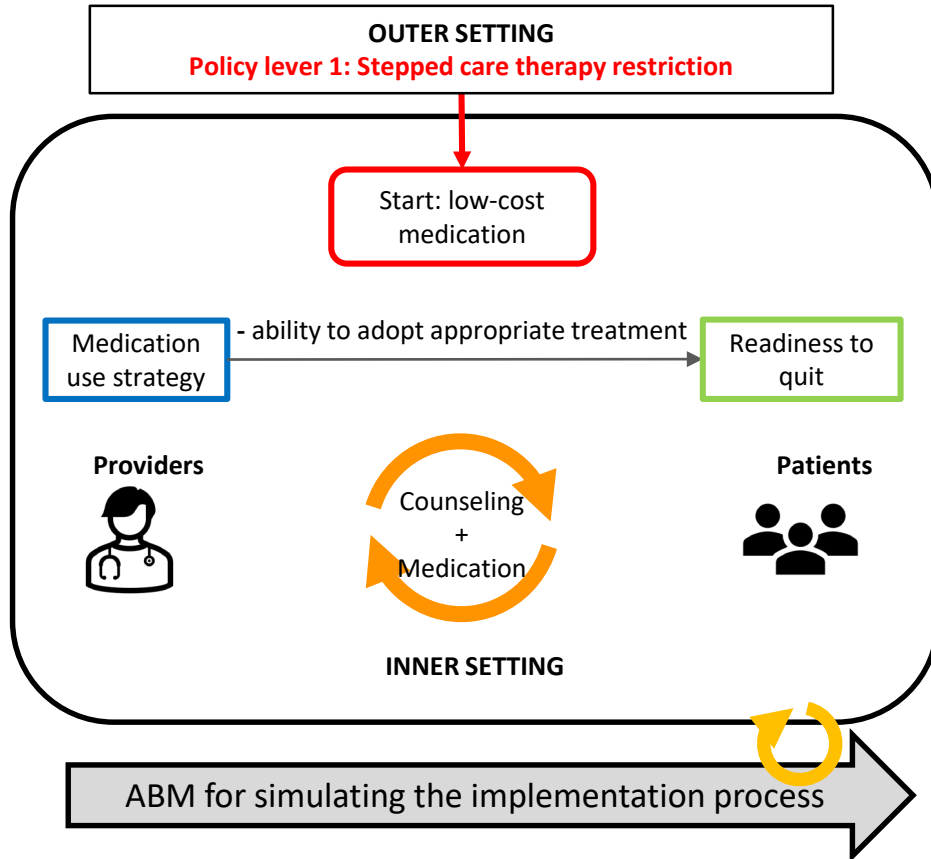


| Determinant       | Implementation strategy | Mechanism             | Implementation outcome         |
|-------------------|-------------------------|-----------------------|--------------------------------|
| Knowledge deficit | Education               | Awareness-building    | Appropriateness, acceptability |
| Skill deficit     | Training                | Skill acquisition     | Fidelity to EBP                |
| Unfavorable view  | Audit and feedback      | Social pressure/norms | Adoption                       |
| Clinical demands  | Leadership training     | Leadership support    | Sustainability                 |

Tailored therapy requires additional work

-> high competing clinical demands

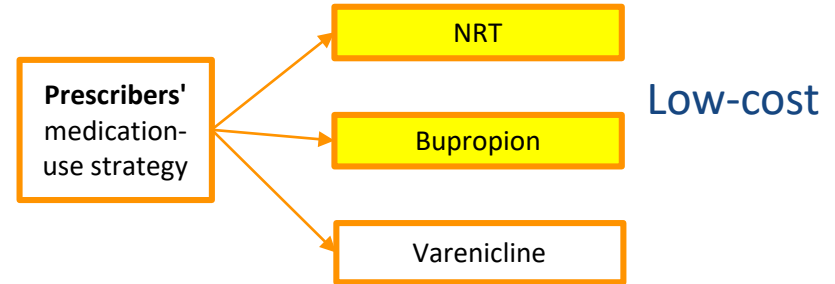
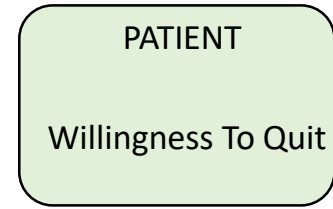
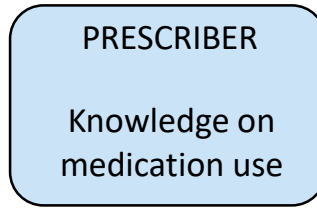
# Policy lever test 1: Stepped care therapy restriction



