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Assessing User Engagement With an Interactive Mapping Dashboard for Overdose Prevention Informed by Predictive Modeling in Rhode Island

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ABSTRACT

Context: Predictive modeling can identify neighborhoods at elevated risk of future overdose death and may assist community organizations' decisions about harm reduction resource allocation. In Rhode Island, PROVIDENT is a research initiative and randomized community intervention trial that developed and validated a machine learning model that predicts future overdose at a census block group (CBG) level. The PROVIDENT model prioritizes the top 20th percentile of CBGs at highest risk of future overdose death over the subsequent 6-month period. In CBGs assigned to the trial intervention arm, these predictions are then displayed for partnering community organizations via an interactive mapping dashboard.

Objective: To evaluate whether CBGs prioritized by the PROVIDENT model were associated with increased user engagement via an online dashboard for fatal overdose forecasting and resource planning.

Design: We estimated prevalence ratios using modified Poisson regression models, adjusted for CBG-level characteristics that may confound the relationship between model predictions and dashboard engagement.

Setting: We used CBG-level data in Rhode Island (N = 809) from November 2021 to July 2024.

Intervention: Our exposure of interest was whether each CBG was prioritized by the PROVIDENT model and shown as prioritized on the interactive mapping dashboard.

Main Outcome Measure: Our primary outcome was whether a dashboard user from any partnering community organization engaged (eg, clicked, interacted with dashboard elements, or completed assessment or planning surveys) with each CBG on the interactive mapping dashboard.

Results: After adjusting for previous model predictions and dashboard engagement, nonfatal overdose counts, and distribution of race and ethnicity, poverty, unemployment, and rent burden, dashboard users were 1.0 to 2.4 times as likely to engage with CBGs prioritized by the PROVIDENT model that were shown as prioritized on the dashboard as compared to CBGs that were prioritized by the PROVIDENT model that were blinded on the dashboard.

Conclusions: Interactive mapping tools with predictive modeling may be useful to support community-based harm reduction organizations in the allocation of resources to neighborhoods predicted to be at high risk of future overdose death.

KEY WORDS: dashboard implementation, overdose prevention, predictive modeling

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To prioritize limited public health resources in response to the ongoing overdose crisis in the US, overdose prevention efforts are often concentrated in communities with historically elevated overdose burden.[1] However, this approach may not provide resources to communities at highest risk of *future* overdose deaths due to rapid changes in the local drug use context.[2-4] In Rhode Island, PROVIDENT (PReventing OVerdose using Information and Data from the EnvironmeNT) is a research initiative and randomized community intervention trial intended to assist community-based harm reduction organizations in making decisions about resource allocation for overdose prevention by predicting future overdose deaths at a census block group (CBG) level.[5] Using a previously validated machine learning-based forecasting model, predictions are generated such that the top 20% of CBGs prioritized (ie, those at highest predicted risk) consistently contain more than 40% of overdose deaths occurring over the subsequent 6-month period.[6]

These predictions were utilized as part of the PROVIDENT trial (NCT05096429) that aimed to determine whether providing community organizations with CBG-level predictions of future overdose risk can lead to reductions in overdose morbidity and mortality as compared to traditional surveillance approaches.[5] Predictive modeling was intended to supplement "standard of care" data sources and statewide overdose surveillance practices, such as the monitoring of nonfatal opioid overdose burden and visualization of these data in heat maps, municipal-level reports, etc. While some of these data are collected in near real-time, their analysis and reporting almost always incur a delay. Thus, the PROVIDENT model was designed to complement other surveillance activities that may be more limited by varying degrees of time lags. Partnering community organizations were provided with access to the PROVIDENT model predictions for CBGs within municipalities randomized to the intervention arm via an interactive mapping dashboard (Figure 1).

Prior research, including from the PROVIDENT study team, has begun to explore the utility of machine learning predictions for overdose forecasting at a neighborhood level,[2,3,6-8] although there is little knowledge of stakeholders' receptiveness to predictive modeling as a tool for allocation of overdose prevention resources. Predictive modeling offers promise over traditional surveillance approaches that often rely on lagged, incomplete, or inconsistent data. We have previously identified varying degrees of organizational engagement with the PROVIDENT dashboard,[9,10] although we have yet to examine whether this engagement is concentrated in CBGs prioritized by the PROVIDENT model. The present study aimed to assess whether community organizations considered PROVIDENT model predictions in determining which CBGs to examine for resource planning activities. Our objective was to evaluate a CBG-level association between prioritization by the PROVIDENT model (as displayed by the interactive mapping dashboard) and users' dashboard engagement (ie, clicks, interactions with dashboard elements, completion of neighborhood assessments). We hypothesized that organizations would be more likely to click to view additional information for resource allocation for CBGs shown to be prioritized by the PROVIDENT model than those that were prioritized but blinded.

