Visualizing Inequity: 3D Mapping of Redlining Effects on Climate and Health

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ABSTRACT

This exploratory study aimed to investigate the perceptions of redlining on climate and health using three-dimensional (3D) visualization models. Mapbox Studio was employed to create visualizations of two neighborhoods in Bronx County, New York. A user study involving twenty-three respondents was conducted to gather feedback on five visualizations, with participants generally supporting the use of these visualizations in conveying the information about how climate factors influence respiratory health, notably asthma. This research seeks to promote the further development of 3D visualization techniques to enhance interactive comprehension of structural racism.

CCS CONCEPTS

• **Human-centered computing** → **Virtual reality**; • **Computing methodologies** → *Perception.*

KEYWORDS

data visualization, structural racism, redlining, climate, asthma, perception

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1 INTRODUCTION

Structural racism refers to systemic and institutionalized patterns of discrimination that disadvantage racial and ethnic minorities while privileging white individuals [8]. It encompasses the ingrained political, social, and legal norms that perpetuate racial disparities across various aspects of life, including housing, healthcare, education, employment, and the criminal justice system. Despite legal advancements such as the Civil Rights Act, structural racism persists, shaping access to opportunities, resources, and outcomes based on race [8]. This systemic inequality also includes environmental injustices, such as disproportionate exposure to pollutants and environmental hazards, leading to higher rates of respiratory illnesses in communities of color [13].

The legacy of structural racism exerts a profound influence on various aspects of society, including housing valuation, climate change, and respiratory illnesses. In housing valuation, discriminatory practices such as redlining have systematically devalued properties in predominantly minority neighborhoods, perpetuating disparities in wealth accumulation and access to resources [8]. This led to limited investment in infrastructure and services, thereby exacerbating vulnerabilities to climate change impacts such as flooding and extreme heat in these communities[6]. Municipal disinvestment, characterized by the deliberate withdrawal of financial, social, and political investments from these communities, further aggravates these disparities, restricting access to quality housing, healthcare, and education [11]. This dual impact underscores how historical and contemporary policies shape inequalities, affecting property values negatively and contributing to differential outcomes in health and environmental justice. Additionally, the concentration of industrial facilities in these neighborhoods contributes to higher rates of respiratory illnesses, particularly asthma, due to increased exposure to pollutants such as particulate matter, ozone, and nitrogen dioxide, which trigger asthma attacks [2, 7].

The intertwined nature of these issues emphasize the pervasive and enduring effects of structural racism, necessitating comprehensive and equitable strategies to address systemic inequities and promote environmental justice. The objective of this project is to examine perceptions of 3D mapping and its ability to illustrate the effects of redlining on climate and health by constructing detailed 3D maps of two communities within Bronx County, New York. Building on Lisa's previous work, which focused on exploring perceptions of structural racism in housing valuation through 3D visualizations, our study specifically aims to visualize the historical and contemporary impacts of redlining on climate and health [5]. The 3D maps will serve as a powerful tool to highlight these inequities, facilitating a deeper awareness and informing potential interventions to address these long-standing issues.

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2 RELATED WORK

Examining structural racism and its intersection with housing valuation is critical for understanding enduring urban disparities. Lynch and her colleagues studied historic redlining and current neighborhood lending discrimination, revealing the persistent effects of government-endorsed redlining on mental health, physical health, and infant mortality [8]. Their research demonstrated that current lending practices result in disinvestment and lead to adverse health outcomes in segregated neighborhoods. Similarly, Mitchell and Franco underscore the importance of this historical context by revealing how areas labeled as "hazardous" or "redlined" were systematically denied capital investment, obstructing improvements in housing quality and economic opportunities for residents [9]. Their findings highlight how past discriminatory practices continue to manifest in present-day urban landscapes. The lack of investment in these neighborhoods not only perpetuates economic inequality but also exacerbates health disparities, as these areas often lack access to quality healthcare, nutritious food, and safe living environments.

Hoffman, Shandas, and Pendleton found that historically redlined neighborhoods face disproportionate exposure to current heat events, implying that past housing policies may be directly responsible for this vulnerability [6]. Recent research indicates that housing market valuations increasingly incorporate both existing and projected climate risks, although there is limited evidence of consistent pricing of climate risk by market participants [12].

The connection between housing value and climate change has intensified respiratory illnesses, particularly asthma. Climate change is causing warming trends and an increase in extreme weather events across the United States, with disproportionate health impacts on people of color, including children [3]. Moreover, it was found that structural discrimination and climate change exacerbate health disparities, particularly among minoritized populations [1]. Their research reveals that these health inequities are deeply intertwined with historical colonial practices, which led to resource exploitation, environmental degradation, and continued vulnerabilities. Specifically, their study highlights that colonial legacies contribute to increased exposure to environmental hazards, such as air pollution and extreme weather, disproportionately affecting marginalized communities.

