



# EXPLORING THE ASSOCIATION BETWEEN REDLINING POLICIES AND POOR MENTAL HEALTH IN REDLINED CITIES

Research funded by the MITRE Independent Research and Development Program: *Case study for using health equity framework in population health*

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**August 2022**

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## KEY FINDINGS

- Historic redlining is associated with poor mental health in modern cities. Twenty-four of the 63 cities with more than 50 census tracts have statistically significant relationships between redlined grades and present-day poor mental health outcomes, after controlling for residential segregation, poverty, unemployment, education, housing stress, and demographics.
- National-level analyses related to historic redlining are limited due to the localized context (i.e., lack of standardization) of Home Owners' Loan Corporation (HOLC) grades, as well as numerous other population and policy changes that vary from one city to the next.
- Future investigation on the relationship between redlining and mental health would benefit from:
  - Accounting for patterns of neighborhood change, such as gentrification and blockbusting
  - More detailed examination of public and private neighborhood investment levels, including lending disparities

## INTRODUCTION

In 2019, 51.5 million adults (20.6%) in the United States reported experiencing a mental illness in the past year [1]. While prevalence estimates for certain mental health conditions are roughly equivalent across racial and ethnic groups [2] people who identify as racial or ethnic minorities are less likely to receive treatment than those who identify as non-Hispanic White [3], with 23% of non-Hispanic White adults reporting any mental health treatment in the past year compared with 13.6% of non-Hispanic Black adults and 12.9% of Hispanic adults [3].

The social, economic, and physical environments in which people live, learn, work, and play are essential factors that shape physical and mental health over the life course [2], [4]. Frequently cited risk factors related to the social determinants of mental health include racial discrimination and social exclusion; adverse early life experiences; poor education; unemployment,

underemployment, and job insecurity; poverty, income inequality, and neighborhood deprivation; poor access to sufficient healthy food; poor housing quality and housing instability; adverse features of the built environment; and poor access to health care [5]. Where a person resides affects their level of exposure to risk factors, as well as their access to protective resources and opportunities that promote good mental health. We sought to explore the hypothesis that census tracts exposed to historic redlining, as one form of residential discrimination and structural racism, are associated with poorer population-level mental health outcomes.

To better understand the impacts of racial residential discrimination and structural racism on mental health disparities, we focused on a specific federal housing policy implemented from approximately 1935 through 1940 in the United States under the Home Owners' Loan Corporation (HOLC; described below). While there have been countless discriminatory policies and

practices implemented at federal, state, and local levels over the past hundred years, the classifications (“grades”) of city neighborhoods under HOLC represent the most detailed available codification at the national level of de jure residential segregation on the basis of race, ethnicity, and nationality [6]. In order to explore the long-term impacts of these policies, we used statistical modeling to examine the association between historically redlined census tracts and present-day prevalence of poor mental health.

## PURPOSE

This paper summarizes the association between historic redlining and poor mental health prevalence across U.S. cities that were part of the HOLC City Survey program, and identifies potential considerations for interpreting these findings in a local context. We begin with a brief overview of historic redlining policies and the literature linking historic redlining to mental health outcomes. We describe methods to model the association between historic redlining and poor mental health prevalence and general findings across all included cities. The underlying causal structure between historic redlining and present-day poor mental health is complex, given the length of time since HOLC grading practices, unmeasured confounders including structural racism, and reverse causality between social determinants of health and mental health, among others. The purpose of this work is to provide a high-level descriptive exploration of these associations across multiple cities as a basis for other researchers to continue to investigate and theorize the nature of this association.

To explore potential applications and considerations for future users of the model,

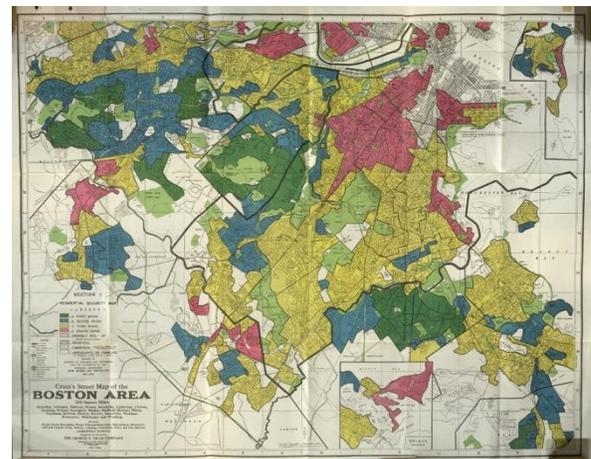
we explore in detail the example of Baltimore, Maryland, a city with a positive, statistically significant association between HOLC grade and prevalence of poor mental health, to highlight local outputs from our model. Finally, we report findings from additional research about local factors in Baltimore that may be relevant to the interpretation of the model.

## BACKGROUND

### Historic Redlining Policies

In the 1930s, the federal government, seeking to stabilize the housing market and improve financial conditions for homeownership in the midst of the Great Depression, created the Federal Housing Administration and HOLC [6]. These entities implemented policies and programs to standardize lending and make homeownership more accessible for many Americans. For some families, these policies created access to capital and possibilities for generational accumulation of wealth. However, these policies and programs also systematically excluded people of color and immigrant communities, thereby promoting segregation and disinvestment in these communities [6].

*Figure 1. HOLC Map of Boston Area*



HOLC created “Residential Security” maps of 202 cities across the United States as part of its City Survey program from 1935 until about 1940. Appraisers and real estate professionals across these cities were tasked with assigning grades according to their assessment of relative mortgage lending risk in a given neighborhood. For example, a scan of the original HOLC map of the Boston area, pictured in Figure 1, denotes the grades applied to various neighborhoods in green, blue, yellow, and red [7].

HOLC grades were characterized across cities as follows [7]

- *A-graded areas* (shaded in green) were deemed “best” or safest for investment.
- *B-graded areas* (shaded in blue) were categorized as “still desirable” but not as much as A-graded areas.
- *C-graded areas* (shaded in yellow) were described as “definitely declining” due to “obsolescence and infiltration of lower grade population.”
- *D-graded areas* (shaded in red, or “redlined”) denoted a “hazardous” investment due to “detrimental influences in a pronounced degree, undesirable population or an infiltration of it.” They recommended that lenders “refuse to make loans in these areas or only on a conservative basis.”

Surveyors documented their observations about the areas that were used to assign grades, including the neighborhood’s quality of housing, patterns in sale and rent values, and the racial and ethnic identity and class of residents. The “infiltration” of people identifying as racial and ethnic minorities was very likely to result in being marked as a D-graded, “hazardous” investment. Figure

2 shows a scan of the Area Description created for a D-graded area of Boston, located near the present-day South End and Roxbury Crossing neighborhoods. The clarifying remarks describing the presence of Black and Jewish populations as justification for the “D” grade are similar to many descriptions found for D-graded areas [7].

While there is a lack of consensus on the extent to which these maps were broadly shared and directly used to inform lending, at minimum, they reflected the industry standards and local-level discriminatory lending practices and influenced government mortgage lending of the time. Some scholars

Figure 2. Example of HOLC Map Area Description (Boston - South End)

\*Warning: Offensive language is used in this original document scan

FORM 6  
10-1-37

AREA DESCRIPTION - SECURITY MAP OF Greater Boston, Mass.