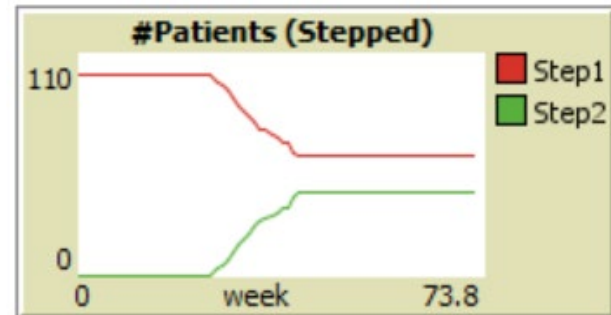
| Stepped care therapy   | Tailored care therapy   |
|--|---|
| <b>Pros:</b> <ul style="list-style-type: none"><li>• Lower time cost</li><li>• Less training requirement</li></ul> | <b>Pros:</b> <ul style="list-style-type: none"><li>• Higher patient outcomes</li></ul>  |
| <b>Cons:</b> <ul style="list-style-type: none"><li>• Lower patient outcomes</li><li>• Lower efficiency</li></ul>   | <b>Cons:</b> <ul style="list-style-type: none"><li>• Higher time cost</li><li>• Higher training requirement</li><li>• More workload</li></ul> |

# Stepped therapy

Stepped therapy

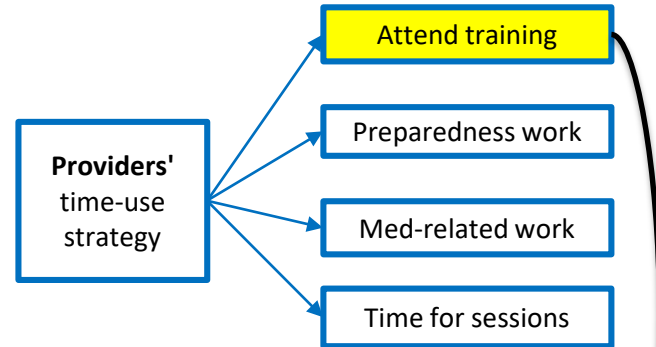
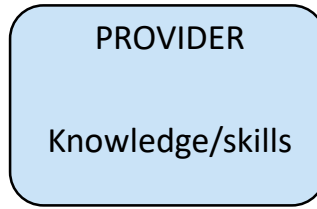


| Determinant       | Implementation strategy | Mechanism             | Implementation outcome         |
|-------------------|-------------------------|-----------------------|--------------------------------|
| Knowledge deficit | Education               | Awareness-building    | Appropriateness, acceptability |
| Skill deficit     | Training                | Skill acquisition     | Fidelity to EBP                |
| Unfavorable view  | Audit and feedback      | Social pressure/norms | Adoption                       |
| Clinical demands  | Leadership training     | Leadership support    | Sustainability                 |

