



Cross-level sociodemographic homogeneity alters individual risk for completed suicide

Bernice A. Pescosolido^{a,b,1} , Byungkyu Lee^{a,b} , and Karen Kafadar^c

^aDepartment of Sociology, Indiana University, Bloomington, IN 47405; ^bIndiana University Network Science Institute, Indiana University, Bloomington, IN 47405; and ^cDepartment of Statistics, University of Virginia, Charlottesville, VA 22904-4135

Edited by Douglas S. Massey, Princeton University, Princeton, NJ, and approved August 10, 2020 (received for review April 3, 2020)

Among deaths of despair, the individual and community correlates of US suicides have been consistently identified and are well known. However, the suicide rate has been stubbornly unyielding to reduction efforts, promoting calls for novel research directions. Linking levels of influence has been proposed in theory but blocked by data limitations in the United States. Guided by theories on the importance of connectedness and responding to unique data challenges of low base rates, geographical dispersion, and appropriate comparison groups, we attempt a harmonization of the National Violent Death Reporting System (NVDRS) and the American Community Survey (ACS) to match individual and county-level risks. We theorize cross-level sociodemographic homogeneity between individuals and communities, which we refer to as “social similarity” or “sameness,” focusing on whether having like-others in the community moderates individual suicide risks. While analyses from this new Multilevel Suicide Data for the United States (MSD-US) replicate several individual and contextual findings, considering sameness changes usual understandings of risk in two critical ways. First, high individual risk for suicide among those who are younger, not US born, widowed or married, unemployed, or have physical disabilities is cut substantially with greater sameness. Second, this moderating pattern flips for Native Americans, Alaska Natives, Asians, and Hispanics, as well as among native-born and unmarried individuals, where low individual suicide risk increases significantly with greater social similarity. Results mark the joint influence of social structure and culture, deliver unique insights on the complexity of connectedness in suicide, and offer considerations for policy and practice.

US suicide | multilevel | homogeneity | risk factors | networks

Suicide’s impact on American society is enormous. Ranked 10th overall in 2018, suicide represents the second leading cause of death for those aged 10 to 34, and the fourth among those aged 35 to 54 (1). With over a half million emergency room visits annually for self-inflicted injury, coupled with estimates that only 30% of those with suicidal behavior use medical services, suicide’s effects are profoundly underreported. Annual societal costs just for individuals identified in medical visits range from over \$1 billion for treating self-inflicted injuries, to over \$32 billion for lost productivity. Despite efforts to understand and reduce suicide, US rates mark suicide’s remarkable resistance to individually focused medical and public health interventions and support claims that our predictive ability has not improved in the last 50 y (2–4). Most recently, the alarming, unexpected, and unexplained rise in suicide among middle-aged men, a group always at high risk, and among young women, traditionally at lower risk, reinforce urgent calls for novel research, prevention, and treatment directions (5–7).

While a deeply personal act, suicide has been shown to be systematically patterned by both individuals’ demographic characteristics (from death certificates or clinical records) and the social contexts (from aggregate suicide rates) in which they live. Findings are consistently robust on the role of sex, age, marital status, and employment at both individual and contextual levels. Since early 19th-century empirical studies (e.g., Italian statistician Morselli, French sociologist Durkheim, Czech sociologist Masaryk),

these sociodemographic factors have been interpreted as tapping into social conditions, social statuses, and social integration (8). In contemporary theories, this translates into explanations centered on connectedness and social safety nets (3, 9), on the one hand, and thwarted belongingness, loneliness, and social isolation (10), on the other hand. The general proposition maintains that an individual’s embeddedness in society protects them from suicide, and, its opposite, predisposes them to it. Findings on the absence of connections (e.g., the unmarried) or the loss of ties (e.g., the divorced, the unemployed) predispose individuals to suicide while those that mark their presence (e.g., the married, the religiously affiliated) have been replicated at both individual and contextual levels (see ref. 11 for a review; also refs. 9, 12).