1. AREA CHARACTERISTICS:

a. Description of Terrain. Level to hilly

b. Favorable Influences. Good transportation, schools, etc. Close to central Boston employment area.

c. Detrimental Influences. Congested. Heavy traffic. Large assessments. unimproved property. Poor housing. Cosmopolitan population. Obsolescence.

d. Percentage of land improved 100 %; e. Trend of desirability next 10-15 yrs. Down

2. INHABITANTS:

a. Occupation Clerks - labor - relief; b. Estimated annual family income \$ 600-1500

c. Foreign-born families 50 %; Mixture predominating; d. Negro Yes; 25 %

e. Infiltration of Foreign - negro; f. Relief families Heavy

g. Population is increasing \_\_\_\_\_; decreasing \_\_\_\_\_; static Yes

3. BUILDINGS:

	PREDOMINATING 50 %	OTHER TYPE 30 %	OTHER TYPE 20 %
a. Type	<u>3 fam 5/8/9 rms</u>	<u>2 fam 5-6 rms</u>	<u>Singles 5-12 rms</u>
b. Construction	<u>Frame</u>	<u>Frame-brick</u>	<u>Frame</u>
c. Average Age	<u>40-50</u> Years	<u>15-60</u> Years	<u>50-60</u> Years
d. Repair	<u>Poor</u>	<u>Poor</u>	<u>Poor</u>
e. Occupancy	<u>98-99</u> %	<u>98-99</u> %	<u>98-99</u> %
f. Home ownership	<u>40</u> %	<u>50</u> %	<u>50</u> %
g. Constructed past yr.	<u>0</u>	<u>0</u>	<u>0</u>
h. 1929 Price range	<u>\$3500-11,000</u> 100%	<u>\$4000-11,000</u> 100%	<u>\$3000-8000</u> 100%
i. '33-36 Price range	<u>\$1800- 5,500</u> 50 %	<u>\$2000- 6,000</u> 55 %	<u>\$1600-4000</u> 50 %
j. 1937 Price range	<u>\$1800- 5,500</u> 50 %	<u>\$2000- 6,000</u> 55 %	<u>\$1500-4000</u> 50 %
k. Sales demand	<u>\$</u>	<u>\$</u>	<u>\$</u>
l. Activity	<u>Poor</u>	<u>Poor</u>	<u>Poor</u>
m. 1929 Rent range	<u>\$25 - 25</u> 100%	<u>\$25 - 40</u> 100%	<u>\$30 - 55</u> 100%
n. '33-36 Rent range	<u>\$16 - 22</u> 60 %	<u>\$16 - 28</u> 60 %	<u>\$20 - 30</u> 60 %
o. 1937 Rent range	<u>\$16 - 22</u> 60 %	<u>\$16 - 28</u> 60 %	<u>\$20 - 30</u> 60 %
p. Rental demand	<u>\$</u>	<u>\$</u>	<u>\$</u>
q. Activity	<u>Fair</u>	<u>Fair</u>	<u>Fair</u>

4. AVAILABILITY OF MORTGAGE FUNDS: a. Home purchase Limited; b. Home building \_\_\_\_\_

5. CLARIFYING REMARKS: Negro heavily concentrated north of Ruggles St, on the west side of Washington. Jewish centered near Columbus Square. A large territory with some streets showing better experiences than the balance of the section.

6. NAME AND LOCATION Boston - South End SECURITY GRADE D AREA NO. 9

argue that these grades were used more broadly by both public and private entities, including banking institutions and mortgage lenders, and informed housing sector decisions for up to 30 years after the program had ended [8]. As a result, people living in these areas were deemed ineligible for loans, and were excluded from the public and private capital that allowed many White people born in the United States to become homeowners and pass property on to their children. Housing discrimination by federally funded housing agencies was not banned until 1962 [9], and redlining in the private sector remained legal until the enactment of the Fair Housing Act of 1968 [10].

Nearly 90 years have transpired since the creation of the HOLC maps. In addition to historic redlining policies, a variety of measures implemented in the early-to-mid-20<sup>th</sup> century at federal and local levels—such as exclusionary, race-based zoning ordinances, deeds, and covenants; blockbusting; eminent domain and displacement of people identifying as racial and ethnic minorities; and segregation in federally subsidized housing projects—also enforced racial residential segregation in the United States. More than 50 years after redlining, race-based zoning and other explicitly discriminatory policies and practices in the housing sector were outlawed; however, certain exclusionary zoning, real estate, and lending practices persist [11], [12]. Altogether, these practices have contributed to sustaining the conditions of de facto segregation that have led some of the same communities that were redlined in the 1930s to continue to experience social and economic exclusion and disinvestment today.

## Mental Health and Residential Segregation

Ample literature has described the linkage between racial residential segregation and racial health inequities, including for disparate outcomes related to cardiovascular disease, hypertension, diabetes, and asthma [13], [14]. We identified several studies that analyzed the association between mental health and residential segregation [15]–[18]. Research to date has rendered mixed and inconclusive findings with regard to the association between residential segregation and mental health (e.g., depression and anxiety). The associations vary according to racial, ethnic, or immigrant group affected and the dimension of residential segregation (i.e., evenness, exposure, clustering, concentration, and centralization) investigated. The observed associations across these studies may also be partially mediated by neighborhood poverty level [15]–[18].

Moreover, a growing body of literature specifically examines the ongoing adverse impacts of historic redlining policies, as a metric for structural racism (defined in Appendix A), on present-day health outcomes such as asthma, preterm births, and cancer [11], [19]. Few studies, however, have focused specifically on the association between historic redlining policies and present-day mental health outcomes. Lynch et al. (2021) conducted an ecologic study of Milwaukee, Wisconsin, to assess the relationship between historic redlining policies, current neighborhood lending discrimination, and three key health indicators (mental health, physical health, and infant mortality rate), and found that greater historic redlining was associated with current neighborhood-level lending discrimination and poor physical and mental health [20]. However, this work focused solely on Milwaukee and used current

lending discrimination in addition to redlining. Further research is needed to deepen the understanding of the relationship between historic redlining policies (and racial residential segregation more broadly) and mental health nationally, and shape policies that effectively promote mental health equity.

## METHODS

### Data Sources

Census tracts were used as the primary unit of analysis to allow for more precise exploration of HOLC-graded areas within a city overlaid with present-day, local outcomes. We examined poor mental health prevalence and other covariates related to the social determinants of mental health among the 202 cities that were historically redlined.

### Redlining

Using the digitized HOLC maps available through the University of Richmond’s Mapping Inequality Project, we estimated the HOLC grade associated with current census tracts using a continuous population weighting method with a 20% threshold. For each HOLC area within a census tract, census block populations were used to assign total population via an area-based weighting and summation. Points were also assigned to each grade (gp): A as 1, B as 2, C as 3, and D as 4. Using the population and points, each census tract grade was assigned as follows, resulting in a grade range from 1 to 4:

$$Grade = \frac{1}{\sum_{gp=1}^4 population_{gp}} \sum_{gp=1}^4 population_{gp} * gp$$

<sup>1</sup> We did not include a row for social capital and support in Table 1, as we could not identify a widely available measure.

We used a 20% threshold; if the total graded population for that tract was less than 20% of the total population of that tract, the tract was not graded. We excluded ungraded areas.

### Mental Health and Covariate Data

Data for mental health outcomes and model covariates were obtained from 2018 CDC PLACES [21] and the 2019 5-year U.S. American Community Survey [22], as well as 2017 HUD CHAS [23], 2015 CDC NEPHTN [24], 2019 USDA Food Access Research Atlas [25], and 2018 ACAGPM [26] data for variables tested but unused.