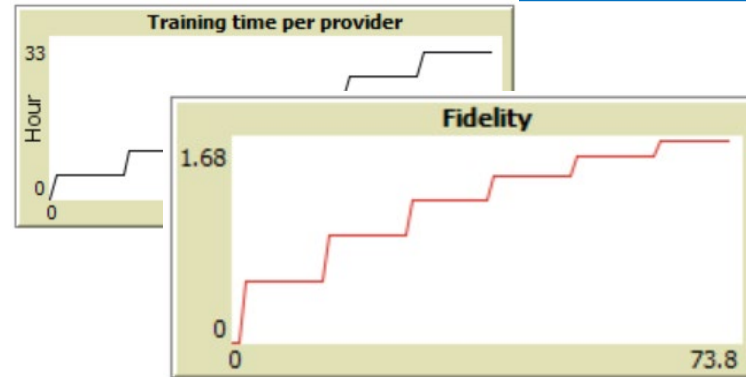


# Tailored therapy

Training for tailored therapy



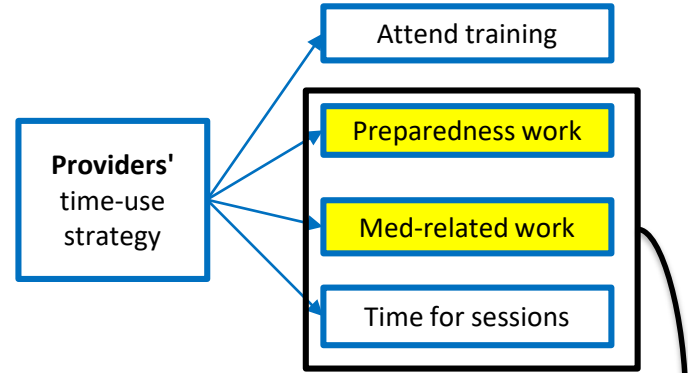
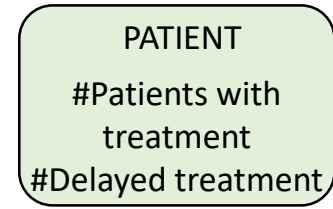
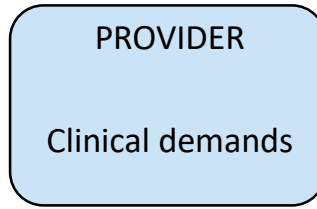
| Determinant          | Implementation strategy | Mechanism             | Implementation outcome         |
|----------------------|-------------------------|-----------------------|--------------------------------|
| Knowledge deficit    | Education               | Awareness-building    | Appropriateness, acceptability |
| <b>Skill deficit</b> | Training                | Skill acquisition     | Fidelity to EBP                |
| Unfavorable view     | Audit and feedback      | Social pressure/norms | Adoption                       |
| Clinical demands     | Leadership training     | Leadership support    | Sustainability                 |