Methods

Data source

We used data from the PROVIDENT trial from November 2021 to July 2024, aggregated at the CBG level in Rhode Island. According to the 2010 census, Rhode Island has 815 CBGs across 39 municipalities. We excluded CBGs with special land use designations (eg, airports), resulting in a final sample of 809 populated CBGs. PROVIDENT model predictions were updated with the latest data and released to community organizations in 6 iterations. Each set of predictions thus corresponds to a distinct prediction period, with Period 1 spanning from the trial launch date on November 15, 2021, to June 13, 2022; Period 2 from June 14, 2022, to November 10, 2022; Period 3 from November 11, 2022, to July 25, 2023; Period 4 from July 26, 2023, to December 19, 2023; Period 5 from December 20, 2023, to July 10, 2024; and Period 6 from July 11, 2024, to the trial end date on August 15, 2024. Across each of these periods, we tracked organizational engagement with the online dashboard, including when users clicked on a CBG, activated a toggle to zoom into that CBG, or activated a module to launch embedded planning and assessment surveys for a given CBG. For the present study, we excluded data from Period 6 due to its brevity and community organizations' limited engagement with the online dashboard as the trial end date approached.

Exposure

As part of the PROVIDENT trial, each of Rhode Island's 39 municipalities was randomized to either the intervention or comparison arm. Municipalities assigned to the trial's intervention arm received neighborhood (ie, CBG-level) risk predictions generated by the PROVIDENT machine learning model, subject to

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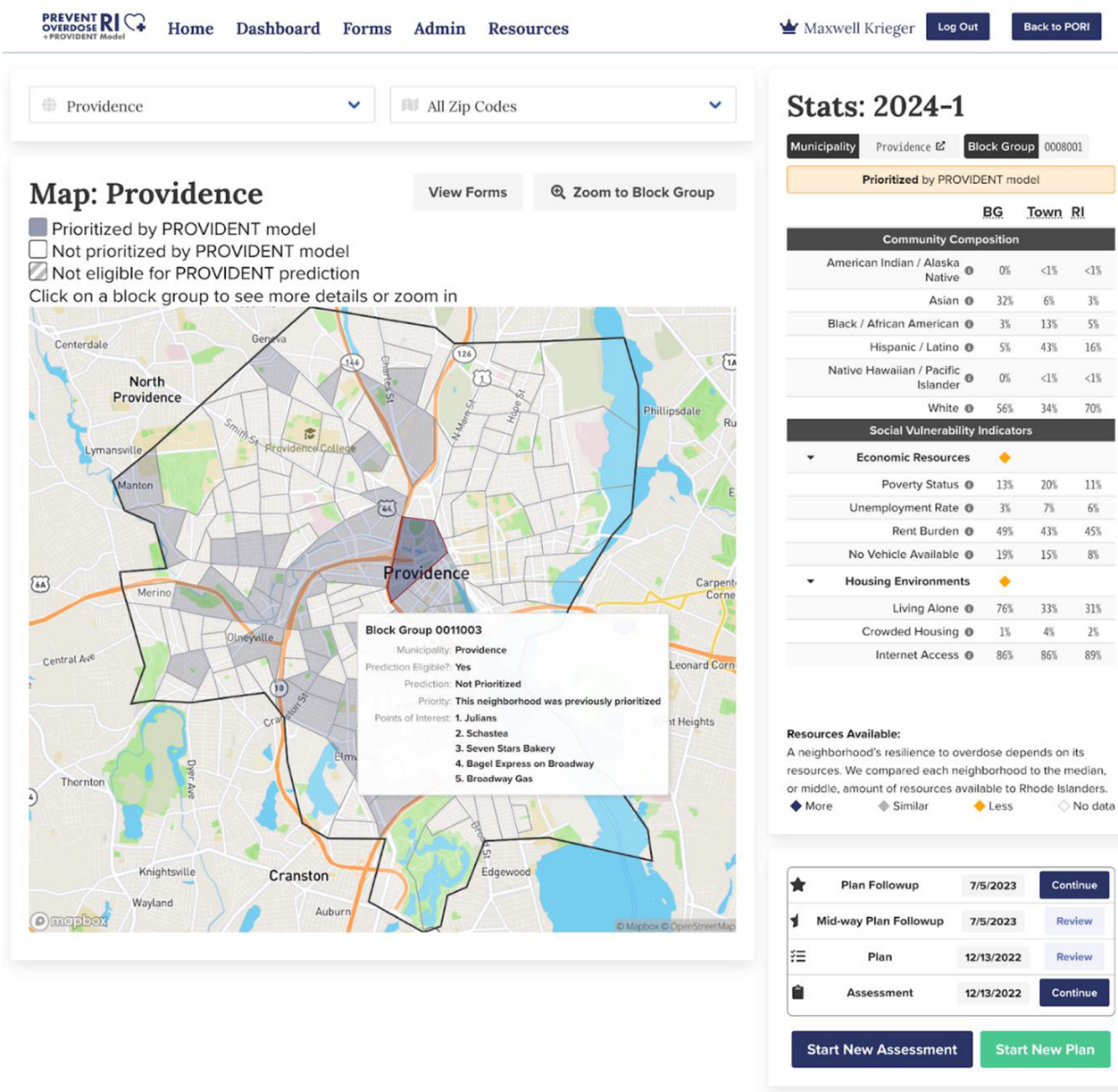

