Applying ABM to the Problems of Addiction and Drug Markets

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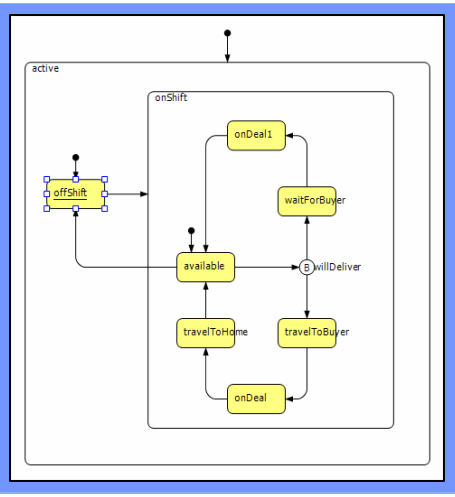

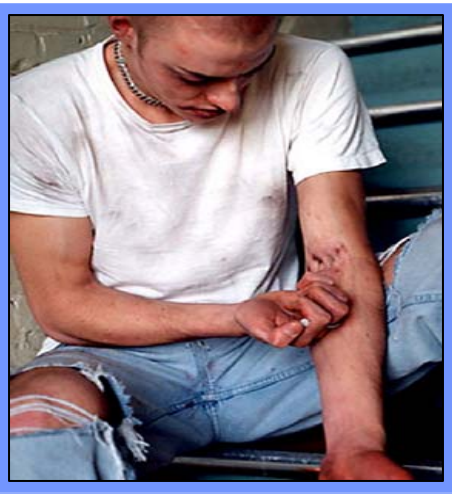

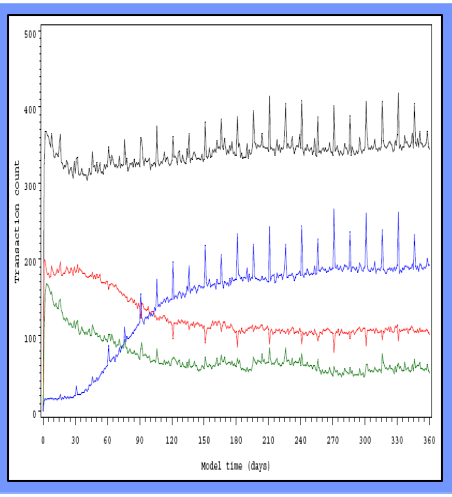

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idms:Lab
Illicit Drug Market Simulation

National Institutes of Health, National Institute on Drug Abuse: DA09232, DA06016, & DA019476

For my talk…

- ✓ Discuss how we are using agent-based modeling (ABM) to research addiction & illicit drug markets
- ✓ Introduce agent-based modeling
- ✓ Highlight the potential of combining ABM & social network research

The Illicit Drug Market Simulation Project (IDMS)

An experimental project combining ethnographic data & agent-based modeling (ABM) to analyze the operation of a local heroin market

Specific Aims:

1. Develop a computational model to quantify, experiment with, and extend *ethnographic findings* (re-analysis)

2. Design protocols to expand this hybrid methodology for drug policy research

(DA019476)

Ethnographic Research Methods

Overview

1. The hallmark of cultural anthropology (qualitative method)
2. Open ended interviewing & participant-observation techniques (i.e., fieldwork)
3. Collecting & verifying – accounts, beliefs, and observed behaviors *over time* (analytically inductive & iterative)
4. Involves developing considerable rapport with participants
5. Findings are typically descriptive (an ethnography)

The IDMS Project (Past, Present, & Future)

(1992-2001) University of Colorado, Denver, CO.

- ✓ Ethnographic research on drug users risk behaviors
- ✓ NIH, NIDA *Social Network Intervention Project* – DA09232 (Koester, PI)
- ✓ NIH, NIDA F31 Pre-doctoral fellowship – DA06016 (*Junkie Business*: Sept.1997 – Feb. 1999)

(2005-2008) Washington University School of Medicine, St. Louis, MO.

- ✓ IDMS Project, NIH, NIDA R21 *Evaluating the Social Structure of a Local Heroin Market* – DA019476 (Hoffer, PI)

(2008-2014) Case Western Reserve University, Dept. of Anthro., Cleveland, OH.

1. NSF *Merging Agent-based Modeling Techniques and Ethnography: A New Analytic Tool for Studying Illicit Drug Use Behaviors, Markets and Economies* – BCS-0724320 (Hoffer, PI)

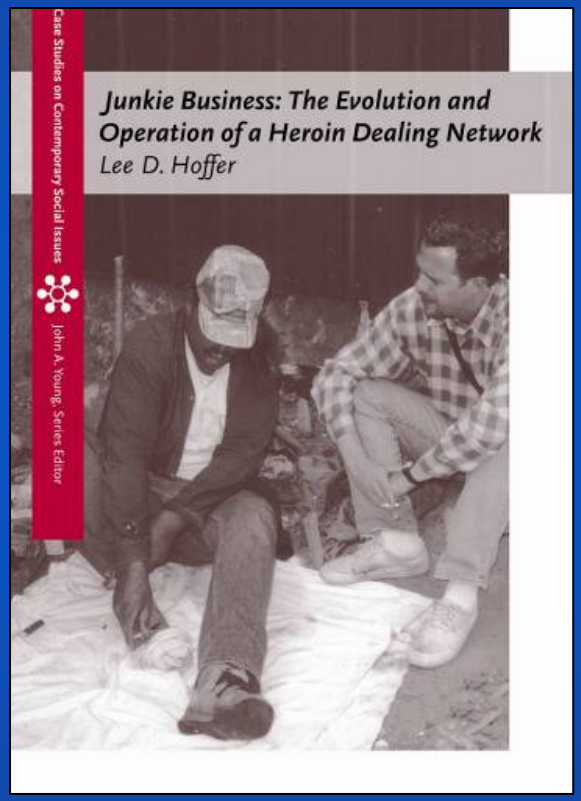
2. NIH, NIDA RO1 *Researching the Social Dynamics of a Local Methamphetamine Market* – DA025163 (Hoffer, PI)

The Ethnographic Data

Junkie Business was an eighteen month ethnographic case-study of a heroin dealing network (Denver, CO., 1997-1999)