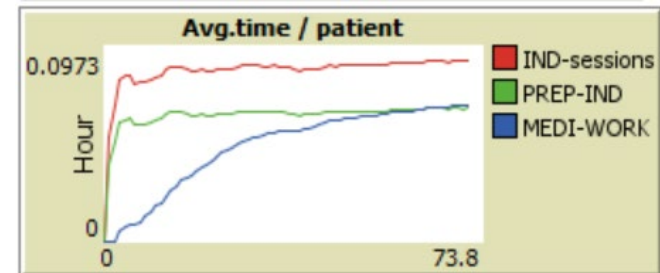


# Tailored therapy

Tailored therapy

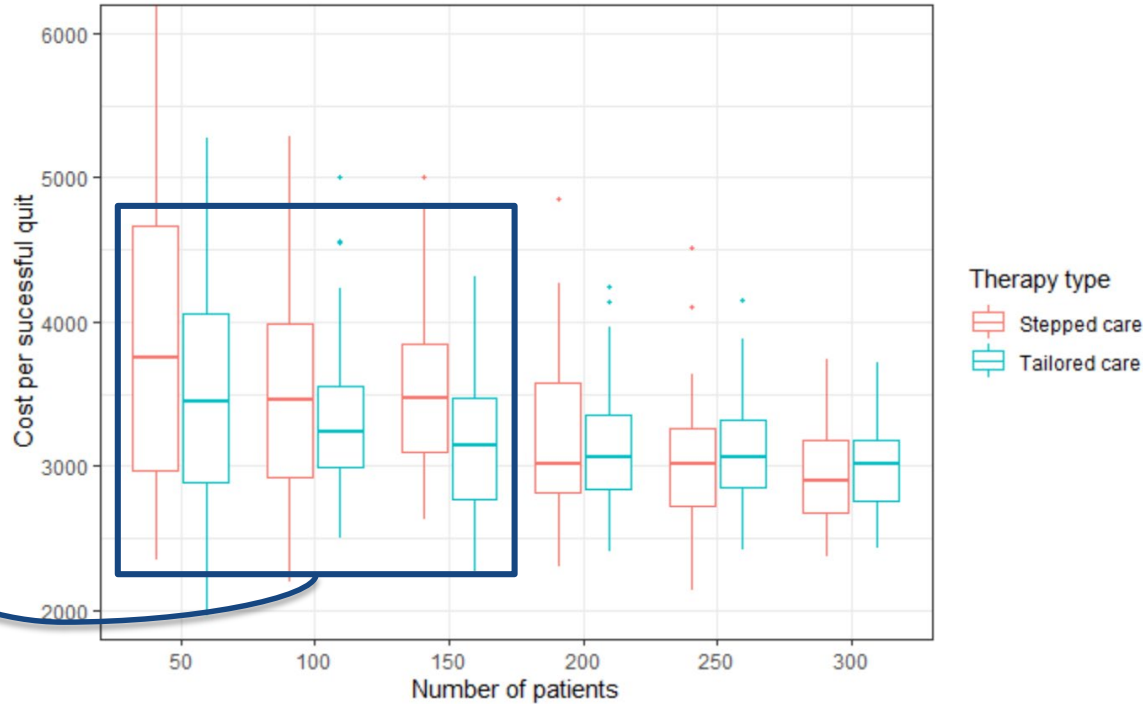


| Determinant             | Implementation strategy | Mechanism             | Implementation outcome         |
|-------------------------|-------------------------|-----------------------|--------------------------------|
| Knowledge deficit       | Education               | Awareness-building    | Appropriateness, acceptability |
| Skill deficit           | Training                | Skill acquisition     | Fidelity to EBP                |
| Unfavorable view        | Audit and feedback      | Social pressure/norms | Adoption                       |
| <b>Clinical demands</b> | Leadership training     | Leadership support    | Sustainability                 |