FIGURE 1 Snapshot of the PROVIDENT Interactive Mapping Dashboard
The dashboard displays all census block groups (CBGs) in Rhode Island, shaded according to 3 distinct categories: (1) "Prioritized by PROVIDENT model," shown as a highlighted area; (2) "Not prioritized by PROVIDENT model," shown as a non-highlighted area; or (3) "Not eligible for PROVIDENT predictions," (ie, CBGs in municipalities randomized to the control arm) shown as a cross-hatched area. Dashboard users may view the statewide model predictions graphically, click or zoom in on certain municipalities (ie, Providence, as shown above) or CBGs (ie, Block Group 0011003, as shown above), and complete planning and assessment surveys embedded in the dashboard.

a constraint in which at least 1 CBG in each municipality was designated as high risk for each prediction period. Municipalities assigned to the comparator did not receive model predictions. All municipalities received traditional surveillance information and overdose prevention resources in accordance with the state's strategic plan.

The interactive dashboard only displayed model predictions for CBGs within municipalities that were randomly assigned to the trial intervention arm. Although the PROVIDENT model generated predictions for CBGs in municipalities randomized to the control arm, the prioritization status of control arm CBGs was hidden from dashboard users to maintain blinding. Municipalities assigned to the control arm were shaded on the dashboard to indicate that these areas of the map were not eligible for viewing PROVIDENT model predictions (Figure 1). In control

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arm CBGs, dashboard users could still view American Community Survey (ACS) demographic characteristics and engage with planning and assessment tools as they would in intervention arm CBGs.

In the present study, our exposure of interest was whether the interactive mapping dashboard indicated a given CBG as prioritized by the PROVIDENT model in each prediction period, operationalized dichotomously as "shown as prioritized on the dashboard" versus "not shown as prioritized on the dashboard." Prioritized CBGs were those predicted to be in the top 20th percentile of fatal overdose risk over the subsequent 6-month period.[6] By considering whether CBGs were predicted by the model (ie, prioritization status) *and* whether dashboard users were informed of these predictions (ie, CBGs in municipalities assigned to the trial arm), our analysis examines specific engagement with the model predictions.