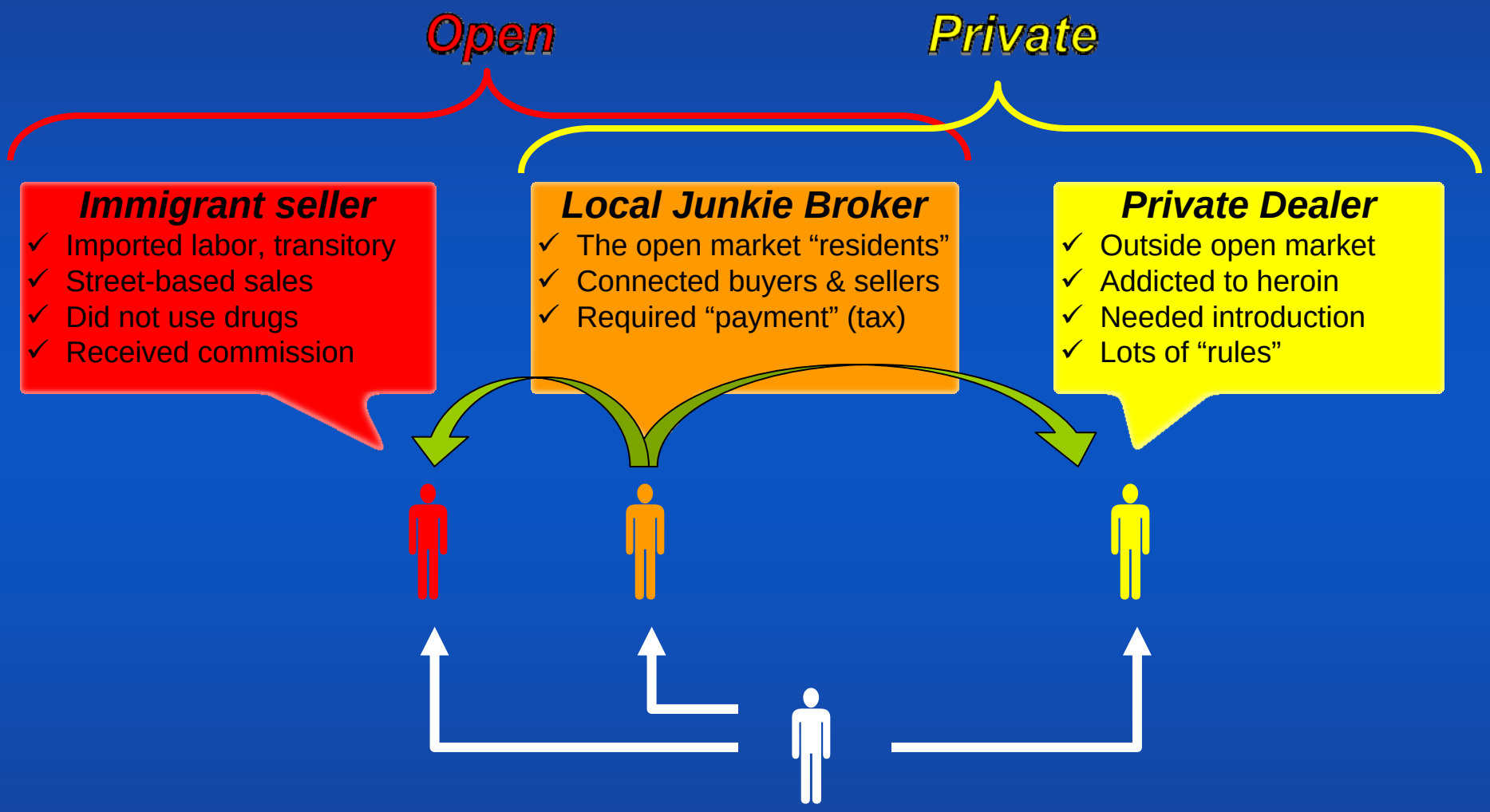
The study described:

1. Interactions between customers & heroin dealers
2. Operational activities & decision-making processes of drug dealers
3. How the heroin market operated
4. The transformation of that market



(Thomson Wadsworth, 2006)

The Heroin Market: Findings



***Three* Options for Customers**

***Junkie Business*: Unsettled Issues**

1. How could findings be *generalized* in order to observe (i.e., quantify) the output of the market?

1. What approach could incorporate the self-organizing & dynamic nature of illicit drug markets?

2. How could health behaviors be integrated into models of market operations? (i.e., policy modeling)

Complex Systems *(a.k.a., Social Dynamics)*

- ✓ Patterns of behavior involve non-linear & dynamic interactions between heterogeneous agents
- ✓ Cannot be explained by aggregating individual behaviors (i.e., the whole is *different* from the sum of its parts)
- ✓ Complex Systems "emerge" from individuals: 1) interacting with other individuals & 2) adapting, interacting, and changing their environment (ecological framework)

Agent-based modeling (ABM) can produce emergence by "growing" or reproducing systems using agents

Agent-based Modeling (ABM)

- ✓ "Agents" are autonomous computer programs (within programs) that can…
  - Perceive their environment & other agents
  - Perform actions & interactions (motion, communication, exchange)
  - Remember previous states & actions (non-Markov process)
  - Execute rules, heuristics, & strategies
  - Update actions, change & adapt

  (Gilbert, 2008; also Wooldridge & Jennings, 1995)

- ✓ ABMs are simplified models for expressing dynamic processes thought to exist in the social world
  - Agents can represent: individuals, households, firms, nations...
  - Can incorporate heterogeneity, feed-back loops, randomness

  (Macy & Willer, 2002; Sawyer, 2004)

Agent-based Modeling: Types of ABMs

IDMS Project

Abstract	Middle Range	Facsimile
Basic social process implicated in a variety of social domains. Not intended to model an empirical case.	Models are abstract enough to have some generalizable outcomes but still not case specific.	Models reproducing a specific case as precisely as possible.
Examples:	Examples:	Examples:
• Segregation (Schelling)	• Segregation (Macy)	• Archeological models (Kohler)
• Cooperation (Axelrod)	• Networks (Barabási)	• Bali water temples (Lansing)
• Artificial life (Epstein & Axtell)	• Power law distributions	• Drug trends (Agar)

(Gilbert, 2008)

	Agent-based Modeling	***Equation-Based Modeling***
Objective	**To represent a system through time**	
Perspective	Individual level	System level
The Data	Individual agents relationships, interactions & behaviors	Data from output of the system
The Method	Uses agents behaviors to produce the system, "bottom-up"	Uses equations to represent the system
The Product	A simulated system, generating outputs of that system	An equation showing relationships between outputs of the system
Strengths	1. Can generate emergent properties of a system 2. Incorporates heterogeneity 3. Provides a natural description of a system 4. Experimentation	1. Data driven 2. Conventional 3. Macro oriented
Weaknesses	1. Local / micro orientation 2. Data might not be available for validation 3. Young method	*1. A priori* assumptions about system 2. Relies on homogeneity 3. Not easy to experiment with

Experimenting with ABMs

Model 1: agents + environment → Outcome(s) of interest

(Change)

