

Web Material

Limiting Alcohol Outlet Density to Prevent Alcohol Use and Violence? Estimating Policy Interventions Through Agent-Based Modeling

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Web Appendix 1

Model calibration

To calibrate our model, estimates from the ABM were compared to individual and neighborhood level data on drinking (overall and stratified by demographic characteristics), violence, and alcohol outlet density. An iterative process was used to adjust the model parameters until the ABM results matched the empirical data reasonably well (1). Each model was run for 120 time steps, the first 100 of which were used as a burn-in period as the age distribution stabilized and agents developed a history of violence, and were discarded in analysis (2)

Alcohol outlet selection among agents

Preference for drinking in public was based on the agent's gender, age, race, education, income, and drinking status. Heavy drinkers, light/moderate drinkers who preferred to drink outside of home settings, and a fraction of non-drinkers then searched the area around their location for a preferred on-premise alcohol outlet. Heavy drinkers and light/moderate drinkers who preferred to drink at home searched for a preferred off-premise alcohol outlet. After taking into account preference for drinking in public, a random outlet within the designated radius was assigned to the agent at baseline. For light drinkers who could not be matched to an outlet of their preferred type, the matching process was repeated with an outlet of the opposite type. At subsequent steps in the model, agents refined their preferred outlet by minimizing the Euclidean distance between their identity and the identity of their preferred outlet. More details about the outlet selection process can be found in the pseudocode (Web Appendix 2).

Sensitivity analysis

We performed a sensitivity analysis for each of 10 parameters using the Latin hypercube sampling method (3). We generated 50 random values, within specified ranges, for each parameter we were testing, namely, the neighborhood and social network influences on agent behavior, the radius within which a perpetrator looked for a victim, the radius within which an agent looked for a preferred on- or off-premise outlet, the influence of violent alcohol outlets on an agent's probability of being involved in a violent incident, and the threshold of heavy or light drinkers at an agent's preferred outlet needed to influence an agent's drinking status. More details about the range of values tested can be found in Web Table 1. We ran the ABM 50 times, the random parameters changing with each run, under three different scenarios (no intervention, capping alcohol outlet density at the 50th percentile, and closing the top 25% most violent alcohol outlets). Using the results from these models, we calculated the average value of the outcomes across runs under each scenario, and calculated the difference between the values from each intervention scenario and the no intervention scenario. Finally, we used linear regressions to predict these differences (one model for each difference of interest), using the parameters we tested as the independent variables. After this, we looked at the maximum/minimum fitted value for each regression and compared it to the difference we observed in our model results. We also visualized the correlation between the model parameters and our outcomes of interest with scatterplots – Figure S1 shows results for the alcohol outlet density intervention and Figure S2 shows results for the targeted violence intervention).

Web Appendix 2: Pseudo-code for Alcohol Outlet Density Agent-Based Model

MODEL INITIALIZATION

- ⇒ Set parameters (user-defined or read from a parameter file).
- ⇒ Create the grid for agent locations.
- ⇒ Create lists for all agents, neighborhoods, alcohol outlets, and police patrol areas.

// CREATE AGENTS

- ⇒ For 1 to the defined number of agents (specified by the user or file):
 - Create a new agent, with age, sex, race/ethnicity, and education.
 - Add agent to list of agents.

// CREATE NEIGHBORHOODS AND CELLS WITHIN NEIGHBORHOODS

// ASSIGN POLICE OFFICERS AND ALCOHOL OUTLETS TO LOCATIONS

- ⇒ For 1 to the defined number of neighborhoods:
 - Create a new neighborhood corresponding to a particular NYC neighborhood.
 - Add neighborhood to list of neighborhoods.
 - Specify boundaries of the neighborhood.
 - Create individual cells within that neighborhood.
 - Randomly select initial locations of police officers on cells within the neighborhood.
 - Notify selected cells that police officer is present.

- Randomly select locations of on-premise and off-premise alcohol outlets on cells within the neighborhood.
- Notify selected cells that on-premise or off-premise alcohol outlet is present.
- Add alcohol outlet to list of outlets in the neighborhood.
- Assign other external neighborhood characteristics (e.g., percent unemployed).