We used the literature related to the social determinants of mental health to inform a preliminary list of potential covariates for inclusion within our model. These overlapped with many of the recognized social determinants of chronic diseases and commonly included employment; education; income; housing quality; neighborhood and built environment; access to healthy food; adverse childhood experiences; exposure to violence; mass incarceration and police violence; substance use; access to transportation; environmental air, water, or land pollution; and social capital and support<sup>1</sup>. Table 1 lists relevant measures and data we identified for each of these concepts, indicating with an asterisk those measures that were ultimately included as variables in our model, a plus for those variables considered, and a minus for variables with no national tract data available.

The available literature examining the association between residential segregation and/or redlining and mental health outcomes was used to identify the most relevant mental health outcomes, as well as to validate the list (see above) of potential

covariates for our model and explore best-fit analytic approaches to examine these relationships. After developing the list of the most relevant mental health outcomes as well as predictors/covariates, we researched available national data sets that would offer the required level of granularity for inclusion in our model. The Centers for Disease Control and Prevention (CDC) PLACES measure for “Mental Health Not Good for  $\geq 14$  Days Among Adults Aged  $\geq 18$  Years” was selected as our primary mental health indicator for poor mental health prevalence [21] due to its national availability at the census tract level.

## Inclusion /Exclusion

To further narrow the list of variables to include in a multivariate mental health model for all cities, we:

- Filtered out cities that had less than or equal to 50 census tracts in order to draw more meaningful conclusions with statistically significant sample sizes.
- Filtered out univariate models where the coefficients showed insignificant P-values ( $>0.05$ ).
- Ordered the models by their P-values (ascending), then R-squared (descending), and then AIC value (descending). We then grouped by the specific city and chose the top 10 univariate models (out of 20, since we consider 20 variables to start) based on our ordering.
- Calculated the number of city-models that contain each covariate in the top 10 ordering.
- Removed redundant variables (i.e., multiple education measures) by identifying the variable categories and subcategories and choosing the variable from each category represented by the largest number of city-models. We also introduced some variables based on contextual evidence and literature.

## Statistical Models

Our final list of covariates for inclusion in the multivariate model included Index of Concentration at the Extremes (ICE); Non-White by Income; Percent of the Population Below 200% of the Federal Poverty Line (FPL); Unemployment Rate, 16 Years and Over; Percent Completed Less than High School; Percent Non-White; and Housing Stress.

We ran multivariate linear regression models for each of the HOLC-graded cities with greater than 50 HOLC-graded census tracts and explored outputs according to the significance and strength of the association between HOLC grade and poor mental health prevalence. Below we describe our findings at the national level and at the city level, in the case example of Baltimore, Maryland.

## RESULTS

### National Findings

Applying a simple univariate linear regression model for each city, and filtering for cities with greater than 50 tracts with HOLC grades (66 out of 202 cities; 33% of all HOLC-graded cities), we observed a significant association between HOLC grade and poor mental health prevalence in 63 of

Table 1. Selection of Measures and Covariates Related to the Social Determinants of Mental Health

Mental Health Outcome and Covariates	Measures Considered (* selected for final model, + tested variable, - no national tract data available)	Data Sets Used
Mental Health	Poor Mental Health Prevalence (Self-Reported)* Admissions/Discharge Rates for Treatment Episode for Mental Health Diagnosis - Prevalence of Serious Mental Illness (Diagnosis) - Mental Health Services Facility Availability -	2018 CDC PLACES
Population Composition	Percent Non-Hispanic White + Percent Non-Hispanic Black + Percent Non-Hispanic American Indian/Alaska Native + Percent Non-Hispanic Asian + Percent Non-Hispanic Native Hawaiian/Other Pacific Islander + Percent Native Hawaiian/Other Pacific Islander + Percent Non-Hispanic Other + Percent Hispanic + Percent Non-White +	2019 American Community Survey 5-year
Employment	Unemployment Rate, 16 Years and Over* Labor Force Participation Rate +	2019 American Community Survey 5-year
Education	Percent Less than High School Diploma* Percent Bachelor's Degree or Higher +	2019 American Community Survey 5-year
Income	Percent Population Below 200% of the Federal Poverty Level (FPL)*	2019 American Community Survey 5-year
Housing Quality	Housing Stress*	2017 HUD CHAS
Neighborhood and Built Environment	ICE Non-White by Income* ICE, Rent Versus Owned + Alcohol Outlet Density - Percent Population Within a Half Mile to Parks +	2019 American Community Survey 5-year 2015 CDC NEPTN
Access to Healthy Food	Percent Population with Access to Healthy Foods +	2019 USDA Food Access Research Atlas
Adverse Childhood Experiences	Adverse Childhood Experiences -	
Exposure to Violence	Violent Crime Rates -	
Mass Incarceration and Police Violence	Incarceration Rate - Police Killings -	
Substance Use	All-cause mortality, Estimated Drug Poisoning -	
Access to Transportation	Vehicle Access -	
Environmental Air, Water, or Land Pollution	Particulate Matter +	2018 ACAGPM

Figure 3. Flowchart of Model for HOLC-Graded Cities.



66 (95%) cities. However, controlling for the six covariates in the multivariate model attenuated the association, indicating that much of the linear model variation was likely explained by other factors. HOLC grade remained statistically significant but weakly positive in 24 (38%) of 63 cities after applying the multivariate model.

Figure 3 summarizes results of our exploratory analysis at the city level. Cities are grouped according to their significance in the univariate and multivariate models, and whether they had a positive or negative coefficient for the association between HOLC grade and poor mental health prevalence.

In Figure 4, we examine the distribution for each of our selected covariates according to HOLC grades, across all cities with greater than 50 HOLC-graded tracts. HOLC grades A through D were binned by rounding, where scores from 1.0 to 1.5 are binned as a grade “A,” scores from 1.5 to 2.5 are binned as “B,” scores from 2.5 to 3.5 as “C,” and scores of 3.5 to 4.0 as “D.” Moreover, we conducted ANOVA tests of covariates to determine whether the distributions varied significantly from each other (Table 2). Each covariate has 3 degrees of freedom, given that only HOLC-graded tracts are included in this analysis. This test assumes that each HOLC-graded group has a normally distributed population composition, each group is independent of one another, and variance among groups is approximately equal; this is verified by census blocks used to create the assignments and can be seen in Figure 4.

At the 0.01 significance level, we can conclude for every covariate that the distribution of a sample population varies significantly by HOLC grade.