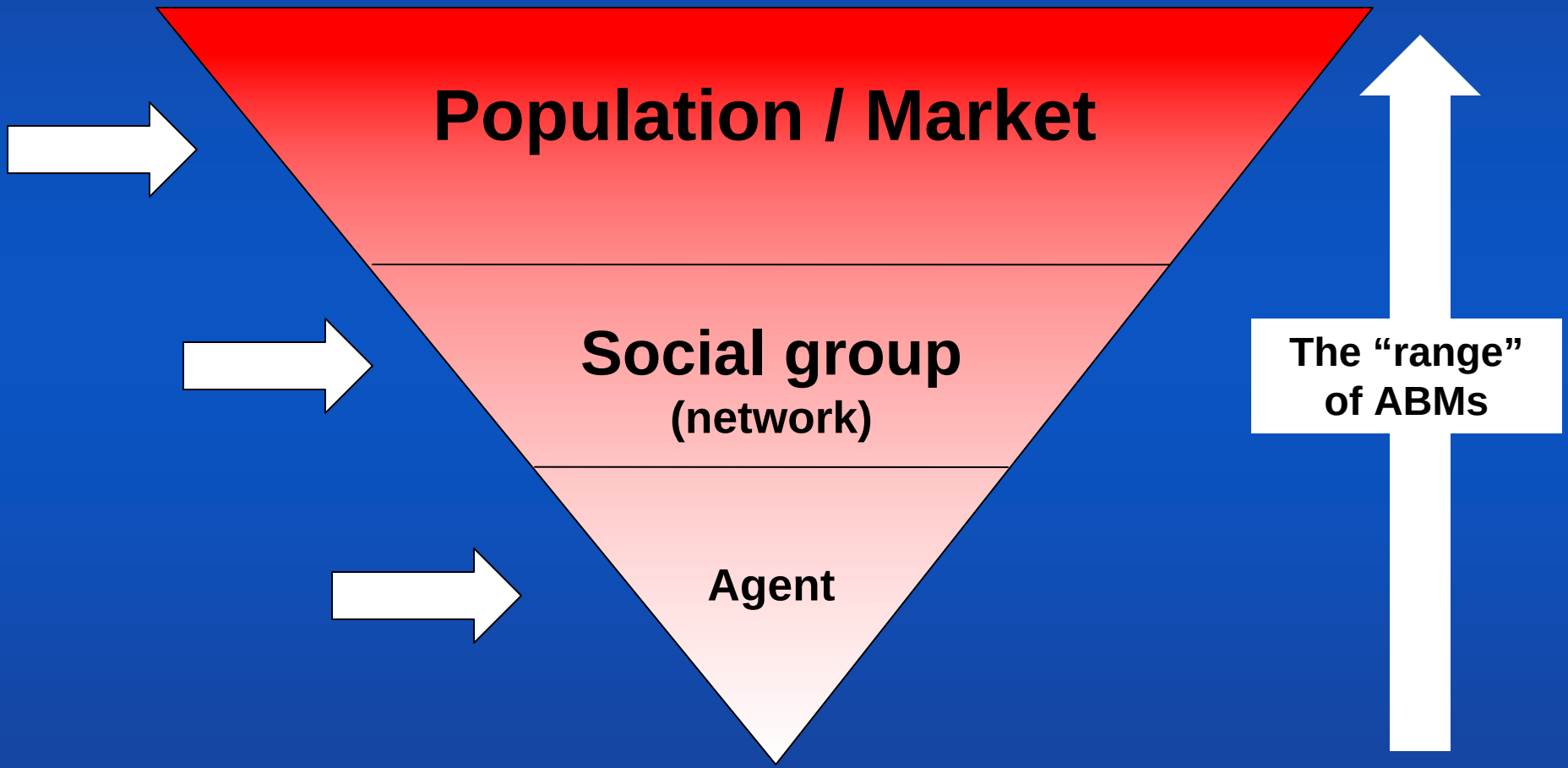
Model 2: agents + environment → Outcome(s) of interest

Model 3: agents + environment → Outcome(s) of interest

Model 4: agents + environment → Outcome(s) of interest

Model …

The Resolution of ABMs



The Market Simulation: Overview

The Objective:

Model the operation of the Larimer area heroin market

The Environment:

Open-air & private market areas

The Agent behaviors:

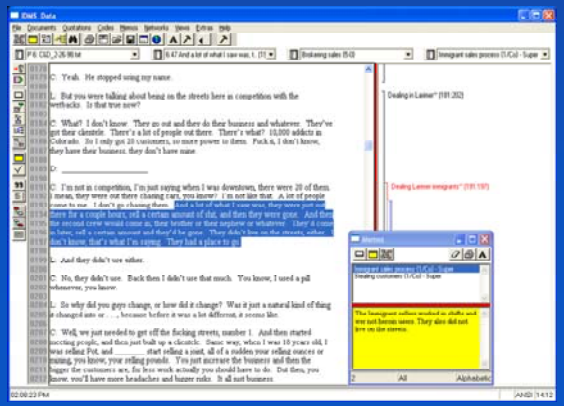
1. *Customers*: *addicted to & use heroin*, purchase heroin, remember dealer locations
2. *Street dealer*: sell heroin in market, are "visible" to any agent, work specific hours
3. *Private dealer:* sell heroin outside market area, only visible to customers who "know" them, meet customers through brokers
4. *Brokers*: make purchases for customers, know street dealer locations, can know private dealer locations
5. *Homeless:* wander the market (i.e., noise)
6. *Police:* stop, investigate, and remove (i.e., arrest) agents that possess heroin

The Market Simulation: Extracting Data

1) Raw data

2) Findings from notes & memos

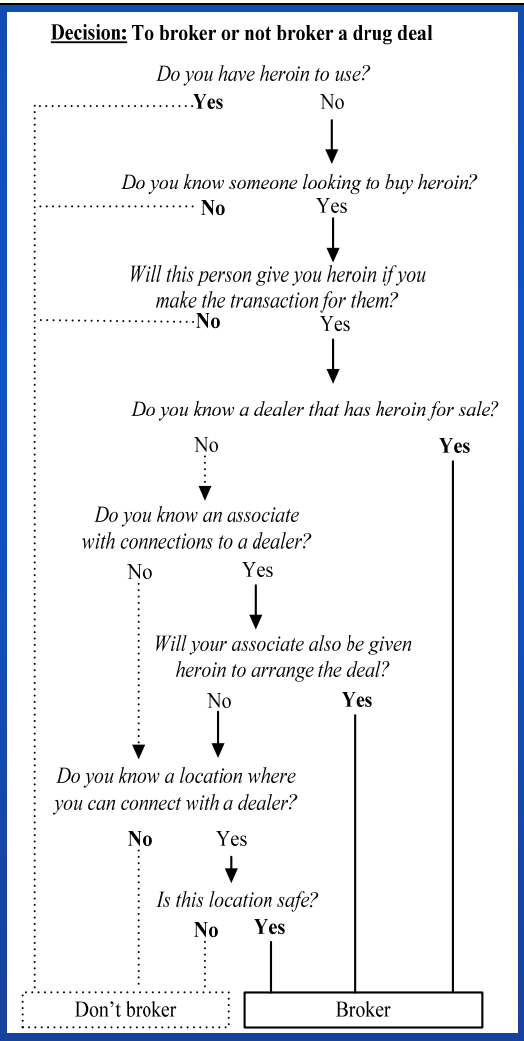
Junkie Business data



(Atlas.ti)