// ASSIGN AGENTS TO NEIGHBORHOODS AND SPECIFIC CELL LOCATIONS

⇒ For 1 to the defined number of agents:

- Select a neighborhood for the agent based on the agent's characteristics.
- Randomly assign X, Y values for specific location of agent within the neighborhood.
- Notify cell that agent is present.
- Add agent to list of agents in the neighborhood.

// CALCULATE CHARACTERISTICS OF NEIGHBORHOODS

⇒ For 1 to the defined number of neighborhoods:

- Calculate average neighborhood characteristics by averaging characteristics of all agents located in that neighborhood.
- Identify neighborhoods with above- and below-average levels of income and violence.
- Create police patrol areas within the neighborhood.

- Assign boundaries to each police patrol area.

// ASSIGN BASELINE DRINKING STATUS AND DRINKING LOCATION

PREFERENCE

⇒ For 1 to the defined number of agents:

- Calculate probability of being a light/moderate drinker and probability of being a heavy drinker.
- Calculate probability of being a non-drinker as $1 - \text{probability of being a light/moderate drinker} - \text{probability of being a heavy drinker}$.
- Select random number from 0 to 1.
- If random number is less than the agent's probability of being a non-drinker:
 - Identify agent as a non-drinker.
- Else if random number is less than the sum of agent's probabilities of being a non-drinker and a light/moderate drinker:
 - Identify agent as a light/moderate drinker.
- Else identify agent as a heavy drinker.
- If agent is a light/moderate drinker:
 - Calculate agent's probability of preferring to drink in public places.
 - Select random number from 0 to 1.
 - If random number is less than agent's probability of drinking in public:
 - Identify agent as a public drinker.

- Identify agent's drinking preference as drinking in public.

// CHARACTERIZE DRINKING CONTEXT OF EACH NEIGHBORHOOD

⇒ For 1 to the defined number of neighborhoods:

- Calculate proportion of light/moderate and heavy drinkers in the neighborhood.

// SELECT INITIAL ALCOHOL OUTLET FOR AGENTS

⇒ For 1 to the defined number of agents:

- If agent is a heavy drinker:
 - Create a list of all on-premise alcohol outlets within the specified radius of the agent.
 - Randomly select one of the alcohol outlets as the agent's preferred on-premise outlet.
 - Create a list of all off-premise alcohol outlets within the specified radius of the agent.
 - Randomly select one of the alcohol outlets as the agent's preferred off-premise outlet.
- If agent is a light/moderate drinker:
 - Create a list of all on-premise or off-premise alcohol outlets within the specified radius of the agent, depending on the agent's preference for drinking in public.

- Randomly select one of the alcohol outlets as the agent's preferred outlet.
- If agent is a non-drinker:
 - Select a random number from 0 to 1.
 - If random number is less than specified proportion of non-drinkers who visit on-premise alcohol outlets:
 - Create a list of all on-premise alcohol outlets within the specified radius of the agent.
 - Randomly select one of these alcohol outlets as the agent's preferred outlet.

// CHARACTERIZE DRINKING CONTEXT OF ALCOHOL OUTLETS

⇒ For 1 to the defined number of alcohol outlets:

- Specify the on-premise outlet identity by calculating the average income, education, and age of the outlet's patrons, the percent white, black, Hispanic, and other, and the percent of non-, light/moderate, and heavy drinkers at the outlet.
- Specify the off-premise outlet identity by calculating the average income and education, and the percent of white, black, Hispanic, and other drinkers at the outlet.

// CREATE SOCIAL NETWORK

⇒ For 1 to the defined number of agents:

- While the selected agent (“a”) still has fewer than their assigned number of social network members and fewer than 10,000 attempts have been made to find social network members:
 - Randomly select another agent from the agent population (“b”).
 - If agent “b” does not have his/her assigned number of social network members and is not already linked to agent “a”:
 - Select a random number from 0 to 1.
 - If random number is less than the assigned proportion of social network links that will be based on spatial proximity:
 - Determine whether agents “a” and “b” are located within the specified radius of each other.
 - Select random number from 0 to 1.
 - If random number is less than the specified proportion of social network links that will consider age:
 - Determine whether agents “a” and “b” are within 10 years of age of each other.
 - Select random number from 0 to 1.
 - If random number is less than the specified proportion of social network links that will consider gender:
 - Determine whether agents “a” and “b” are the same gender.
 - Select random number from 0 to 1.