Existing literature indicates higher incidences of severe asthma visits due to poor housing conditions. According to a report by the New York City Department of Health, issues such as cracks, holes, water leaks, and unventilated gas stoves in substandard housing are significant contributors to the development and exacerbation of asthma symptoms. The report highlights that approximately 25 percent of asthma cases in the city are linked to these housing conditions. Specifically, homes with unventilated gas stoves have been shown to increase asthma symptoms by up to 30 percent, and damp conditions due to water leaks can exacerbate asthma in 20 percent of affected individuals [10]. These substandard living conditions can lead to pest infestations and mold, further exacerbating respiratory problems. Moreover, demographic studies reveal that children and non-Hispanic Black or African American individuals disproportionately experience asthma exacerbations requiring emergency care. These health inequities, intensified by extreme weather events such as the wildfire smoke event in New York [4], underscore the critical role that poor-quality housing plays in exacerbating asthma incidence and severity among vulnerable populations. Substandard housing conditions significantly increase susceptibility to environmental hazards, thereby worsening health outcomes.

While numerous studies have explored the correlation between structural racism and housing valuations using two-dimensional models, only a limited number have employed 3D data visualizations to visualize structural racism. Lisa and her colleagues investigated how individuals interpret various 3D representations of two Bronx neighborhoods regarding housing valuation and redlining [5]. They found that people responded positively to multidimensional visualizations that included physical depictions of red lines, racial demographic data, and properties scaled and colored based on specific parameters.

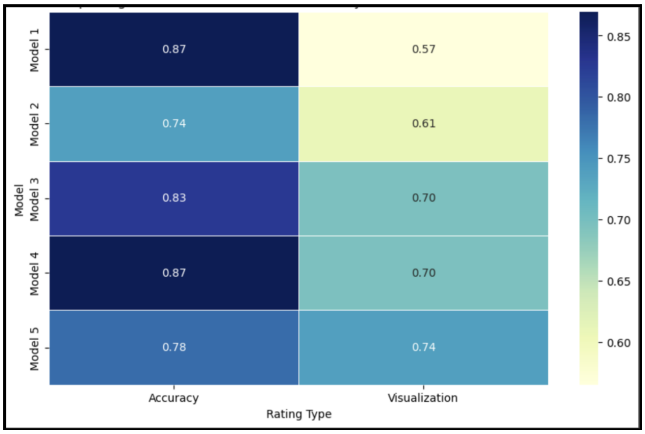

Figure 1: Heat Map of Agreement Levels for Model Accuracy and Visualization Effectiveness

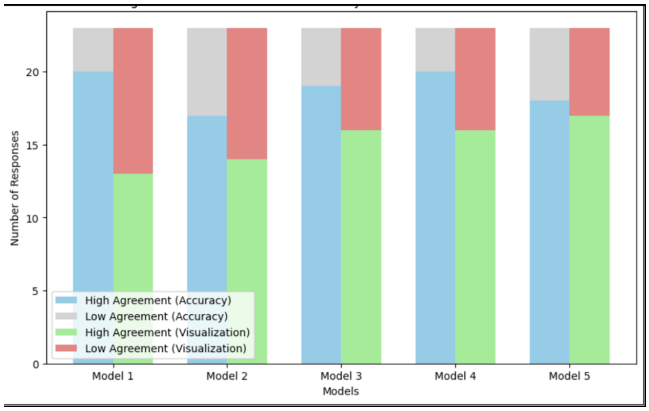

Figure 2: Agreement Levels for Model Accuracy and Visualization Effectiveness

3 METHODS

This research investigates the enduring impact of structural racism and housing valuation on climate conditions and respiratory illnesses in New York City's neighborhoods of Soundview and Riverdale.

Figure 3: Visualizations (numbered from left to right): 1 (top-left) to 5 (middle-bottom)

Spatial mapping techniques were employed using Mapbox Studio to visually represent critical factors influencing public health disparities. The maps focused on several thematic areas: Heat Vulnerability and Environmental Factors depicted areas susceptible to extreme heat events, highlighting disparities in greenspace distribution and air pollution levels. Socioeconomic Status maps illustrated vulnerability differences based on income levels and housing conditions. Access to Healthcare maps displayed the distribution of healthcare facilities to assess spatial accessibility. Data sources included publicly available datasets from sources such as the U.S. Census Bureau, the Environmental Protection Agency (EPA), and New York City's Department of Health and Mental Hygiene, as well as local health agency reports detailing health outcomes and environmental conditions. Visualization techniques such as color schemes, size differentiation, symbol representation, and map layout adjustments were utilized to enhance clarity and communicate spatial patterns. An online survey administered via Google Forms gathered feedback from voluntary participants to assess perceptions of the mapped data.