3) Literature review, general info., & estimates

“Decision” trees:
Incorporating social context & agent decisions

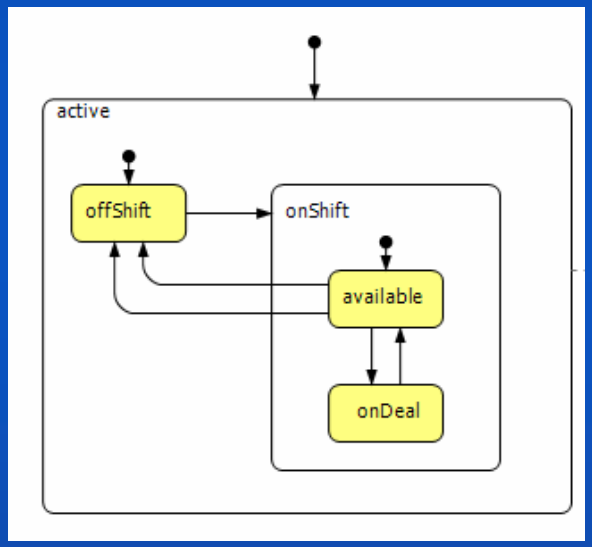


Gaps: Data was not originally collected to construct an ABM

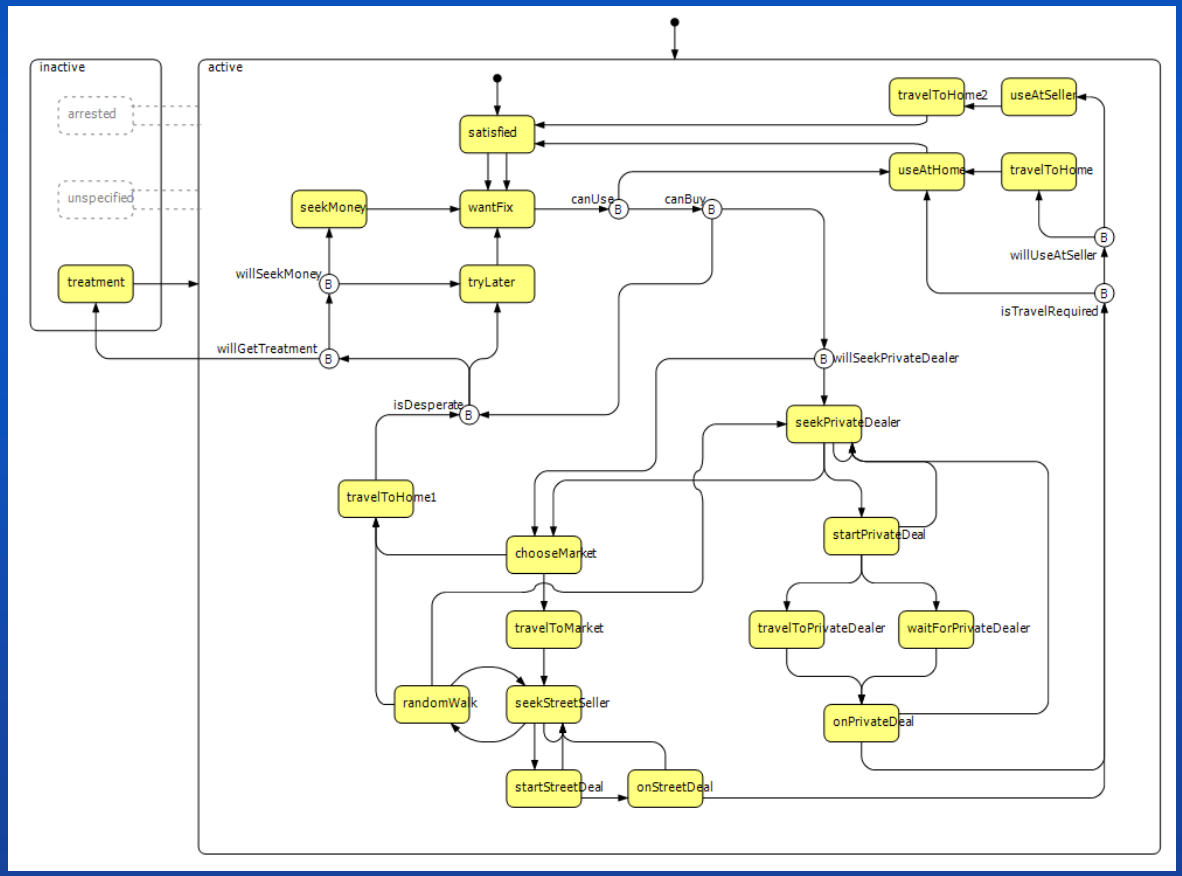
The Market Simulation: Agent Specifications

- ✓ Both simple & complex agents
- ✓ Most behaviors were “generic”… – e.g., buying / selling heroin, interactions