- If random number is less than the specified proportion of social network links that will consider race/ethnicity:
 - Determine whether agents “a” and “b” are the same race/ethnicity.
- Select random number from 0 to 1.
- If random number is less than the specified proportion of social network links that will consider education:
 - Determine whether agents “a” and “b” have the same education.
- Select random number from 0 to 1.
- If random number is less than the specified proportion of social network links that will consider drinking status:
 - Determine whether agents “a” and “b” have the same drinking status.
- If agents “a” and “b” match on spatial proximity, age, gender, race/ethnicity, education, and drinking status:
 - Create a link between agents “a” and “b”.
 - Increase count of friends for agents “a” and “b” by one.

// CHARACTERIZE DRINKING CONTEXT OF SOCIAL NETWORKS

⇒ For 1 to the defined number of agents:

- Calculate the number of social network members who are non-, light/moderate, and heavy drinkers.

EACH MODEL STEP

// RESET CELL VARIABLES

⇒ For 1 to the defined number of cells:

- Reset cell variables.

// RESET PATROL AREA VARIABLES

⇒ For 1 to the defined number of patrol areas:

- Reset patrol area variables.

// RESET AGENT VARIABLES AND ALLOW DEATH AND MOVEMENT

⇒ For 1 to the defined number of agents:

- Increase age by one year.
- If agent died at last time step:
 - Reset age, history of violence, drinking status, and preferred outlet.
- Reset movement, victimization, and perpetration variables.
- Update agent's probability of dying.
- Select random number from 0 to 1.
- If random number is less than agent's probability of death:
 - Agent dies at this time step.
- Update agent's probability of moving to a new neighborhood.
- Select random number from 0 to 1.
- If random number is less than agent's probability of moving:

- Remove agent from list of agents in old neighborhood.
- Select a new neighborhood for the agent based on the agent's characteristics.
- Randomly assign X, Y values for the specific location of agent within the new neighborhood.
- Notify cell that agent is present.
- Add agent to list of agents in the neighborhood.
- Select initial alcohol outlet for agents who moved, permitting light/moderate drinkers to look for nonpreferred outlet types (i.e., on-premise or off-premise) if there are no outlets of the preferred type in the search area within which the agent will look for an outlet.

// UPDATE NEIGHBORHOOD AND OUTLET CHARACTERISTICS AFTER
MOVES

⇒ For 1 to the defined number of neighborhoods:

- Update average neighborhood income and proportions of different types of drinkers.

⇒ For 1 to the defined number of outlets:

- Update outlet identity.

// DRINKING STATUS TRANSITIONS AND SELECTION OF NEW PREFERRED
OUTLET

⇒ For 1 to the defined number of agents:

- Calculate probability of being a light/moderate drinker and heavy drinker based on individual and neighborhood characteristics.
- Calculate probability of being a non-drinker as $1 - \text{probability of being a light/moderate drinker} - \text{probability of being a heavy drinker}$.
- Adjust probability of transitioning to a different drinking status by accounting for drinking status of agent's friends and proportion of light and heavy drinkers at agent's preferred outlet.
- Adjust probability of transitioning by accounting for the agent's current drinking status.
- If agent was a non-drinker at the last time step:
 - Select a random number from 0 to 1.
 - If random number is less than agent's calculated probability of being a light drinker:
 - Identify agent as a light/moderate drinker.
 - Else identify agent as a non-drinker.
- If agent was a light/moderate drinker at the last time step:
 - Select a random number from 0 to 1.
 - If random number is less than the agent's probability of being a light drinker:
 - Identify agent as a light drinker.
 - Else if random number is less than the sum of agent's probabilities of being a non-drinker and a light/moderate drinker:

- Identify agent as a non-drinker.
 - Else identify agent as a heavy drinker.
- If agent was a heavy drinker at the last time step:
 - Select random number from 0 to 1.
 - If random number is less than agent's probability of being a light drinker:
 - Identify agent as a light drinker.
 - Else identify agent as a heavy drinker.
- If agent transitioned to heavy drinking:
 - If agent has a preferred outlet, improve outlet selection:
 - Create a list of all on-premise or off-premise alcohol outlets within the specified radius of the agent, based on type of outlet selection being improved.
 - Randomly select an outlet from the list.
 - Calculate the Euclidean distances between the new outlet's identity and the agent's identity, and between the old outlet's identity and the agent's identity. On-premise outlets account for the number of an agent's friends who prefer a given outlet in the distance calculation.
 - If the new outlet has a smaller distance than the agent's current preferred outlet:
 - Select that outlet as the agent's new preferred outlet.

- Assign agent to another preferred outlet, such that the agent has both a preferred on- and off-premise outlet. If there are no outlets of a given kind within the specified radii, that preferred outlet type will not be assigned.
 - If the agent does not have a preferred outlet:
 - Select initial on- and off-premise outlets within specified radii.
 - If agent transitioned to light/moderate drinking:
 - Update probability of drinking in public.
 - If agent transitioned from heavy drinking, disassociate agent from the outlet of the nonpreferred type.
 - If agent has a preferred outlet, improve outlet selection:
 - Create a list of all on-premise or off-premise alcohol outlets within the specified radius of the agent, based on type of outlet selection being improved.
 - Randomly select an outlet from the list.
 - Calculate the Euclidean distances between the new outlet's identity and the agent's identity, and between the old outlet's identity and the agent's identity. On-premise outlets account for the number of an agent's friends who prefer a given outlet in the distance calculation.
 - If the new outlet has a smaller distance than the agent's current preferred outlet:

- Select that outlet as the agent's new preferred outlet.
 - If the agent does not have a preferred outlet:
 - Select initial outlet within specified radius, allowing agents to look for nonpreferred outlet types (i.e., on-premise or off-premise) if there are no outlets of the preferred type in the search area.
- If agent transitioned to non-drinking:
 - Select random number from 0 to 1:
 - If random number is less than specified proportion of non-drinkers who visit on-premise alcohol outlets:
 - If the agent has a preferred on-premise outlet, improve outlet selection:
 - Create a list of all on-premise alcohol outlets within the specified radius of the agent, based on type of outlet selection being improved.
 - Randomly select an outlet from the list.
 - Calculate the Euclidean distances between the new outlet's identity and the agent's identity, and between the old outlet's identity and the agent's identity. On-premise outlets account for the number of an agent's friends who prefer a given outlet in the distance calculation.

- If the new outlet has a smaller distance than the agent's current preferred outlet:
 - Select that outlet as the agent's new preferred outlet.
 - If the agent does not have a preferred on-premise outlet:
 - If agent has preferred off-premise outlet, disassociate agent from outlet.
 - Select initial on-premise outlet within specified radius. If there are no on-premise outlets within the specified radius, no preferred outlet is assigned.
 - If random number is greater than the specified proportion of non-drinkers who visit on-premise alcohol outlets:
 - Disassociate agent with preferred outlet.
 - If agent remained a heavy drinker:
 - If agent had a preferred on- and off-premise outlet and both selections had been improved: select random number from 0 to 1.
 - If random number is less than specified probability of switching preferred outlet or if either of the agent's preferred outlets were initial (random) assignments, improve outlet selection:
 - Create a list of all on-premise or off-premise alcohol outlets within the specified radius of the agent, based on type of outlet selection being improved.
 - Randomly select an outlet from the list.

- Calculate the Euclidean distances between the new outlet's identity and the agent's identity, and between the old outlet's identity and the agent's identity. On-premise outlets account for the number of an agent's friends who prefer a given outlet in the distance calculation.
 - If the new outlet has a smaller distance than the agent's current preferred outlet:
 - Select that outlet as the agent's new preferred outlet.
 - If agent does not have a preferred on- and off-premise outlet:
 - Select initial alcohol outlet of the missing type within the specified radius.
 - If agent remained a light/moderate:
 - If agent had a preferred outlet and the outlet selection had been improved: select random number from 0 to 1.
 - If random number is less than specified probability of switching preferred outlet or if the agent's preferred outlet was an initial (random) assignment, improve outlet selection:
 - Create a list of all on-premise or off-premise alcohol outlets within the specified radius of the agent, based on type of outlet selection being improved.
 - Randomly select an outlet from the list.