Outcome

We partnered with 3 community-based organizations responsible for a majority of harm reduction service provision across Rhode Island. Distribution of these organizations' services ranged from urban brick-and-mortar locations to statewide mobile outreach, creating a tapestry of overlapping service areas encompassing CBGs in all of Rhode Island's 39 municipalities. Access to the PROVIDENT interactive dashboard was offered to all staff at our partnering organizations who were involved in resource allocation, including managers as well as programmatic and outreach staff. To onboard dashboard users, we hosted an initial 8-hour training series at the trial launch. Subsequent training and technical assistance sessions were held with the partnering organizations throughout the trial period as new staff joined. Any invited staff who registered to access the dashboard and obtained a unique login were able to view the model predictions, click or zoom in on a map of each CBG, and complete planning and assessment surveys embedded in the dashboard. By clicking on a particular CBG, dashboard users could view that CBG's prioritization history based on previous iterations of the model predictions, as well as a set of demographic characteristics (ie, community composition and social vulnerability indicators) based on ACS estimates and designated points of interest, selected as locations with high foot traffic according to SafeGraph anonymous cellular data.[11] Assessment surveys captured perceptions of CBG-level characteristics, availability of resources, and barriers to outreach and planning surveys cataloged proposed neighborhood activities, such as increases in services and new relationships.

Our primary outcome was whether a dashboard user from any partnering community organization engaged with a given CBG in the interactive mapping dashboard in each prediction period, operationalized dichotomously as any engagement (ie, clicks) versus none. Dashboard users must click on a CBG in order to pursue additional engagement activities (ie, zoom into that CBG or launch embedded planning and assessment surveys), and so clicks captured the most fundamental level of user engagement. Because we invited users from a select group of organizations in the trial context, we encountered data sparsity concerns that limited us from exploring secondary outcomes such as the number of users engaged with each CBG, the number of clicks on a CBG per engaged user, or whether an assessment or planning survey was submitted for each CBG. Over the entire study period, we enrolled 36 unique users who engaged with the web tool in 630 CBGs and submitted surveys for 84 CBGs.

Covariates

We decided, a priori, to adjust the analyses for several CBG-level characteristics that may confound the relationship between PROVIDENT prioritization status and dashboard user engagement. These variables included prioritization status in previous prediction periods, dashboard engagement (ie, clicks) in previous prediction periods, suspected nonfatal opioid-related overdose counts captured by emergency medical services (EMS) runs in the prior 6 months, as well as a set of CBG-level demographic characteristics, using data from 5-year ACS estimates for calendar year 2020. ACS demographic characteristics included measures of community composition, such as Black race and Hispanic/Latino ethnicity, and economic resources, such as poverty status, unemployment rate, and rent burden (proportion of households that put more than 30% of their income toward rent).

Statistical analysis

We first described the distribution of CBGs that received any engagement on the interactive dashboard by prediction period, prioritization status, and PROVIDENT trial arm. We then estimated crude and adjusted prevalence ratios for each prediction period to evaluate the CBG-level association between the interaction of model prioritization with trial intervention arm and dashboard engagement, using Poisson regression models with robust error variance (ie, modified Poisson regression[12]) to account for overdispersion in our data. The adjusted model included the covariates described above. The primary effect

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estimates of interest were linear combinations of parameters that allowed us to compare CBGs that were prioritized by the PROVIDENT model and in the trial intervention arm (and thus, shown as prioritized on the dashboard) to those that were not prioritized by the PROVIDENT model and in the trial control arm (and thus, not shown as prioritized on the dashboard). The PROVIDENT trial received ethical approval from the Brown University institutional review board.

Results

Across the 5 prediction periods included in this analysis, dashboard users from partnering community organizations engaged with 630 of the 809 populated CBGs in RI (77.9%) at least once, with the most engagement during the first period (see Table 1, Figure 2, Figure 3). Of the CBGs in municipalities assigned to the intervention arm and prioritized by the model in each prediction period, 91.6% received engagement by dashboard users in period 1, 28.7% in period 2, 61.1% in period 3, 54.2% in period 4, and 31.5% in period 5 (Table 1). Dashboard engagement was most prevalent in intervention arm CBGs that were currently prioritized in each period (Table 1). Of the CBGs in municipalities assigned to the control arm and prioritized by the model in each prediction period, 52.2% received engagement by dashboard users in period 1, 10.3% in period 2, 43.3% in period 3, 22.7% in period 4, and 32.9% in period 5 (Table 1). Dashboard engagement was disbursed approximately evenly by prioritization status across the control arm CBGs, as would be expected in this arm due to blinding.