Street dealer

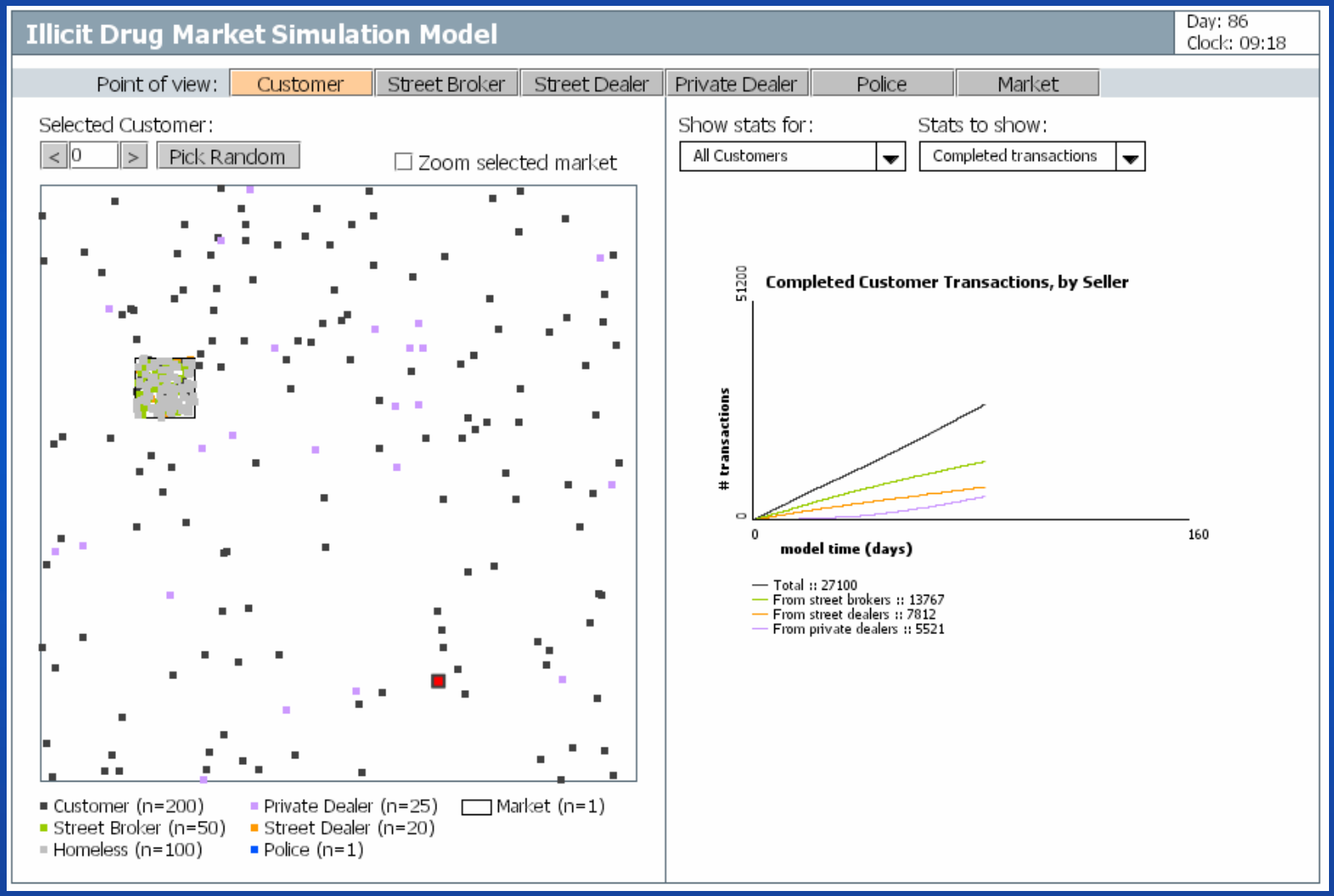


Customer



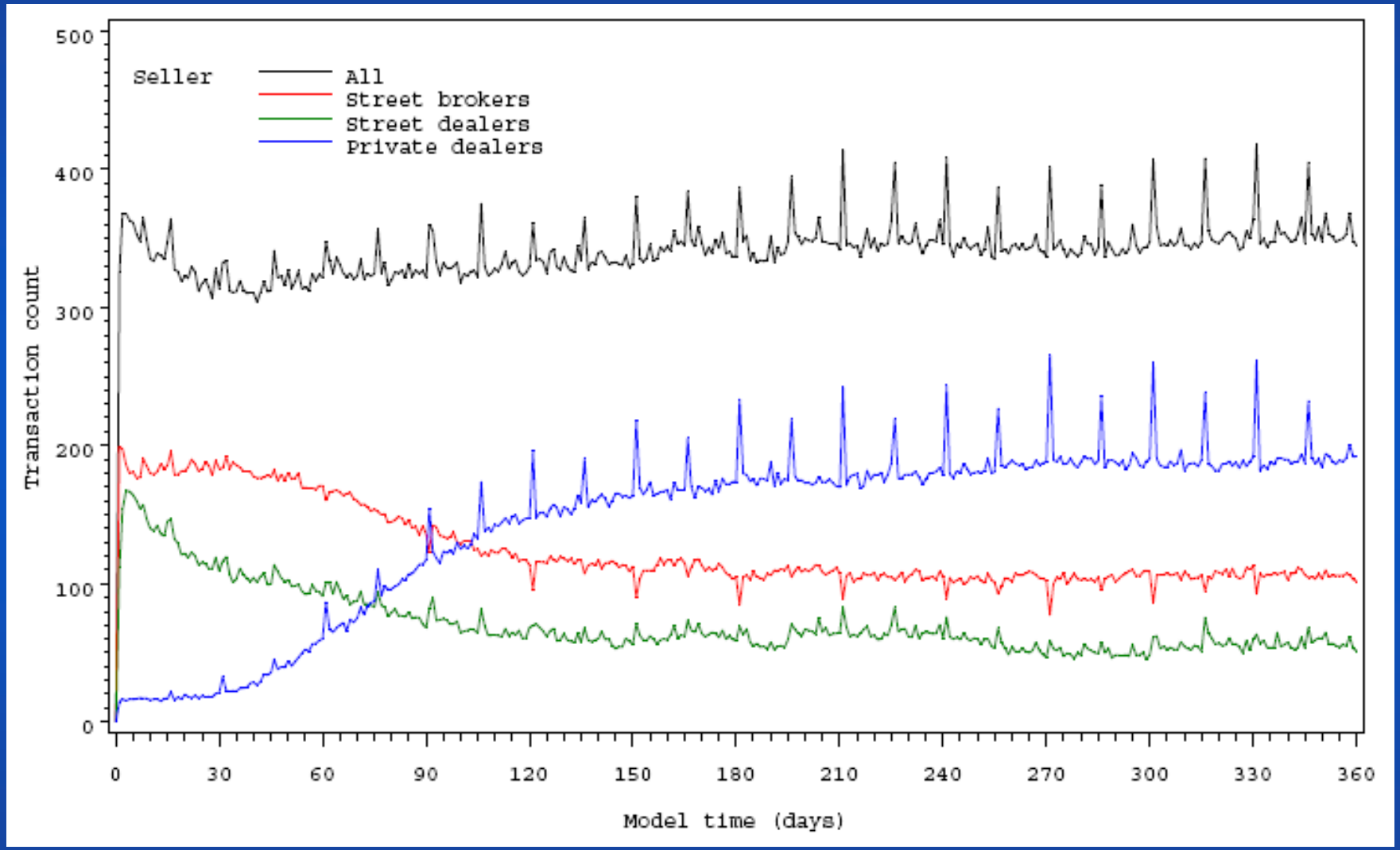
Anylogic™ 5.0, XJ Technologies

The Market Simulation: Screen shot



Anylogic™ 5.0, XJ Technologies

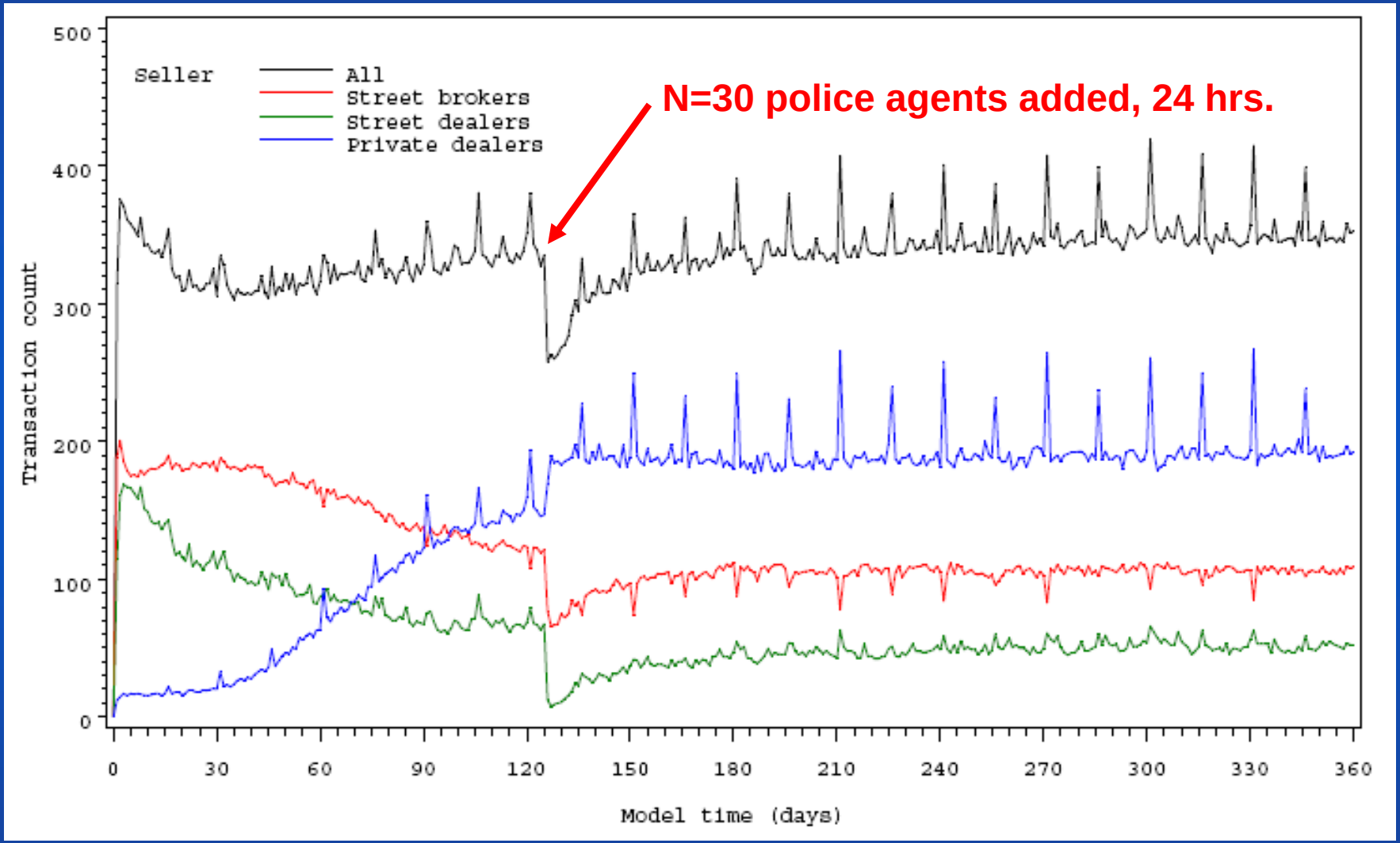
Market transaction totals (by seller)