Figure 4. Distribution of Selected Covariates Across HOLC Grades (Cities with >50 HOLC-Graded Tracts)

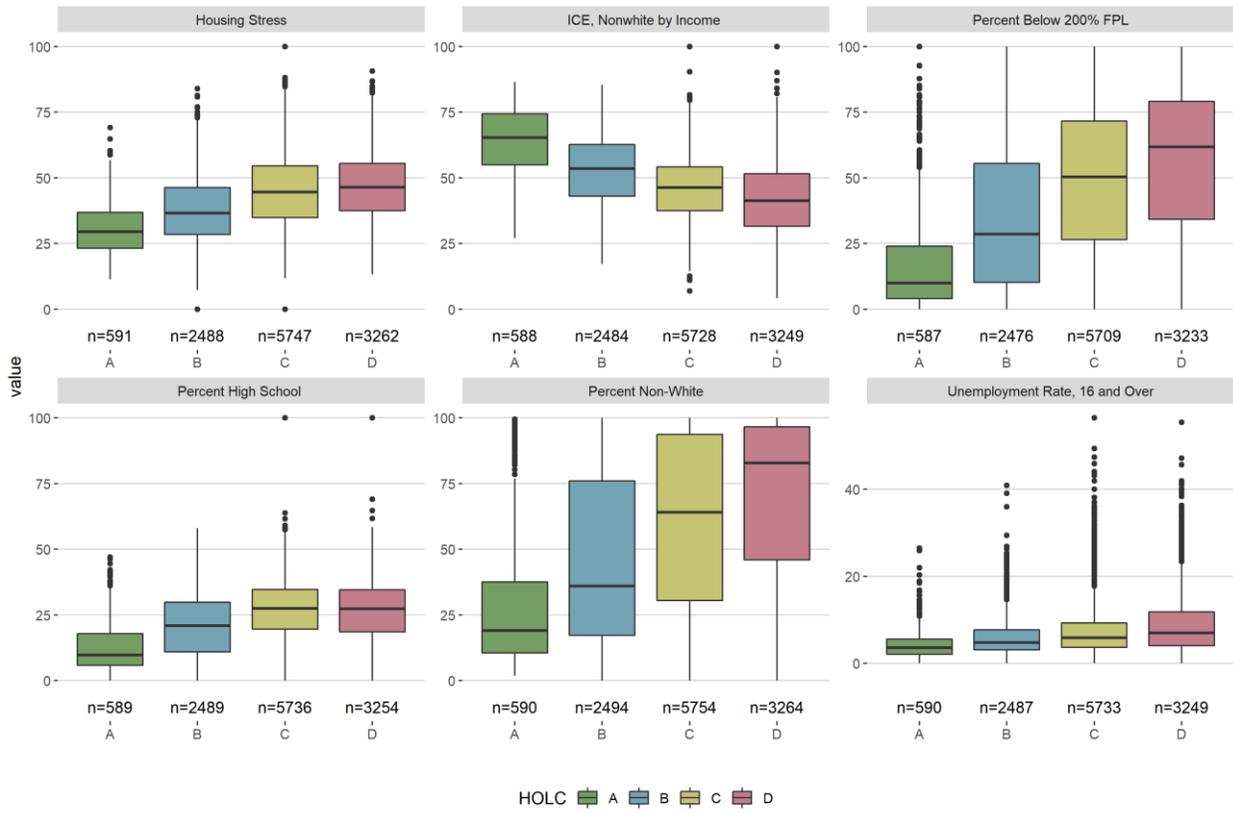


Table 2. Analysis of Variance for HOLC-Graded Tracts (Cities with >50 HOLC-Graded Tracts)

Coefficient	F Value	Pr(>F)
<b>ICE Non-White by Income</b>	668.36	<1E-16
<b>Percent Below 200% FPL</b>	547.77	<1E-16
<b>Unemployment Rate Over 16</b>	177.42	<1E-16
<b>Percent Less than High School</b>	393.50	<1E-16
<b>Percent Non-White</b>	479.91	<1E-16
<b>Housing Stress</b>	424.25	<1E-16

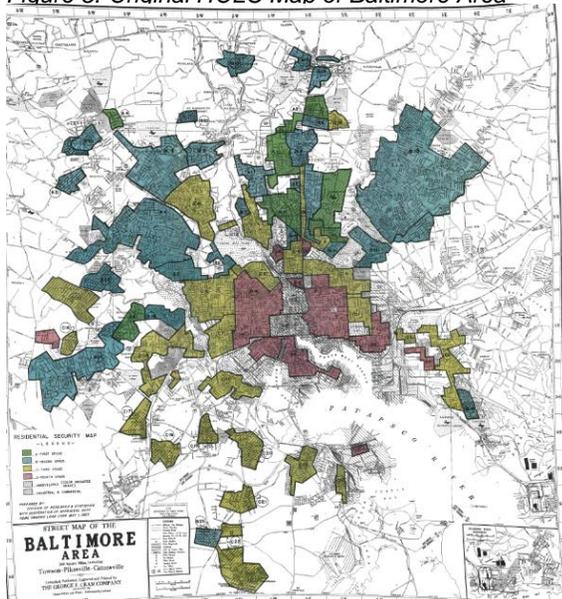
In Figure 4, we observe that generally C- and D-graded tracts appear to have higher average Housing Stress, Percent Below 200% FPL, Percent Less than High School, Percent Non-White, and Unemployment Rate than A- and B-graded tracts, and a lower overall ICE Non-White by Income for C- and D-graded tracts than for A- and B-graded tracts (albeit to varying degrees). When comparing these in individual cities, covariates demonstrated varying levels of significance from one city-model to the next. Further, redlining association varied both in magnitude and direction between cities, such that there were no generalizable trends in redlining associations across city-models.

## City-Level Findings: Baltimore, Maryland

To further explore the association between historic redlining and present-day mental health, we investigated Baltimore, Maryland, as a case example. We selected Baltimore because of the statistically significant association between redlining and poor mental health prevalence after adjusting for covariates listed above, and the availability of literature on housing and other place-based discrimination and exclusion in the city. Baltimore is the most populous city in Maryland, with a population of 585,708 according to the 2020 U.S. Census [27]. The population of Baltimore has been declining since 1950, when it had a population of nearly 1 million residents [28]. The majority of the population (58%) identifies as Black or African American, followed by non-Hispanic White (28%). The fastest-growing demographic group according to the 2020 Census was the Hispanic or Latino population, now composing nearly 8% of the population [29].

According to the 2019 American Community Survey, 21.2% of Baltimore

Figure 5. Original HOLC Map of Baltimore Area



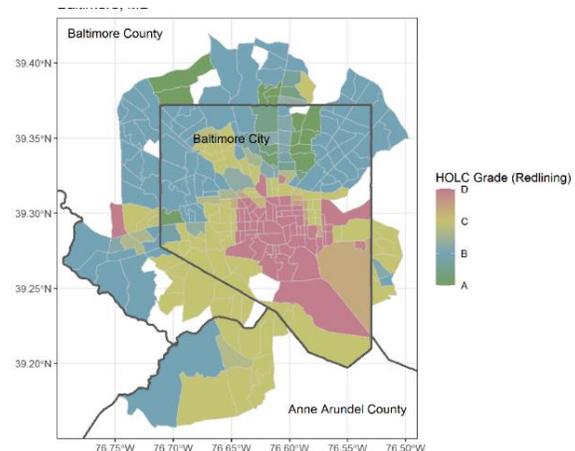
residents live in poverty, which is nearly double the national average (11.4%) and more than double the state average (9.0%) [27]. Baltimore's per capita income of \$31,271 is lower than that of other cities in the surrounding region [27].

The original HOLC map for Baltimore is pictured in Figure 5, while Figure 6 displays the HOLC grades applied to present-day census tracts, with city and county border lines. As seen in Figure 6, the HOLC map for the Baltimore Area included some census tracts pertaining to Baltimore and Anne Arundel Counties, which are legally distinct jurisdictions with separate governments. from Baltimore City. Baltimore and Anne Arundel Counties are wealthier and whiter than Baltimore City, with 8.9% and 5.2% of residents living in poverty, respectively, and non-Hispanic White majorities of 60.2% and 66.7%, respectively [24].