After adjusting for previous prioritization status, previous dashboard engagement, EMS-attended nonfatal overdoses, Black race, Hispanic/Latino ethnicity, poverty status, unemployment rate, and rent burden, dashboard users were 1.67 (95% confidence interval [CI]: 1.31-2.14) times in period 1, 2.20 (95% CI: 1.00-4.86) times in period 2, 1.29 (95% CI: 0.93-1.78) times in period 3, 2.41 (95% CI: 1.50-3.86) times in period 4, and 0.97 (95% CI: 0.67-1.42) times in period 5 as likely to engage with intervention arm CBGs that were prioritized by the PROVIDENT model as compared to control arm CBGs that were prioritized by the PROVIDENT model (Table 2, Supplemental Digital Content Table 1, available at http://links.lww.com/JPHMP/B549). Conversely, in CBGs that were not prioritized by the PROVIDENT model, dashboard users were often less likely to engage with intervention arm CBGs than control arm CBGs (Supplemental Digital Content Table 2, available at http://links.lww.com/JPHMP/B549).

Discussion

In this community randomized trial sub-study, we identified an association between prioritization by the PROVIDENT model and dashboard engagement in all prediction periods, although we found reduced engagement with the dashboard following the initial period. Across the approximately 4-year study period, dashboard users were between 1.0 and 2.4 times as likely to engage with intervention arm CBGs that were prioritized by the PROVIDENT model compared to control arm CBGs that were prioritized by the PROVIDENT model, demonstrating that the display of these CBGs' prioritization status on the dashboard corresponded to increased engagement. In contrast, dashboard users were less likely to engage with intervention arm CBGs that were not prioritized

TABLE 1
Census Block Group-Level Engagement by Partnering Community-Based Harm Reduction Organizations, Stratified by Prediction Period, Prioritization Status, and Trial Arm (N = 809)

	Census Block Groups (CBGs) With Any Dashboard Engagement				
Trial Designation	**Period 1**	**Period 2**	**Period 3**	**Period 4**	**Period 5**
Intervention arm (n = 499)	49.7% (248/499)	8.4% (42/499)	29.3% (146/499)	18.4% (92/499)	32.3% (161/499)
Currently prioritized	91.6% (87/95)	28.7% (27/94)	61.1% (58/95)	54.2% (52/96)	31.5% (29/92)
Not currently prioritized but prioritized in the past	N/A	1.5% (6/405)	3.7% (15/404)	2.5% (10/403)	5.2% (21/407)
Never prioritized	39.9% (161/404)	2.2% (9/405)	18.1% (73/404)	7.4% (30/403)	27.3% (111/407)
Control arm[a] (n = 310)	37.4% (116/310)	7.4% (23/310)	37.7% (117/310)	22.6% (70/310)	38.7% (120/310)
Currently prioritized	52.2% (35/67)	10.3% (7/68)	43.3% (29/67)	22.7% (15/66)	32.9% (23/70)
Not currently prioritized but prioritized in the past	N/A	0.8% (2/242)	4.9% (12/243)	4.5% (11/244)	7.9% (19/240)
Never prioritized	33.4% (81/243)	5.8% (14/242)	31.3% (76/243)	18.0% (44/244)	32.5% (78/240)

[a]*To maintain blinding, the prioritization status of CBGs within municipalities assigned to the control arm was not viewable by the community-based harm reduction organizations.*

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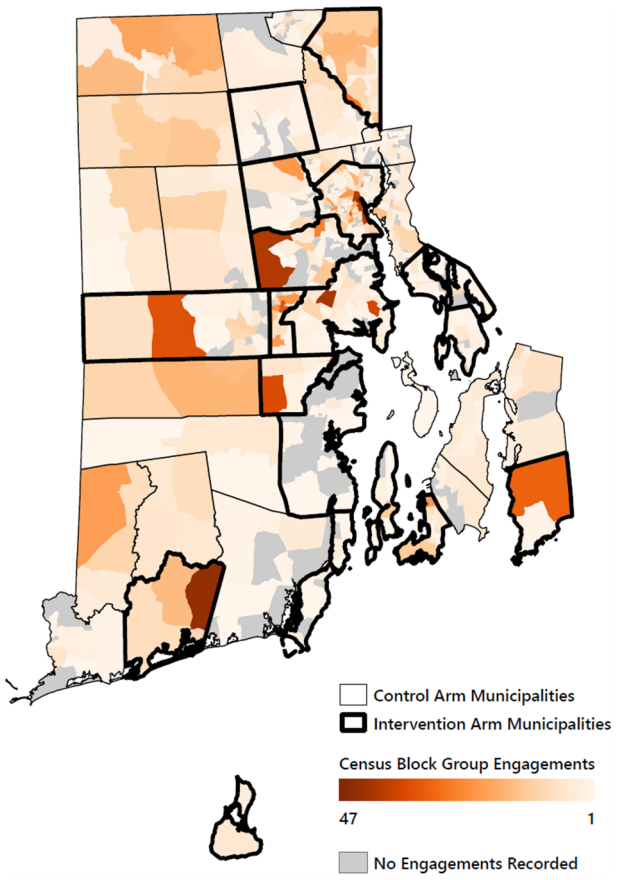