Customers: N=200; Street Dealers: 20; Private Dealers: 25; Brokers: N=50; Homeless: N=100

(20 simulation runs)

Transaction totals: “bust scenario”



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(20 simulation runs)

Conclusion: IDMS

Limitations:

- ✓ Computational / data restrictions
- ✓ Missing important agent behaviors
    1. Groups but not networks (no resource / information sharing, affiliations)
    2. “Networked agents”
- ✓ Undeveloped environment & no risk behaviors

Next Steps:

- ✓ COLLECT DATA FOR ABM – multiple techniques
- ✓ Integrate “environmental” factors
    1. Data & feedback from providers
- ✓ Model verification

Current Research Projects

Data Requirements for ABM

- ✓ Understanding agent interactions & decisions over time
- ✓ Setting parameters / metrics
- ✓ Verify data
- ✓ *Biologic markers**

Methods

1) Ethnographic research
(Ethno. decision-tree modeling)

2) Ecological Momentary Assessment (transactional diaries on PDA)

3) Panel Survey

4) Oral Fluid Collection*

Strengths of ABM

1. A new research tool – asking different questions, expanding the science

1. Takes advantage of explanatory models produced from ethnography (analytical framework)

2. Offers a solution to observe biological, social & environmental interactions over time

1. Provides potential opportunities to evaluate interventions & identify unintended consequences (i.e., experimental manipulation, scenario modeling)

(e.g., The community responses to meth. use in Summit county)

ABM & Network Dynamics

ABM offers techniques to…

1. Integrate “social network” influences on health behavior
2. Observe the flow of resources, information, disease, etc. through networks
3. Evaluate the structures of networks, how do they evolve
4. Manipulate networks (interventions)
5. Test, scale-up, further explore, & extend findings

To get started… http://ccl.northwestern.edu/netlogo/

Challenges of ABM

1. A new research tool – the application of ABM is still developing
2. Data collection – requires detailed micro-level longitudinal data
3. Collaborations – researchers with different methodological expertise
4. No undergraduate, graduate, or postdoctoral training opportunities – applications of ABM (health research)

Acknowledgements

Georgiy Bobashev *RTI International, Durham, NC*
Robert (Joey) Morris *RTI International, Durham, NC*

Michael Agar *Redfish Group, Santa Fe, NM*
Joshua Thorp *Redfish Group, Santa Fe, NM*
Burchan Bayazit *Washington University, St. Louis, MO*

CWRU Research Team: Smaranda Ene, Sarah Koopman-Gonzalez, John Heintz, Jonathan Metcalfe, & Allison Schlosser

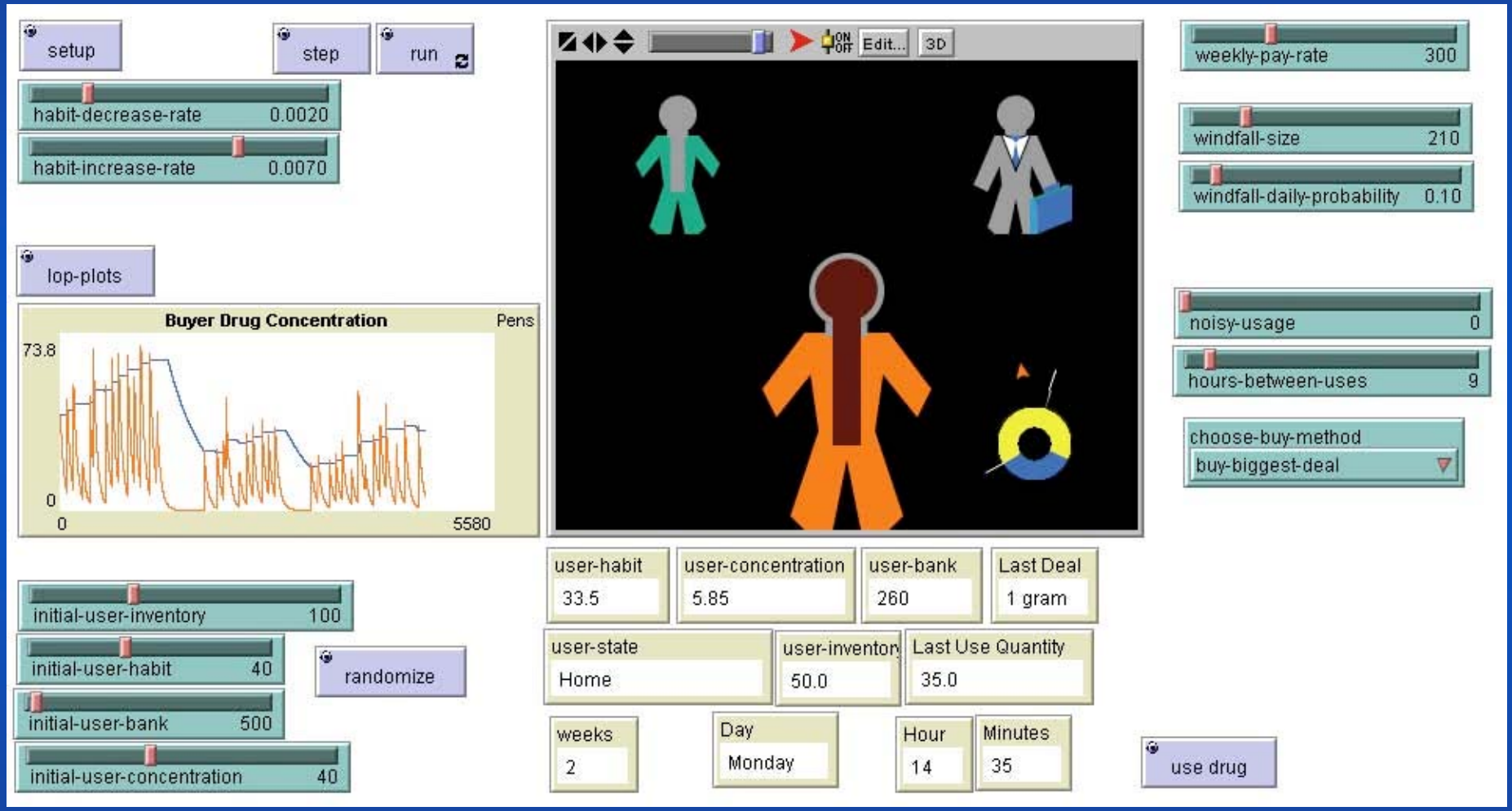
National Institute on Drug Abuse: DA06016, DA019476

Website: case.edu/artsci/anth/Hoffer.html (model doc. Available)

THANK YOU...