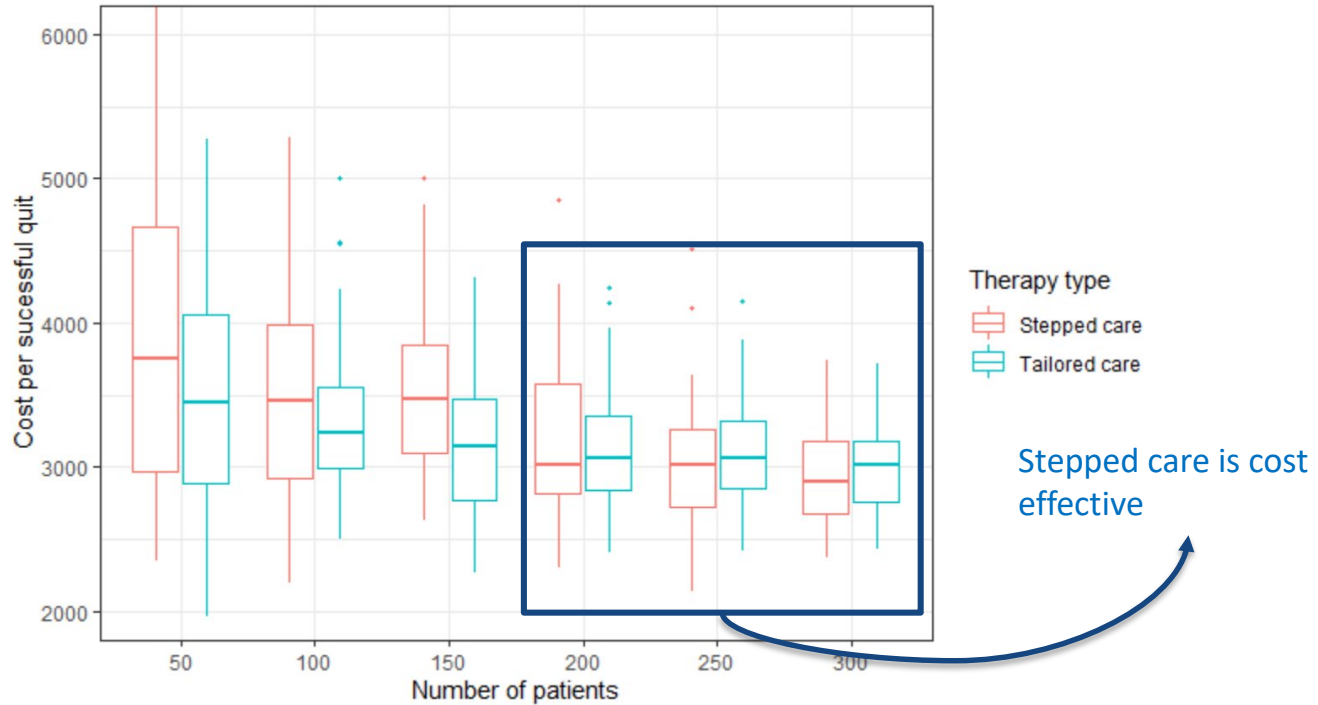


# Cost effectiveness of Medicaid payer

Tailored care is cost effective



# Cost effectiveness of Medicaid payer



# Sensitivity analyses results

- ▶ Stepped care therapy → sites with more patients
  - sites with limited human resources
- ▶ Tailored care therapy → sites with less competing clinical demands
  - sites with more training investment
- ▶ Barrier for choosing tailored care: heavy workload of health providers

# Simulation of the implementation processes using NetLogo



normal speed  view updates  
 Edit Delete Add abc Button | ticks: 73 continuous Settings...