### Historic Context

Baltimore was the second largest city in the United States, after New York City, until 1850. It was an important port city and manufacturing hub until after World War II, when both its industries and population began to decline [25]. Prior to the establishment of HOLC, the city of

Figure 6. HOLC Grades Applied to Current Baltimore Census Tracts



Baltimore passed a 1910 city ordinance aimed at preventing Black people from living anywhere near White people. Although the Supreme Court deemed such housing segregation laws unconstitutional in 1917, Baltimore City government and private entities persisted in enforcing similar policies through the use of discriminatory covenants and housing ordinances [30]. Twenty years later, the HOLC maps further reinforced some of these discriminatory policies and practices, and codified those areas that city leaders, lenders, and real estate brokers saw as “appropriate” for White populations as opposed to non-White and/or immigrant populations.

### Redlining and Mental Health

Our fully-adjusted multivariate linear regression model for the association between HOLC grades and poor mental health prevalence had an adjusted R-squared of 0.8436, suggesting the model as a whole explains a substantial amount of the linear

variability in poor mental health prevalence. Here, as HOLC increases by one grade, poor MH prevalence increases by 0.56%, controlling for the covariates listed in Table 1 below. This means that the majority of the linear variation in prevalence of poor mental health at the census tract level is explained by the included characteristics, including HOLC grade and social, economic, and demographic indicators. Areas with grades “C” and “D” on the HOLC map of Baltimore were primarily concentrated near the Patapsco River and south of the waterfront, with A- and B-graded tracts fanning out to the north. The map in Figure 7 correlates current-day census tracts to the original HOLC-graded areas, and overlays shaded circles indicating poor mental health prevalence for each census tract.

Figure 7. Baltimore Area HOLC Grades by Census Tract and Poor Mental Health Prevalence

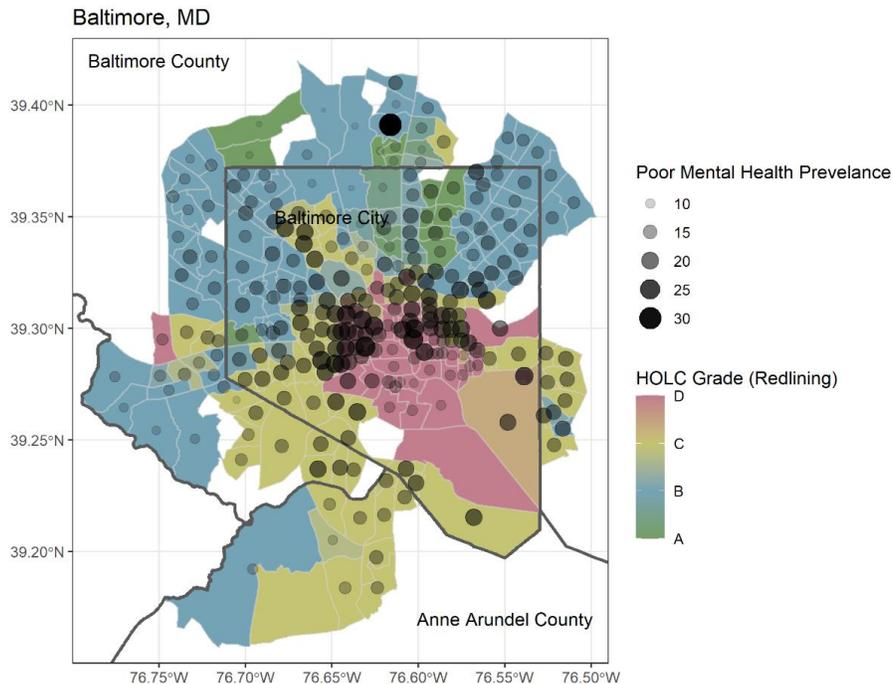
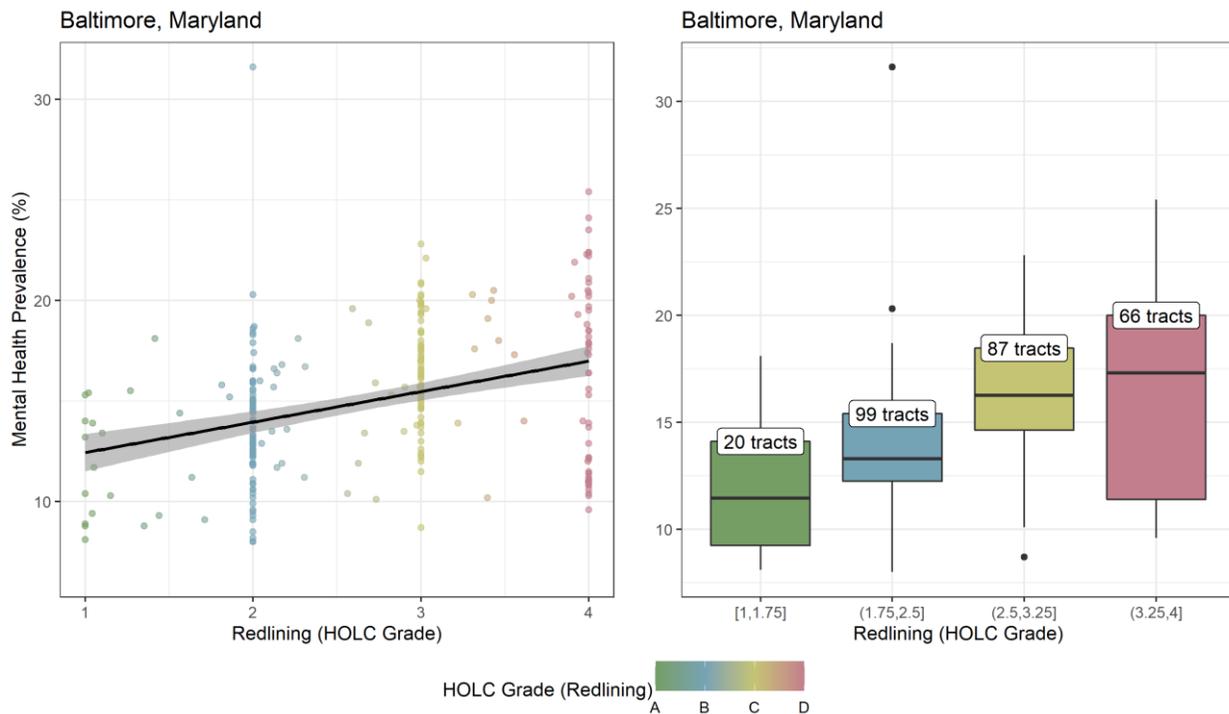


Figure 8. Baltimore Distribution of Census Tracts by HOLC Grade



While the map denotes several tracts with higher prevalence of poor mental health in historically redlined areas and lower prevalence of poor mental health in tracts with HOLC grades of “A” or “B,” we also observe several D-graded tracts near the Patapsco River waterfront with low prevalence of poor mental health. The waterfront tracts with low prevalence of poor mental health largely coincide with the sites of major investments by the city and a regional board of business leaders in the late 1950s and 1960s to transform downtown areas and the Inner Harbor [31]. As discussed later in this section, these formerly redlined downtown and waterfront tracts with lower prevalence of poor mental health appear to largely coincide with tracts labelled as “gentrified areas” in the National Community Reinvestment Coalition map for Baltimore [32].