- Calculate the Euclidean distances between the new outlet's identity and the agent's identity, and between the old outlet's identity and the agent's identity. On-premise outlets account for the number of an agent's friends who prefer a given outlet in the distance calculation.
 - If the new outlet has a smaller distance than the agent's current preferred outlet:
 - Select that outlet as the agent's new preferred outlet.
 - If agent does not have a preferred outlet:
 - Select initial alcohol outlet of the preferred type within the specified radius, allowing agents to look for nonpreferred outlet types (i.e., on-premise or off-premise) if there are no outlets of the preferred type in the search area.
- If agent remained a non-drinker:
 - Select random number from 0 to 1:
 - If random number is less than specified proportion of non-drinkers who visit on-premise alcohol outlets and agent prefers to drink in public:
 - If agent has a preferred on-premise outlet, improve outlet selection:
 - Create a list of all on-premise alcohol outlets within the specified radius of the agent.

- Randomly select an outlet from the list.
- Calculate the Euclidean distances between the new outlet's identity and the agent's identity, and between the old outlet's identity and the agent's identity. On-premise outlets account for the number of an agent's friends who prefer a given outlet in the distance calculation.
 - If the new outlet has a smaller distance than the agent's current preferred outlet:
 - Select that outlet as the agent's new preferred outlet.
 - If the agent does not have a preferred on-premise outlet:
 - Select initial alcohol outlet within the specified radius.
 - If the random number is greater than the specified proportion of non-drinkers who visit on-premise alcohol outlets and the agent has a preferred on-premise outlet that was initially (randomly) assigned:
 - Improve outlet selection:
 - Create a list of all on-premise alcohol outlets within the specified radius of the agent.
 - Randomly select an outlet from the list.

- Calculate the Euclidean distances between the new outlet's identity and the agent's identity, and between the old outlet's identity and the agent's identity. On-premise outlets account for the number of an agent's friends who prefer a given outlet in the distance calculation.
 - If the new outlet has a smaller distance than the agent's current preferred outlet:
 - Select that outlet as the agent's new preferred outlet.

// CAP NEIGHBORHOOD ALCHOL OUTLET DENSITY WHEN INTERVENTION IS IMPLEMENTED

⇒ For 1 to the defined number of neighborhoods:

- If neighborhood on-premise alcohol outlet density is greater than the specified percentile cutoff:
 - For 1 to the defined number of on-premise alcohol outlets:
 - Select random number from 0 to 1.
 - If number is less than proportion of outlets that need to close for the neighborhood outlet density to be at or under the cutoff:
 - Close outlet.
 - Recalculate neighborhood on-premise alcohol outlet density.
 - Update list of on-premise outlets in the neighborhood.

- Repeat for off-premise alcohol outlets.
- ⇒ For 1 to the defined number of agents:
 - If agent's preferred alcohol outlet closed:
 - Select initial alcohol outlet of the preferred type within the specified radius, allowing light drinkers to look for nonpreferred outlet types (i.e., on-premise or off-premise) if there are no outlets of the preferred type in the search area.

// CLOSE MOST VIOLENT ALCOHOL OUTLETS IN THE CITY WHEN
INTERVENTION IS IMPLEMENTED

- ⇒ Sort all alcohol outlets by the number violent events that occurred within a specified radius during the last time step
- ⇒ Calculate the number of outlets to closed based on the target percent closed
- ⇒ Using the list of alcohol outlets sorted by violent events, close the defined number of outlets
 - Update list of outlets in the neighborhood.
- ⇒ For 1 to the defined number of agents:
 - If agent's preferred alcohol outlet closed:
 - Select initial alcohol outlet of the preferred type within the specified radius, allowing light drinkers to look for nonpreferred outlet types (i.e., on-premise or off-premise) if there are no outlets of the preferred type in the search area.

// UPDATE DRINKING CONTEXT

⇒ For 1 to the defined number of agents:

- Calculate the number of social network members who are non-, light/moderate, and heavy drinkers.