FIGURE 2 Number of Clicks on Each Rhode Island Census Block Group by Dashboard Users Over the PROVIDENT Study Period, November 2021 to July 2024
Municipalities randomized to the intervention arm are outlined in bold.

by the model compared to control arm CBGs that were not prioritized by the PROVIDENT model, demonstrating that the display of these CBGs' non-prioritization status on the dashboard corresponded to decreased engagement. Onboarding and early training activities at the trial launch may have bolstered dashboard engagement in prioritized CBGs in the initial period, with waning effects over time. Initial curiosity about the dashboard's functions may have been concentrated in familiar CBGs that community organizations suspected to be at high risk of overdose, regardless of model predictions. By period 5, some dashboard users continued to engage with CBGs that had been prioritized in the past regardless of their prioritization status in that period, which may have contributed to the null association between model predictions and dashboard engagement. Overall, these findings suggest that community-based harm reduction organizations may be willing to use results from predictive analytics tools in determining which neighborhoods to prioritize for harm reduction resource allocation. Our work offers promising evidence of organizations' receptiveness to predictive modeling for guiding proactive decision-making, which supports the potential for less reliance on lagged, incomplete, or inconsistent overdose surveillance data.

In addition to the PROVIDENT model predictions, community-based harm reduction organizations were encouraged to consider other sources of data (ie, "standard of care" data sources) when identifying neighborhoods with elevated fatal overdose

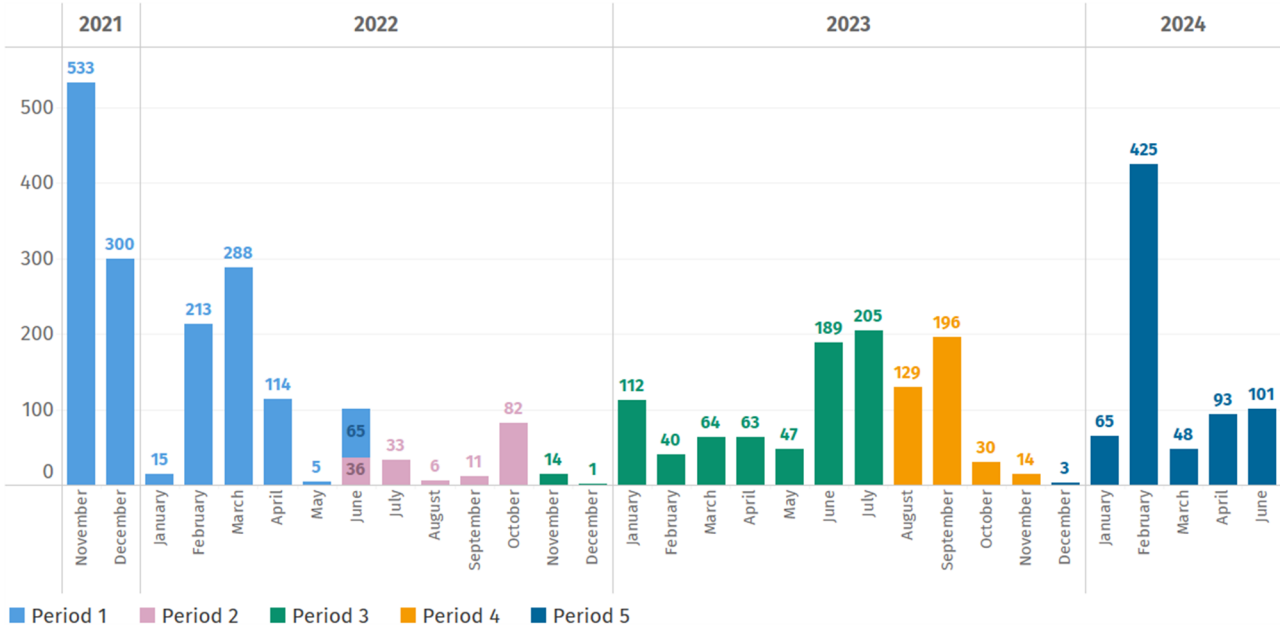

FIGURE 3 Census Block Group-Level Dashboard Engagement by Month Over the PROVIDENT Study Period, November 2021 to July 2024.