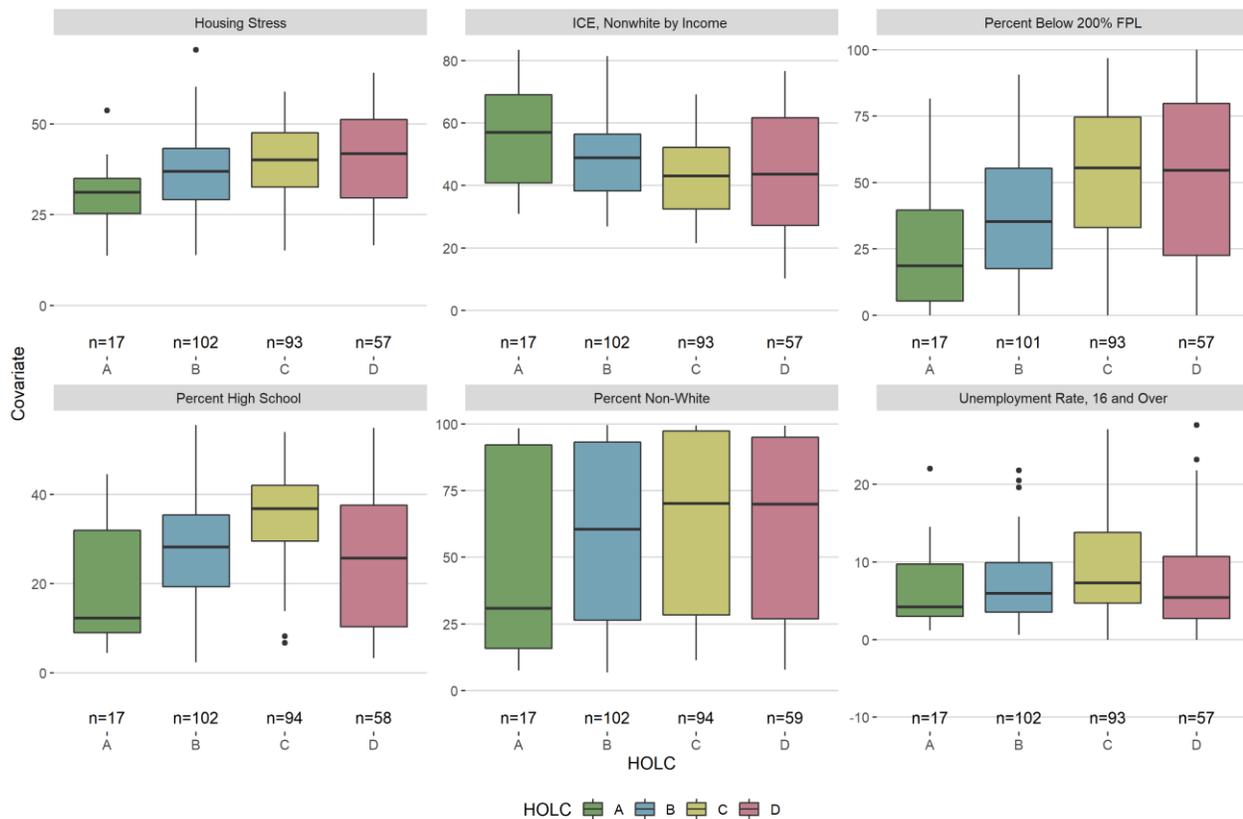
As represented in Figure 8, out of 272 HOLC-graded tracts in Baltimore, 66 are redlined (i.e., graded “D”), 87 are graded “C,” 99 are graded “B,” and 20 are graded “A.” Therefore, tracts that were categorized as D-graded, “hazardous” areas or C-graded “definitely declining” areas outnumber those that were graded “A” for “best” and “B” for “still desirable.” D-graded tracts have greatest variability, as measured by the interquartile range, for poor mental health prevalence.

Similarly, when we examine box plots for each of the covariates in the model binned by HOLC grade (see Figure 9), D-graded tracts have the largest distribution compared with A, B, and C-graded tracts for each covariate except for Unemployment Rate and Percent Non-White.

Table 3. Baltimore Area Multivariate Model for Poor Mental Health Prevalence

Coefficient	Estimate	Std. Error	P-Value
<b>ICE, Non-White by Income</b>	-0.0773	0.0175	<0.001
<b>Percent Below 200% FPL</b>	0.0319	0.0054	<0.001
<b>Unemployment Rate Over 16</b>	0.0959	0.0213	<0.001
<b>Percent Less than High School</b>	0.0712	0.0101	<0.001
<b>Percent Non-White</b>	-0.0115	0.0058	0.048718
<b>Housing Stress</b>	0.0304	0.0118	0.010614
<b>HOLC Grade</b>	0.7734	0.1130	<0.001

Figure 9. Baltimore Distribution of Covariates by HOLC Grade



As noted in Table 3, there are statistically significant associations between all covariates and poor mental health. ICE, Non-White by Income; Percent Below 200% FPL; Unemployment Rate Over 16; and Percent Less than High School are significant at a <0.001 level, while Percent Non-White and Housing Stress are significant at a <0.05 level.

While distributions for the D- and C-graded tracts generally encompass the lowest values for ICE Non-White by Income, and the highest values for Percent Below 200% FPL, Unemployment Rate, Percent Less than High School, Percent Non-White, and Housing Stress, we observe especially large

Table 4. Poor Mental Health in Baltimore Tracts Below Median Percentage Non-White

Coefficient	Estimate	CI	P-Value
<b>ICE, Non-White by Income</b>	-0.03	-0.09 – 0.03	0.281
<b>Percent Below 200% FPL</b>	0.01	-0.01 – 0.04	0.277
<b>Unemployment Rate Over 16</b>	0.26	0.12 – 0.39	<0.001
<b>Percent Less than High School</b>	0.08	0.05 – 0.11	<0.001
<b>Housing Stress</b>	0.02	-0.03 – 0.07	0.380
<b>HOLC Grade</b>	0.55	0.21 – 0.89	0.002

Table 5. Poor Mental Health in Baltimore Tracts Above Median Percentage Non-White

Coefficient	Estimate	CI	P-Value
<b>ICE, Non-White by Income</b>	-0.07	-0.10 – -0.03	<0.001
<b>Percent Below 200% FPL</b>	0.03	0.02 – 0.04	<0.001
<b>Unemployment Rate Over 16</b>	0.06	0.01 – 0.11	0.014
<b>Percent Less than High School</b>	0.08	0.06 – 0.11	<0.001
<b>Housing Stress</b>	0.04	0.01 – 0.06	0.012
<b>HOLC Grade</b>	1.00	0.72 – 1.28	<0.001