4 USER STUDY

Participants were initially briefed on the study's purpose and given a definition of structural racism and its link to respiratory diseases. In the first survey phase, each model was paired with two questions: one asked participants to rate the model's accuracy in representing a description on a scale of 1 to 5 ("On a scale of 1 to 5, how well does the model represent the description above accurately?"), while the other gauged how well the visualization depicted racial differences between Riverdale and Soundview in terms of climate impact on asthma ("How well does the visualization convey the effects of climate on respiratory illnesses, particularly asthma?"). The second phase asked participants to rank their preferences for models illustrating structural racism's influence on climate change and housing disparities, from best to worst.

5 RESULTS AND ANALYSIS

A total of 23 participants completed the survey, with the majority aged 18-20, and over half identifying as Asian/Pacific Islander. The gender distribution included 13 women and 10 men.

Summary Results: The survey evaluated participants' perceptions of the accuracy and visualization effectiveness of five models

Table 1: Model Ratings Summary

Model	Accuracy Mean	Accuracy Median	Accuracy Mode	Accuracy Std Dev	Visualization Mean	Visualization Median	Visualization Mode	Visualization Std Dev
Model 1	4.3	4.5	4, 5	0.58	3.65	3.5	3, 5	1.06
Model 2	3.91	4	4	1.02	3.74	4	4	1.09
Model 3	4.13	4	5	0.96	3.83	4	4	1.02
Model 4	4.13	5	5	0.83	3.96	4	5	1.16
Model 5	4.09	4	4	0.83	3.91	4	4	1.09

in conveying the effects of climate on respiratory illnesses, particularly asthma. Figure 3 showed all the models presented to the participants.

Table 1 provides a statistical overview of the models' ratings. Notably, Model 1 received the highest agreement on accuracy, with 87 percent of participants rating it 4 or 5 (mean: 4.3), indicating strong support for its accuracy. However, it showed more varied responses for visualization effectiveness (mean: 3.65). In contrast, Model 5, although generally effective, had the least consensus on accuracy and visualization effectiveness.

Figure 1, a heat map, illustrates that while accuracy ratings were consistently high across most models, there was notable variability in visualization effectiveness ratings. This suggests specific areas for improvement in visual design to enhance communication. Figure 2, a stacked bar chart, visually summarizes the distribution of agreement levels, highlighting the consistent performance in accuracy versus the more varied feedback on visualization effectiveness.

In the final part of the survey, Model 1 (M1) was preferred for visualizing the influence of structural racism on climate change and health disparities with 43.5 percent, while M5 was the least favored. Models M2, M3, and M4 received mixed responses, indicating they were moderately effective but not as compelling as M1.

6 DISCUSSIONS

The survey results offer valuable insights into the perceptions of model accuracy and visualization effectiveness in illustrating the impact of climate on respiratory illnesses, particularly asthma. Participants rated the models highly, especially Model 1, for accurately depicting asthma prevalence disparities between Soundview and Riverdale. This suggests that the model effectively communicated its intended message, making it a useful tool for demonstrating complex health disparities. However, there was notable variability in the effectiveness of the visualizations, indicating that while the models were recognized for their accuracy, the visual elements (e.g., color schemes and layout) did not uniformly resonate with all users. This highlights the need for improved visual strategies to better communicate complex data.

The study aimed to represent structural racism but faced several limitations. The small sample size of 23 and the online questionnaire format constrained the findings, and issues such as mobile viewing difficulties and limited model descriptions affected participants' interpretations. Technical challenges, such as importing maps into Unity, restricted the visualizations' complexity. The online format may have introduced selection bias, and self-reported data could be subject to social desirability bias.

Future research should address these limitations by increasing sample size and diversity, refining survey design for clarity, and ensuring model accessibility across devices. Expanding visualizations to include broader aspects of structural racism and combining quantitative data with qualitative insights could provide a more comprehensive view. Exploring advanced technologies like VR or AR and conducting longitudinal studies could further enhance understanding and engagement. These improvements will deepen our insights into how visualizing structural racism can influence public awareness and contribute to racial justice discourse.

7 CONCLUSION

This study highlights the potential of innovative visualizations to represent structural racism and its impacts on climate and health disparities. Despite limitations such as a small sample size and technical constraints, the findings indicate a high level of agreement on model accuracy and varied responses on visualization effectiveness. Future research should expand the scope, improve survey design, and utilize advanced technologies to create more comprehensive and impactful visualizations. These efforts will enhance our understanding of structural racism and support the ongoing discourse on racial justice.

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