⇒ For 1 to the defined number of alcohol outlets:

- Update outlet identity.

// RESET POLICE OFFICER LOCATIONS

⇒ For 1 to the defined number of neighborhoods:

- Randomly reassign police officer locations within neighborhood.
- Notify selected cells that police officer is present.

// IDENTIFY POTENTIAL PERPETRATORS AND VICTIMS OF VIOLENCE

⇒ For 1 to the defined number of agents:

- Calculate agent's probability of homicide victimization.
- Calculate agent's probability of non-fatal violent victimization.
- Calculate agent's probability of violent perpetration.
- Select random number from 0 to 1 for homicide victimization.
- If random number is less than agent's probability of homicide victimization:
 - Identify agent as potential homicide victim.
 - Notify agent's cell that potential victim is present.
- Select random number from 0 to 1 for non-fatal violent victimization.

- If random number is less than agent's probability of non-fatal violent victimization:
 - Identify agent as potential non-fatal violence victim.
 - Notify agent's cell that potential victim is present.
- Select random number from 0 to 1 for violent perpetration.
- If random number is less than agent's probability of violent perpetration:
 - Identify agent as potential violent perpetrator.
 - Notify agent's cell that potential perpetrator is present.

// IDENTIFY ACTUAL PERPETRATORS AND VICTIMS OF VIOLENCE

⇒ Shuffle list of agents.

⇒ For 1 to the defined number of agents:

- If the agent is a potential perpetrator:
 - Create a vector containing all cells within the specified perpetration radius of the potential perpetrator.
 - For 1 to the number of cells in the perpetration vector:
 - If the cell contains a potential victim who has not yet been victimized:
 - Create a vector containing all cells within the specified police protection radius of the potential victim.
 - For 1 to the number of cells in the police protection vector:

- If the cell contains a police officer:
 - Violent act is prevented.
- If no cells in the police protection vectors contain an officer:
 - Identify index agent as a perpetrator.
 - Identify agent in selected cell as a victim.
 - Notify cell that actual victim is present.

// UPDATE SOCIAL NETWORK, ALCOHOL OUTLET, NEIGHBORHOOD, AND POLICE PATROL AREA CHARACTERISTICS

⇒ For 1 to the defined number of agents:

- Calculate the number of social network members who were victims or perpetrators of violence.

⇒ For 1 to the defined number of alcohol outlets:

- Calculate the number of violent incidents that occurred within the specified radius of the alcohol outlet.

⇒ For 1 to the defined number of neighborhoods:

- Update average neighborhood violence.
- Identify neighborhood as above or below average in violence.