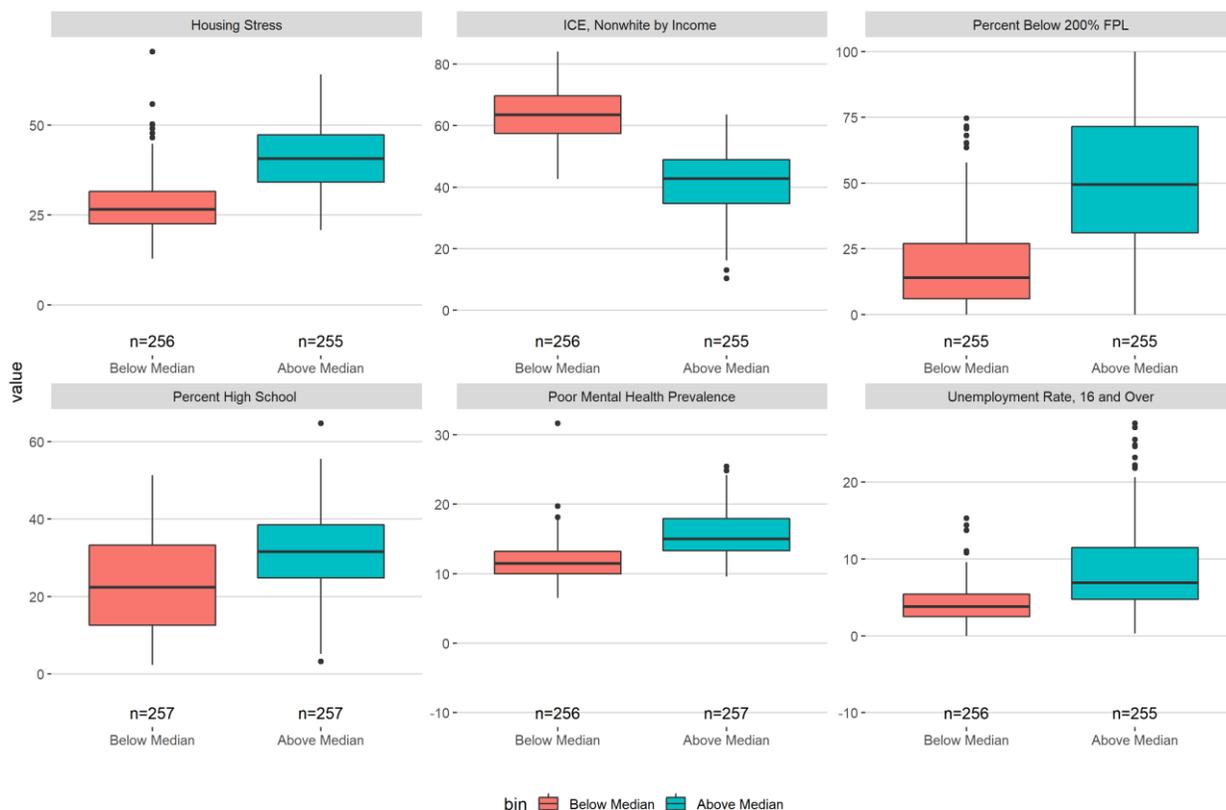
distributions for the D-graded tracts in covariates including Housing Stress, Percent Below 200% FPL, and Percent Less than High School. These large distributions for D-graded tracts may be indicative of neighborhood change (e.g., gentrification) in some portion of D-graded tracts, where some populations in historically redlined areas have been displaced by wealthier, Whiter populations, while others continue to experience conditions of disinvestment.

Next, we stratified our multivariate model for Baltimore by the percentage of the population that is non-White, to compare tracts below the median (i.e., with higher concentrations of White population) to tracts above the median (i.e., with higher concentration of non-White populations). As seen in Table 4, Table 5, and Figure 10, we note that the association between poor mental health prevalence and HOLC grade is higher for tracts with an above median

percentage non-White population than below median. Similarly, ICE, Non-White by Income and Percent Below 200% FPL are more significant and higher in the above median group. These findings suggest that patterns of neighborhood change, such as gentrification and blockbusting (see Appendix A for definitions), warrant future investigation to better understand their relationship with our variables.

Based on a review of available literature, we further explore potential considerations for the interpretation of this model in the Baltimore context. Upstream factors related to neighborhood change and neighborhood investment levels appear most likely to impact the association between HOLC grade and poor mental health prevalence.

Figure 10. Baltimore Distribution of Covariates, Stratified by Proportion of the Population That Is Non-White



### Neighborhood Change and Neighborhood Investment Levels

We conducted additional research to examine upstream factors that may impact the association between HOLC grade and poor mental health prevalence in the Baltimore context, which are not currently captured by our model. Key factors identified in Baltimore included patterns of neighborhood change (i.e., gentrification, displacement, and blockbusting) and neighborhood investment levels. In this section, we describe key takeaways from the literature that may help broaden our understanding of the associations found in the model, as well as offer considerations for future research.

According to the National Community Reinvestment Coalition (NCRC), Baltimore was among the “most intensely gentrifying cities” between 2000 and 2013, with a

gentrification rate of 22% [33], and from 2013 to 2017, with a rate of 10.7% [34]. It was also among the cities with the highest levels of Black displacement between 2000 and 2010 [33]. Patterns of gentrification and displacement have resulted in what is referred to as the “Black Butterfly”—areas of segregated Black communities fanning out to the east and west, delineated by the wealthier, whiter areas along the waterfront, along the Charles Street corridor, and to the north [32], [35], [36]. The Urban Institute report “Neighborhood Investment Flows in Baltimore” presents the distribution of Baltimore residents by race or ethnicity and poverty rate by census tract for 2012–2016, with an apparent overlap between the areas of highest concentration of non-Hispanic Black residents and high poverty rates [36]. This illustrates that displaced tracts are largely associated with higher poverty rates,

while gentrified tracts are largely associated with lower poverty rates.

Two published articles have specifically examined associations between historic redlining policies and other discriminatory housing practices and health-related outcomes in Baltimore [37], [38]—both emphasized the importance of patterns of neighborhood change such as gentrification, displacement, and blockbusting in examining health-related outcomes. A 2021 article examined the relationship between discriminatory housing practices and food environment disparities, comparing the relative associations of redlining, blockbusting, and gentrification with food access [37]. Blockbusting, defined as the percentage decrease in the White population between 1950 and 1980, was most strongly associated with food access. The authors of this article observed that blockbusting and gentrification tended to be mutually exclusive [37]. We note that the areas with high and extreme blockbusting levels, per Figure 6 in the article, appear to overlap with areas denoted in the Urban Institute maps referenced above, with higher concentration of Black residents and higher poverty rates. Additional research on the association between historic redlining and health-related outcomes in Baltimore may benefit from incorporating metrics for gentrification and blockbusting.

A 2019 article exploring neighborhood disparities related to the presence of alcohol outlet clusters found that historic redlining was the strongest predictor of alcohol outlet cluster membership, followed by vacant housing density, which was used as a proxy for level of economic investment [38]. The study pointed to the importance of considering alcohol outlet type, as off-premise alcohol outlet clusters were disproportionately located in areas with a higher concentration of Black residents, and

with greater economic disadvantage and disinvestment, while on-premise clusters were located in more advantaged areas with a larger concentration of White residents. In particular, on-premise alcohol outlet clusters were located in census block groups that were historically redlined and later gentrified [38]. These clusters appear to overlap with many of the D-graded tracts that also had a lower prevalence of poor mental health.

To understand the long-term impacts of redlining in Baltimore, including disinvestment in communities composed primarily of people who identify as racial and ethnic minorities, we also reviewed research relating to neighborhood-level investment. The intention of this research is to understand disparities in different types of capital, including private, public, and mission investment, from one neighborhood to the next. Access to and availability of capital impacts whether the residents of a given neighborhood have access to essential amenities, resources, and services [39]. Just as historic redlining restricted access to mortgage loans for redlined communities for previous generations, neighborhood-level disparities in access to capital and investment impact neighborhood-level disparities in economic opportunity, health, and well-being. In theory, public investments (including city, state, and federal government financing) and mission investments (such as from community development financial institutions) should support capital flows to those neighborhoods that are neglected by private capital and investment. In practice, however, these sources of investment are not always deliberately directed to low-income communities and those composed of people who identify as racial and ethnic minorities (i.e., progressively distributed).