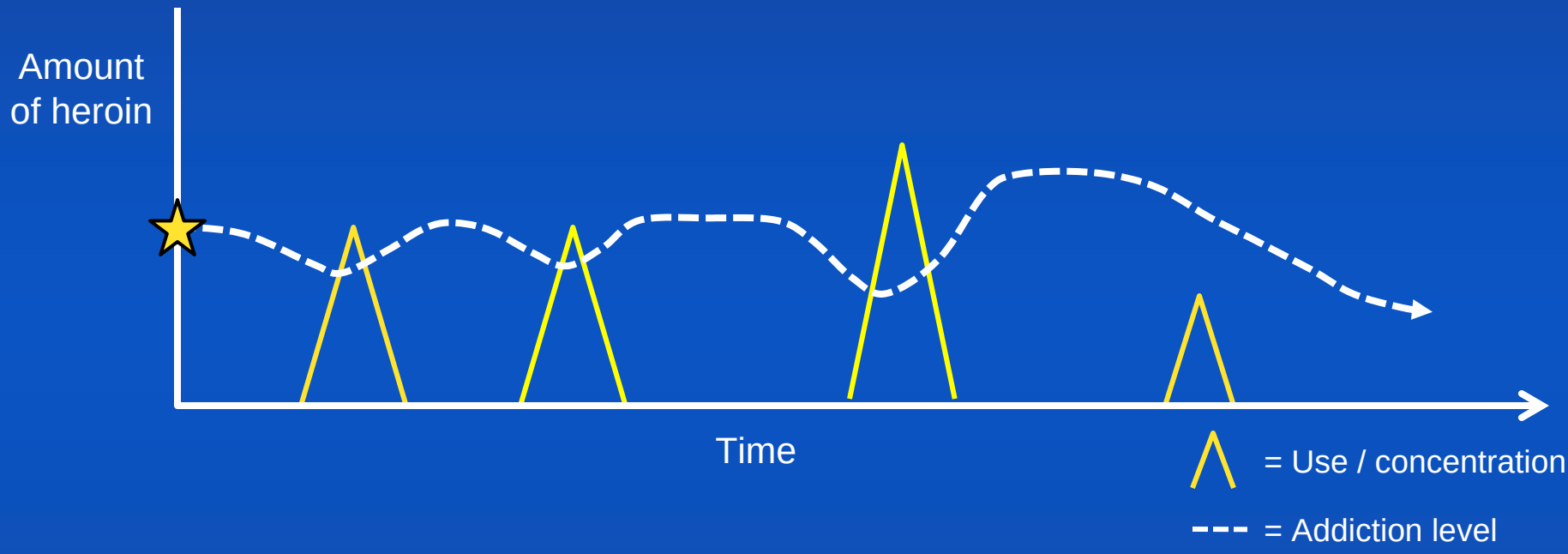
Extra Slides

"Toy" Model: *Customer Agent*



NetLogo

Agent Behaviors: Customer "Addiction Levels"



Addiction level: (i.e., "heroin habit") a compound measure of…

(1) the heroin amount a customer seeks to use *but also* reflects

(2) the outcome of their use

Customer Agent Addictions

Assumption 1:

Agents know how much heroin they *need* to remain "well." (habit maintenance)

Assumption 2:

Agents use as much heroin as they *need* to remain "well." (withdrawal avoidance)

Assumption 3:

Agents use heroin to get "high" (euphoria seeking)

Fact 1:

Opiate use produces tolerance (dynamic)

Fact 2:

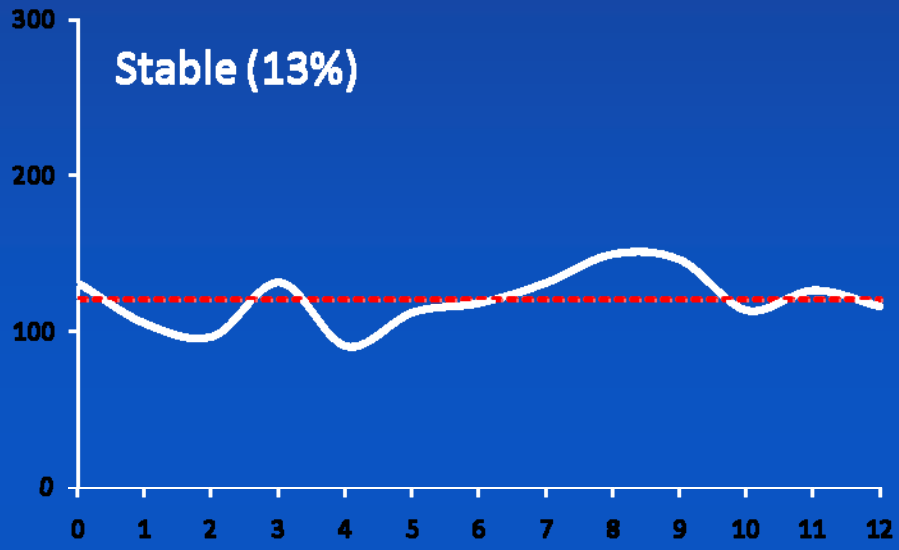
Customers purchase heroin in available amounts– purchased as much as they could (.25) or what they needed & also used randomly

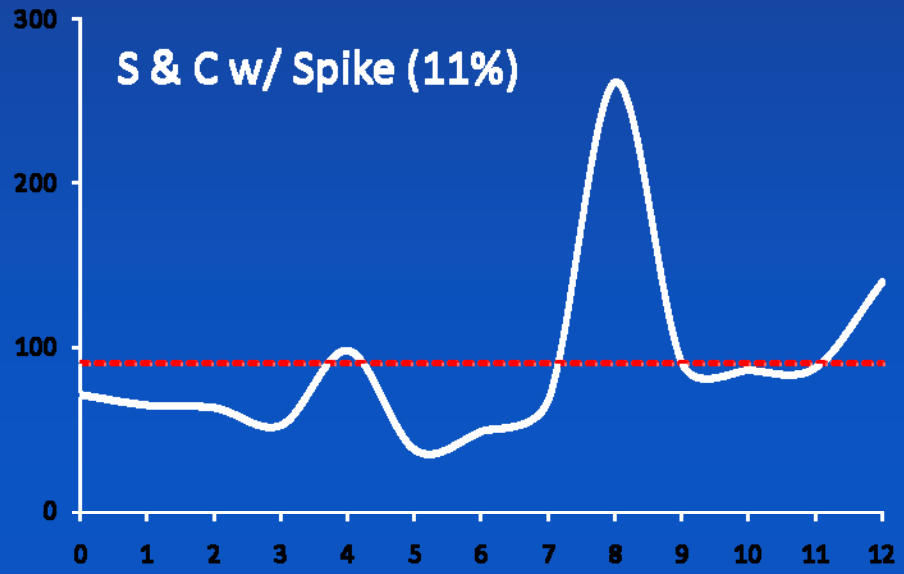
The Market Simulation: Model Parameters

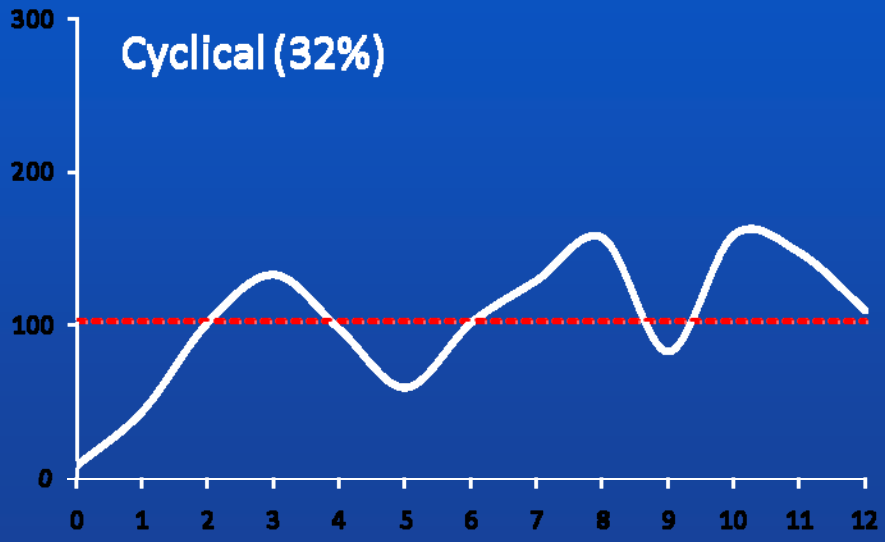
- ✓ Parameters are: 1) Input values (e.g., drug prices) or 2) Probabilities (e.g., probability of knowing a private dealer)