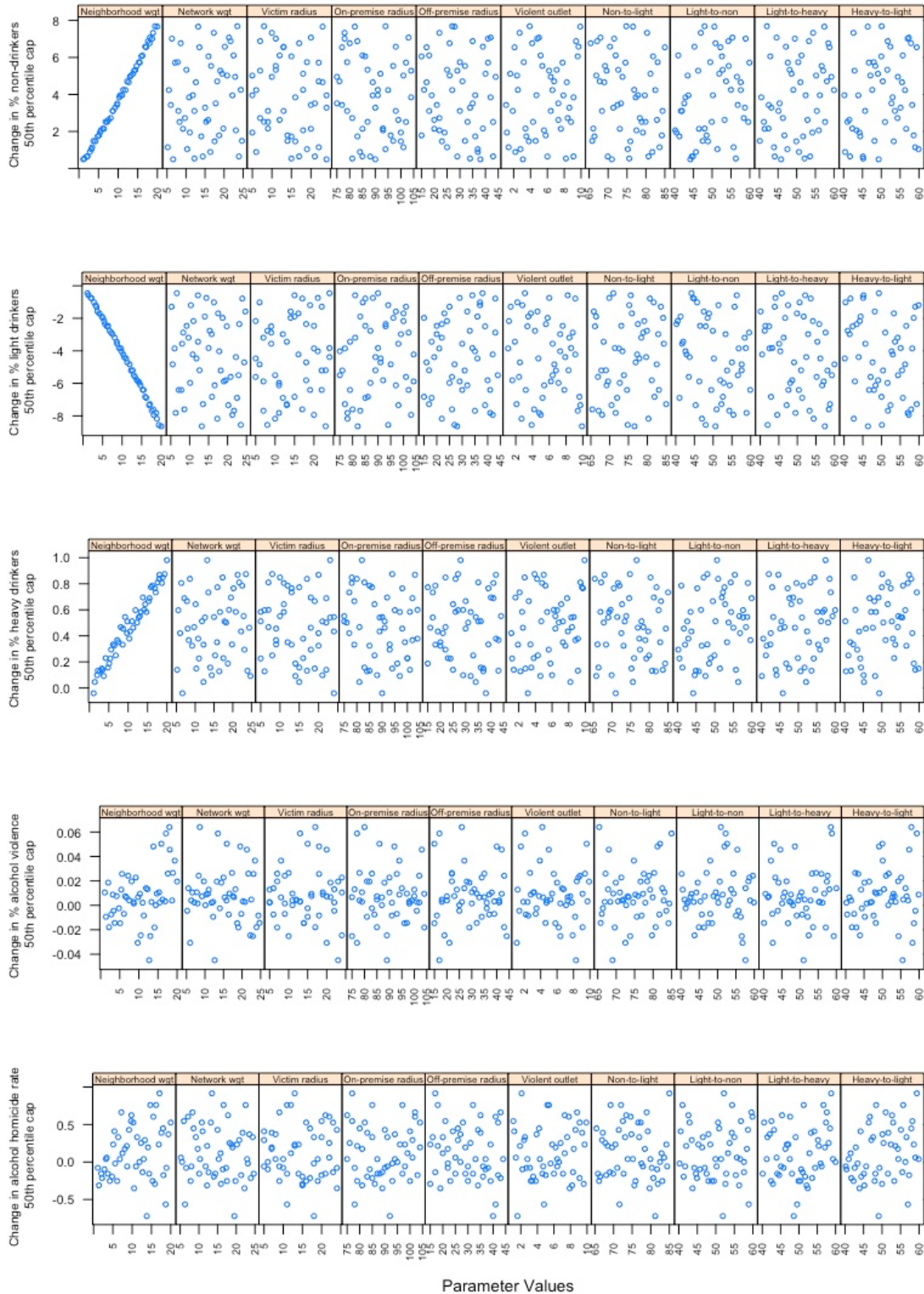
⇒ For 1 to the defined number of police patrol areas:

- Update average violence in patrol area.

Web Table 1: Sensitivity analysis parameters and test values

Parameter	Range tested	Default value
Neighborhood influence on agent behavior	1-20%	10%
Social network influence on agent behavior	5-25%	15%
Perpetrator's crime radius, in cells	5-25	15
Police's crime prevention radius, in cells	1-5	2
Light drinkers at preferred outlet needed to influence nondrinker's probability of becoming a light drinker	65-85%	75%
Light drinkers at preferred outlet needed to influence light drinker's probability of becoming a nondrinker	40-60%	50%
Heavy drinkers at preferred outlet needed to influence light drinker's probability of becoming a heavy drinker	40-60%	50%
Heavy drinkers at preferred outlet needed to influence heavy drinker's probability of becoming a light drinker	40-60%	50%
Contribution of alcohol outlet violence on agent's probability of violence (perpetration and victimization)	1-10%	5%
Radius within which an agent can look for a preferred on-premise alcohol outlet, in cells	75-105	90
Radius within which an agent can look for a preferred off-premise alcohol outlet, in cells	15-45	30