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TABLE 2

Association of Interaction Term Between Census Block Group (CBG) Prioritization Status and Trial Arm With and Dashboard Engagement Among Census Block Groups Prioritized by the PROVIDENT Model for Each Prediction Period (N = 809)

Prediction Period	Crude Prevalence Ratio (95% Confidence Limits)	Adjusted Prevalence Ratio (95% Confidence Limits)
Period 1	1.75 (1.38, 2.22)	1.67 (1.31, 2.14)
	1.47 (1.07, 2.02)	1.37 (0.98, 1.89)
Period 2	2.79 (1.29, 6.03)	2.20 (1.00, 4.86)
	4.98 (1.77, 13.99)	3.81 (1.34, 10.79)
Period 3	1.41 (1.03, 1.94)	1.29 (0.93, 1.78)
	2.35 (1.57, 3.51)	2.20 (1.46, 3.31)
Period 4	2.38 (1.47, 3.86)	2.41 (1.50, 3.86)
	5.41 (2.94, 9.97)	4.81 (2.63, 8.79)
Period 5	0.96 (0.61, 1.51)	0.97 (0.67, 1.42)
	1.20 (0.73, 1.96)	1.13 (0.73, 1.74)

The reported effect estimates reflect the comparison between CBGs prioritized by the PROVIDENT model that were in the trial intervention arm (and thus, shown as prioritized on the dashboard) versus CBGs prioritized by the PROVIDENT model that were in the trial control arm (and thus, not shown as prioritized or non-prioritized on the dashboard).

burden. For instance, the Rhode Island Department of Health issues overdose spike alert notifications triggered by unusually high nonfatal opioid overdose rates in a given region.[13] These nonfatal overdose surveillance data and corresponding spike alerts indicate a perceived need for fatal overdose prevention and may influence resource allocation to CBGs with a high nonfatal overdose burden, regardless of their prioritization status by the PROVIDENT model. Overdose spike alerts may or may not be concordant with PROVIDENT model predictions, although each may drive organizational decision-making. In this context, it is important to note that the PROVIDENT model predictions are designed to guide proactive resource allocation over a relatively long-term 6-month period, whereas spike alerts are designed to address an acute, unexpected spike in nonfatal overdoses. Interventions and responses informed by these disparate sources of information may be distinct; for example, using PROVIDENT forecasts to guide decisions around implementing a new syringe service program or mobile outreach route, versus using spike alerts to generate public health warnings and scale up crisis response. Future research is needed to determine how predictive modeling can best complement and be integrated into existing overdose surveillance systems.

Implications for Policy & Practice

- Community-based harm reduction organizations in Rhode Island may be willing to engage with predictive overdose modeling via online, interactive mapping tools and to examine neighborhoods for resource allocation that are predicted to be at high risk of future overdose death.
- Online dashboards offer a promising platform for disseminating fatal overdose forecasting to local community organizations to inform resource planning efforts.

This study is subject to a number of limitations. First, the results may be subject to unmeasured confounding of the association between PROVIDENT model predictions and dashboard engagement. For instance, urban CBGs may be more likely to be prioritized by the PROVIDENT model and more likely to draw engagement from dashboard users. Second, our findings may not be generalizable to other states that vary in their capacity for harm reduction resource allocation for overdose prevention. Finally, in some prediction periods, the level of engagement stratified by both CBG and intervention arm was low, resulting in sparse data concerns and imprecision in the effect estimates. This additionally prevented us from examining various types of engagement, and so our analysis treats all clicks as if they were prompted by equivalent degrees of user engagement.

Despite these limitations, this study offers promising evidence that community-based harm reduction organizations are willing to engage with interactive, online mapping tools for disseminating predictive modeling results and to examine neighborhoods for resource allocation that are predicted to be at high risk of future overdose death. Online dashboards may be effective tools for community-based organizations to identify, locate, and examine neighborhoods at elevated risk of overdose mortality to inform future resource allocation and other outreach efforts.

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