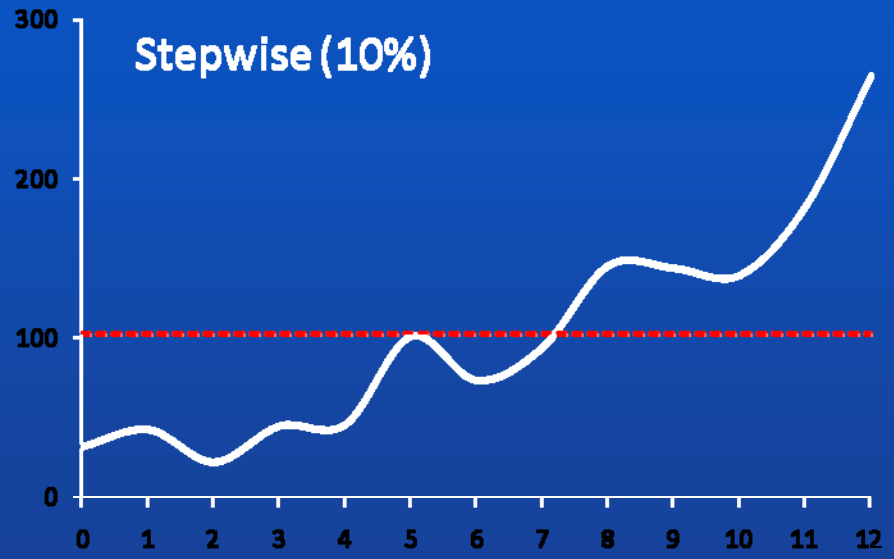
Street Dealer Parameters		
sdInitialInventoryRange	120 / 3600	Minimum and maximum drug inventories (in drug units) for street dealers at the beginning of each day. Each street dealer is assigned an initial drug inventory drawn from a uniform distribution with these bounds.
sdShiftStartRange	6 / 7	Minimum and maximum clock hours when street dealers enter the market. Each day, the street dealers enter the market at a clock hour drawn from a uniform distribution with these bounds.
sdShiftEndRange	22 / 22	Minimum and maximum clock hours when street dealers leave the market. Each day, the street dealers leave the market at a clock hour drawn from a uniform distribution with these bounds.
sdProbChangeLocationRange	0.1 / 0.1	Minimum and maximum probabilities that a street dealer will change his location in the market from one day to the next. Each street dealer is assigned a location change probability drawn from a uniform distribution with these bounds.
sdDealDelayRange	15 / 15	Minimum and maximum lengths of time (in minutes) required for a street dealer to process a drug deal (not including travel). The time required for each deal is drawn from a uniform distribution with these bounds.

Customer "addiction level" patterns

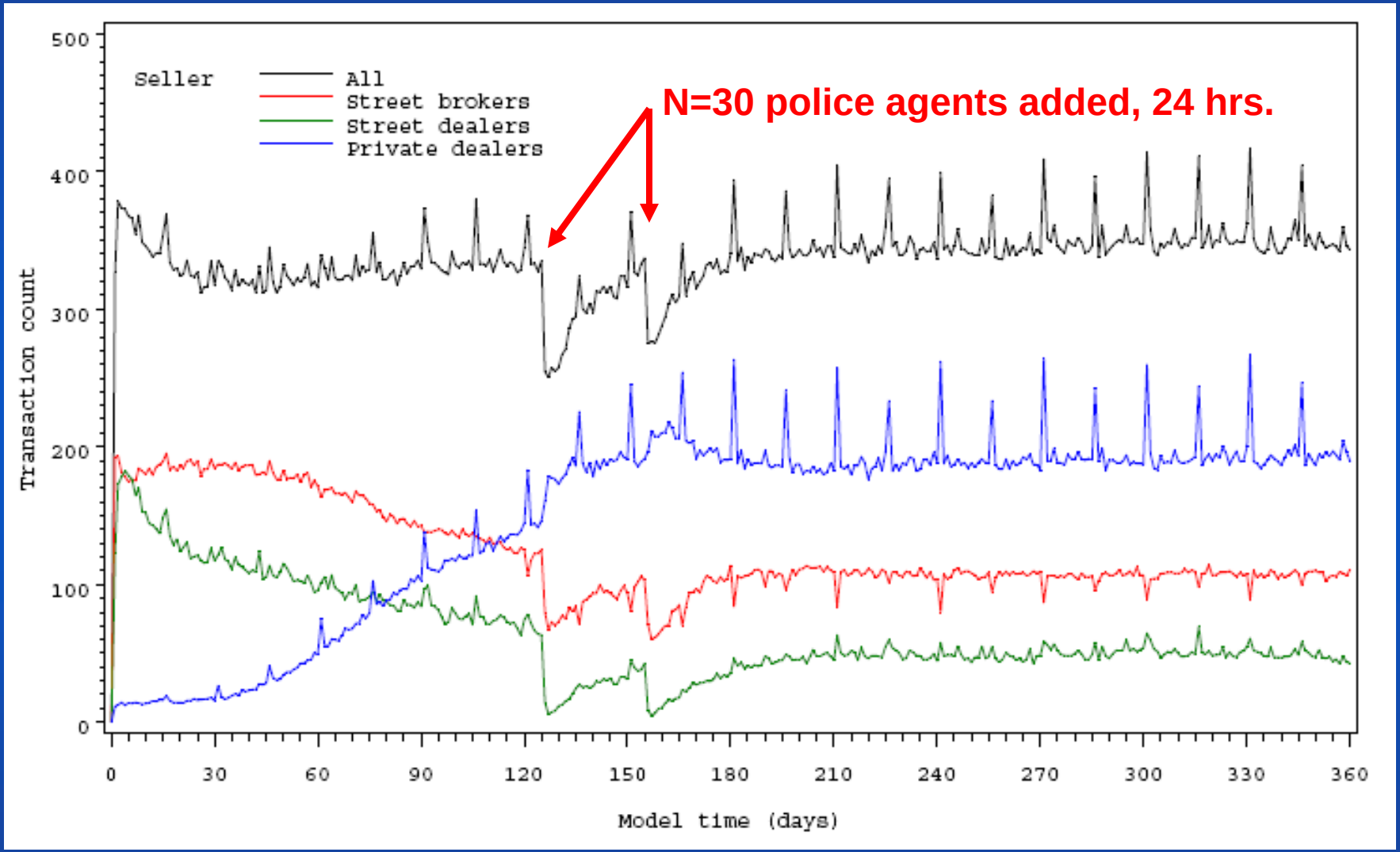








Transaction totals: “bust scenario” X 2



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