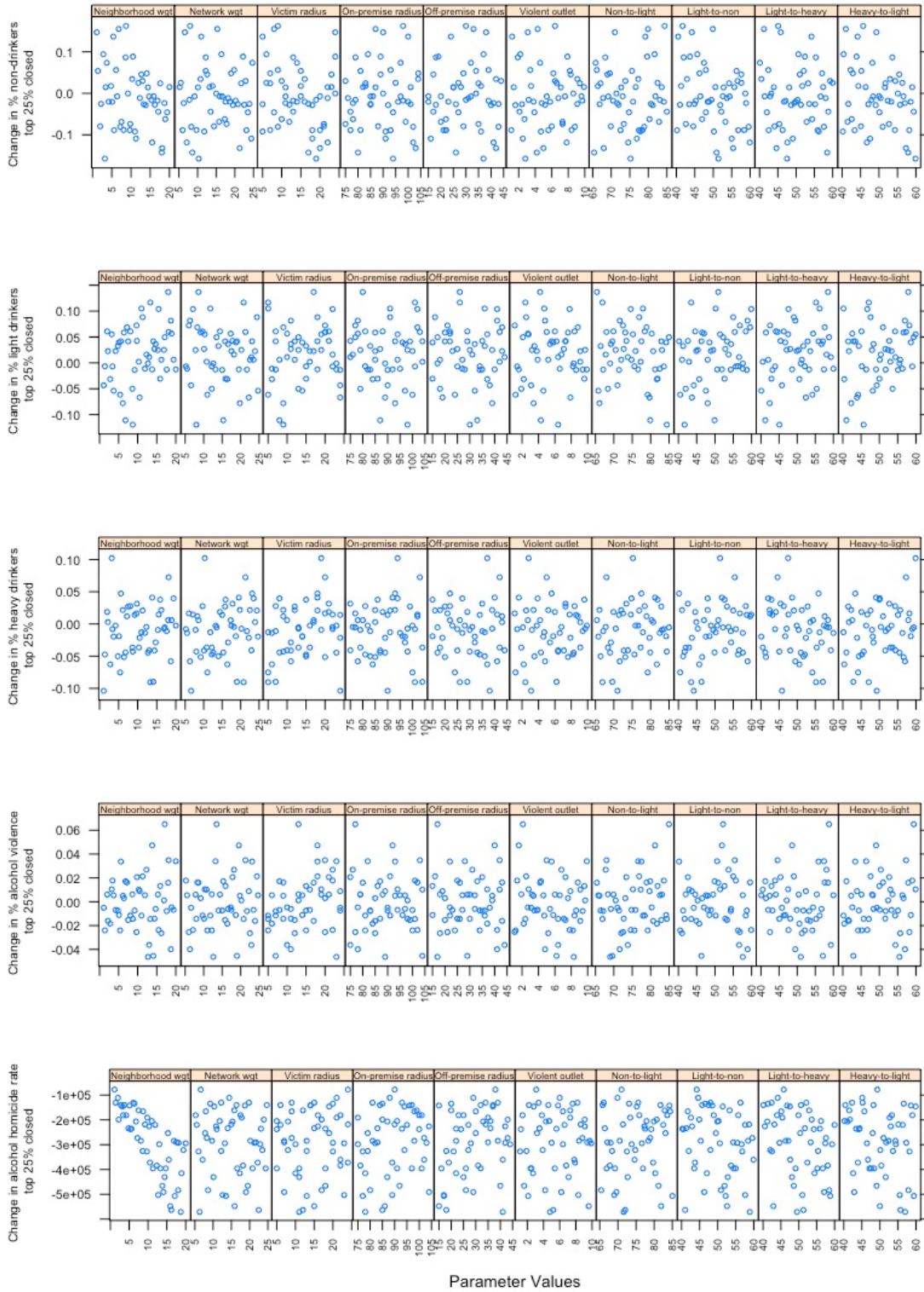
Web Figure 1. Results from sensitivity analysis: percentage difference between baseline and intervention capping alcohol outlet density at the 50th percentile



Note: Scatterplots of the difference in the main outcomes under the most extreme intervention scenario (50th percentile cap) compared to baseline under the range of values tested in the sensitivity analysis.

Outcomes were robust to changes in our model specifications, although when the neighborhood parameters were allowed to have a very large influence on agent behaviors, the intervention resulted in more nondrinkers than expected; and when the neighborhood parameters had very little influence on agent behaviors, the intervention resulted in fewer light drinkers than expected. The direction of the association was always in the expected direction, even when results were larger than anticipated.

Web Figure 2. Results from sensitivity analysis: percentage difference between baseline and intervention closing most violent 25% of alcohol outlets



Note: Scatterplots of the difference in the main outcomes under the most extreme intervention scenario (top 25% violent outlets closed) compared to baseline under the range of values tested in the sensitivity analysis.

References

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