Setup Go Go

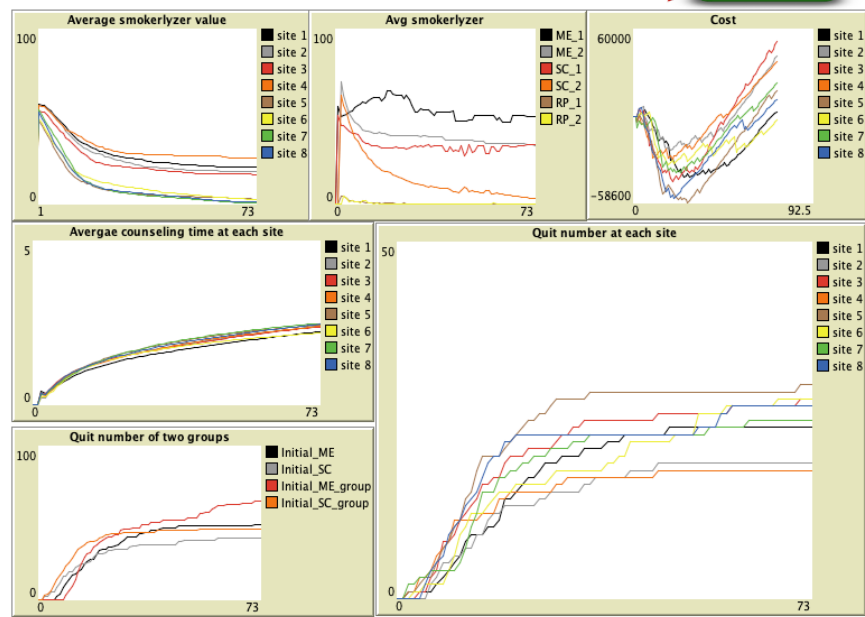
### Policy levers

|   |  |   |
|---|--|---|
| <input type="checkbox"/> On <input type="checkbox"/> Off Train-site1? | <input type="checkbox"/> On <input type="checkbox"/> Off Step-therapy-site1? | <input type="checkbox"/> On <input type="checkbox"/> Off Group-effect-site1 |
| <input type="checkbox"/> On <input type="checkbox"/> Off Train-site2? | <input type="checkbox"/> On <input type="checkbox"/> Off Step-therapy-site2? | <input type="checkbox"/> On <input type="checkbox"/> Off Group-effect-site2 |
| <input type="checkbox"/> On <input type="checkbox"/> Off Train-site3? | <input type="checkbox"/> On <input type="checkbox"/> Off Step-therapy-site3? | <input type="checkbox"/> On <input type="checkbox"/> Off Group-effect-site3 |
| <input type="checkbox"/> On <input type="checkbox"/> Off Train-site4? | <input type="checkbox"/> On <input type="checkbox"/> Off Step-therapy-site4? | <input type="checkbox"/> On <input type="checkbox"/> Off Group-effect-site4 |
| <input type="checkbox"/> On <input type="checkbox"/> Off Train-site5? | <input type="checkbox"/> On <input type="checkbox"/> Off Step-therapy-site5? | <input type="checkbox"/> On <input type="checkbox"/> Off Group-effect-site5 |
| <input type="checkbox"/> On <input type="checkbox"/> Off Train-site6? | <input type="checkbox"/> On <input type="checkbox"/> Off Step-therapy-site6? | <input type="checkbox"/> On <input type="checkbox"/> Off Group-effect-site6 |
| <input type="checkbox"/> On <input type="checkbox"/> Off Train-site7? | <input type="checkbox"/> On <input type="checkbox"/> Off Step-therapy-site7? | <input type="checkbox"/> On <input type="checkbox"/> Off Group-effect-site7 |
| <input type="checkbox"/> On <input type="checkbox"/> Off Train-site8? | <input type="checkbox"/> On <input type="checkbox"/> Off Step-therapy-site8? | <input type="checkbox"/> On <input type="checkbox"/> Off Group-effect-site8 |

### Other levers

|                     |    |                                 |   |
|---------------------|----|---------------------------------|---|
| Num-providers-site1 | 10 | Num-patients-per-provider-site1 | 5 |
| Num-providers-site2 | 10 | Num-patients-per-provider-site2 | 5 |
| Num-providers-site3 | 10 | Num-patients-per-provider-site3 | 5 |
| Num-providers-site4 | 10 | Num-patients-per-provider-site4 | 5 |
| Num-providers-site5 | 10 | Num-patients-per-provider-site5 | 5 |
| Num-providers-site6 | 10 | Num-patients-per-provider-site6 | 5 |
| Num-providers-site7 | 10 | Num-patients-per-provider-site7 | 5 |
| Num-providers-site8 | 10 | Num-patients-per-provider-site8 | 5 |

|                             |      |  |     |  |      |
|-----------------------------|------|--|-----|--|------|
| training-fee-per-provider   | 500  | work-fee-on-counseling-per-provider-per-h... | 50  | patient-cheap-med-used-rate                  | 0.50 |
| med-fee-per-time-nonStepped | 15   | med-fee-per-time-Stepped                     | 5   | patient-cheap-med-succeed-rate               | 0.20 |
| quit-benefit-per-quitter    | 4000 | work-fee-group-session                       | 100 | count patients with [ME_flag = 1]            | 212  |
|                             |      |  |     | count patients with [intervention-phase = 0] | 5    |
|                             |      |  |     | count patients with [ME_flag = 0]            | 188  |
|                             |      |  |     | count patients with [intervention-phase = 1] | 196  |
|                             |      |  |     | count patients with [intervention-phase = 2] | 199  |



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# Acknowledgements

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from the National Institutes of Health