According to a 2021 Urban Institute analysis for the 250 largest U.S. cities, Baltimore was in the 24<sup>th</sup> percentile for overall investment volume that the city receives per household, housing unit, or employee; the 47<sup>th</sup> percentile for overall racial equity in distribution of investments across neighborhoods with different racial and ethnic demographics; and the 58<sup>th</sup> percentile for income equity [40]. Analysis of public and private sector neighborhood-level investment flows by the Urban Institute found that neighborhoods composed of less than 50% Black residents received roughly 3.3 times the investment of neighborhoods with majority Black populations [36]. Investment from all sources in low-poverty neighborhoods (those with a 25% poverty rate or lower) was 1.9 times that of investment in high-poverty neighborhoods. Wide disparities in lending impact individuals and business owners, contributing to the persistence of poor conditions of the built environment, access to jobs, and access to public spaces, among other challenges to achieving healthy outcomes and equitable growth [36]. In 2004–2016, higher average lending levels largely coincided with census tracts with a higher concentration of non-Hispanic White residents [36]. Public sector investments and mission lending have not succeeded in balancing out the inequities observed in private sector lending. While not all public and mission funding sources have been progressively distributed, the analysis indicated that they have become more progressively distributed over time [36].

Future investigation on the relationship between redlining and mental health in Baltimore would benefit from accounting for patterns of neighborhood change such as gentrification and blockbusting. Additionally, more detailed examination of public and private neighborhood investment levels, including lending disparities, may

provide a more nuanced understanding of the relationships between the HOLC grades of the 1930s and poor mental health prevalence today.

## Limitations

Although we believe that the models described above enable us to explore general associations between redlining and poor mental health prevalence across the included U.S. cities, we note that our analysis is subject to several limitations.

Our analysis is likely subject to residual confounding, as not all potential confounders were consistently available at a national scale. In the nearly 90 years since the creation of the HOLC maps, redlined areas and populations have experienced a large variety of social, demographic, economic, policy, environmental, and other changes, making it nearly impossible to account for all possible covariates and confounders. For example, we were unable to account for exposure to violence, incarceration, adverse childhood experiences, or social capital.

Further, in aggregating HOLC grades to census tracts, we are assuming uniform effects within each graded area. This assumption imposes a monotonic relationship between and within grades that may obscure larger differences between graded neighborhoods.

Moreover, other relevant measures for mental health, such as mental health treatment availability, mental health care received in the past 4 weeks, prevalence of co-occurring mental health and substance use disorders, and medical expenditure data, were not available at a national scale and/or at the census tract level. Poor mental health prevalence as an outcome is subject to underreporting in self-reported data [41], exacerbated by the stigma surrounding mental health reporting [42]. As such, our

analysis may be biased toward underestimates of poor mental health prevalence.

For the purposes of this exploratory analysis, we applied a linear regression model for each city, as we acknowledge that the effects of redlining and the covariates stated vary widely from city to city [7].

While a broader mixed effects model binning all the cities may account for a more general picture of redlining across the United States, the local nature of HOLC grading and regional effects in both redlining and our covariates lent itself to city-specific models. This likely limits our interpretation of associations between cities, as magnitudes are relative to the city individually, rather than a common baseline.

Our model does not account for key factors related to neighborhood change (e.g., gentrification and blockbusting) over time. We assume these may be on the causal pathway between historic redlining and present-day health outcomes. Therefore, such factors may contribute to perpetuating the conditions of racial residential segregation in a redlined area, displacing populations residing in a given area, and/or altering the conditions of racial residential segregation in a redlined area. These include patterns of neighborhood change such as gentrification, displacement, and blockbusting, as well as public and private neighborhood investment levels, which

impact the quality of the built environment. While there are no standard metrics available for these factors, they should be evaluated within the history and present-day context of a given city.

## CONCLUSION

Our models indicate a significant association between HOLC grade and current poor mental health prevalence in HOLC-graded cities; however, we found that in certain cities, much of this association may be attributable to other socioeconomic factors. Overall, the precise relationship between HOLC grades, current poor mental health prevalence, and other socioeconomic indicators such as ICE, Non-White by Income is highly complex and city-dependent, especially given that the policies and populations of historically redlined areas have not remained static over the past 90 years. Future research and analysis would benefit from applying metrics for other patterns of neighborhood change, such as gentrification and blockbusting, and neighborhood investment levels. A more complete understanding of the ways in which historic discriminatory policies continue to shape current health inequities may help guide more evidence-based investments and decisions related to health and social policies and programs.

## APPENDIX A: GLOSSARY

**Blockbusting:** “Profiteering by inducing property owners to sell hastily and often at a loss by appeals to fears of depressed values because of threatened minority encroachment and then reselling at inflated prices.” [43]

**Gentrification and Displacement:** Often defined as “the transformation of neighborhoods from low value to high value.” As noted by the CDC, “This change has the potential to cause displacement of long-time residents and businesses. Displacement happens when long-time or original neighborhood residents move from a gentrified area because of higher rents, mortgages, and property taxes.” [44]

**HOLC Grade:** As described by the Mapping Inequality initiative, “HOLC staff members, using data and evaluations organized by local real estate professionals—lenders, developers, and real estate appraisers—in each city, assigned grades to residential neighborhoods that reflected their ‘mortgage security’ that would then be visualized on color-coded maps. Neighborhoods receiving the highest grade of ‘A’—colored green on the maps—were deemed minimal risks for banks and other mortgage lenders when they were determining who should receive loans and which areas in the city were safe investments. Those receiving the lowest grade of ‘D,’ colored red, were considered ‘hazardous.’” [7]

**Housing Stress:** According to Department of Housing and Urban Development (HUD) tabulations from the American Community Survey (ACS), the fraction of households where one or more of the following conditions are met: (1) housing expense/income threshold—monthly housing costs, including utilities, exceed 30% of income; (2) crowding— more household members than rooms; (3) incomplete plumbing—home lacks necessary bathroom facilities; and (4) incomplete kitchen— home lacks essential kitchen facilities [23]

**Index of Concentration at the Extremes, Nonwhite by Income:** A measure of residential segregation and spatial social polarization defined as the difference between the proportion of high-income Non-Hispanic white and low-income Nonwhite or Hispanic populations in a geographic region [45]

**Percent Below 200% FPL:** The proportion of the population with a household income that falls below 200% of the federal poverty line (FPL). This is the official measurement of poverty used by the federal government, and is based on the U.S. Census Bureau’s 2019 poverty threshold for a family with two adults and one child of \$20,578.

**Percent Less than High School:** The proportion of the population, based on American Community Survey data, that did not attain a high school diploma.

**Percent Non-White:** The proportion of the population of a given area, based on U.S. Census data, that does not identify as non-Hispanic White.

**Structural Racism (also Institutional Racism):** “Refers to the processes of racism that are embedded in laws (local, state, and federal), policies, and practices of society and its institutions that provide advantages to racial groups deemed as superior, while differentially oppressing, disadvantaging, or otherwise neglecting racial groups viewed as inferior.” [45]

**Unemployment Rate Over 16:** According to ACS data, the unemployment rate represents the number of unemployed people ages 16 and over as a percentage of the civilian labor force. [22]

## APPENDIX B: ABBREVIATIONS AND ACRONYMS

<b>Term</b>	<b>Definition</b>
CDC	Centers for Disease Control and Prevention
FPL	Federal Poverty Level
HOLC	Home Owners' Loan Corporation
ICE	Index of Concentration at the Extremes

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