What has eluded the understanding of suicide lies at the center of sociology’s contribution to the health sciences, the transdisciplinary agenda, and the promise of personalized medicine. The micro/macro link or the link between personal troubles and public issues fundamentally sees patterns in individual behavior tied to the larger social context in which they live (13). Most relevant here, theories of social comparison, relative deprivation, and status integration, as well as more recent network-based complexity theories, suggest that the association of an individual’s risk factor may be lessened if they live in an area with “like-others” and magnified if they are isolated in confronting life challenges (14–17). Principles of selective attachment or homophily (i.e., the tendency of individuals to connect with similar others) and differential association [i.e., individuals come to behave more like those with whom they interact (18)] suggest that cross-level demographic similarity, or what we refer to as “social similarity” or “sameness,” may increase the probability

Significance

Recent unexpected increases in US suicides reinforce calls for fresh approaches to understanding suicide risk. Theorizing the complexity of suicide risk and harmonizing existing large data sources, we find two distinct patterns. Having more similar others in a geographical context dampens suicide risk for non-native-born, unemployed, and widowed individuals. However, social similarity heightens suicide risk in counties with a larger share of some race/ethnic and marital status groups. Knowing how social contexts alter individual suicide risk suggests innovative research directions, and provides paths to craft personalized and tailored strategies for anti-suicide programs, policies, and treatment.

Author contributions: B.A.P. designed research; B.A.P. and B.L. performed research; B.A.P., B.L., and K.K. analyzed data; and B.A.P., B.L., and K.K. wrote the paper.

The authors declare no competing interest.

This article is a PNAS Direct Submission.

This open access article is distributed under [Creative Commons Attribution-NonCommercial-NoDerivatives License 4.0 \(CC BY-NC-ND\)](https://creativecommons.org/licenses/by-nc-nd/4.0/).

¹To whom correspondence may be addressed. Email: pescosol@indiana.edu.

This article contains supporting information online at <https://www.pnas.org/lookup/suppl/doi:10.1073/pnas.2006333117/-DCSupplemental>.

that social network ties would form, increasing connectedness (19). However, sociology's classic theory of suicide, the Durkheimian theory (14), and its more recent network translation (9) raise two theoretical twists. First, social ties are not without content, and second, cultural content can be protective or detrimental. With connectedness marking influence, culture holds the norms, life scripts, and beliefs that translate that influence to or away from suicide.

In sum, individual-level effects (e.g., employment status) target the influence of personal characteristics and situations that increase the probability of suicide because they mark "personal troubles" (20). The contextual level (e.g., the unemployment rate) indicates "public issues," which mark a community's social safety net, tempering or motivating the individual's suicidal impulse (14, 20, 21). Finally, because cross-level demographic similarity translates into a high probability that ties will form among like individuals (22), multilevel or cross-level hypotheses (i.e., interaction between personal troubles and public issues) posit that the influence of individual risk and protective factors are attenuated or amplified by larger, parallel social contexts of the same factor [e.g., being unemployed in an area of high or low unemployment (9, 13)]. Here, we evaluate the multilevel influence of major individual and aggregate equivalents implicated in previous suicide research that could be matched across datasets (i.e., age, sex, race/ethnicity, nativity, marital status, employment, physical problems).*

Methods

The Data Challenge (and Solution) in the Multilevel Analysis of Completed Suicide. Multilevel analyses of suicidal behavior exist, almost exclusively on suicidal ideation (i.e., attitudes, consideration, or suicide planning), suicide attempt [i.e., nonfatal, self-directed, potentially injurious behavior with intent to die (23)], or in European data analyses using national registries (24–26). While they support the salience of complexity, that is, the synchronized effects of large interacting units, self-injurious behaviors represent different phenomena, with demonstrated different correlates. Absent US national registries, the now standard cross-level analyses that have provided novel social epidemiology insights [e.g., Jackson Heart Study findings on race-neighborhood wealth interactions on serum cholesterol levels (27)] have eluded suicide research. To be clear, in completed suicide, the most appropriate comparison group is all living individuals; concentrated data collection in one geographic area or even long-term prospective national studies would produce multilevel data but insufficient variation in completed suicide deaths (12). These obstacles to US suicide research, as well as methodological interpretation problems associated with level-bifurcated research, have been recognized with efforts to overcome this impasse seen as unsatisfactory (8).

We harmonize two innovative data collections to offer a unique solution. Suicide data (the "ones" or cases) were obtained from the National Violent Death Reporting System (NVDRS) of the Centers for Disease Control and Prevention (CDC). The NVDRS, which compiles demographic and incident-related information on all violent deaths using a follow-back or psychological autopsy approach, solves the problem of having more than basic age, sex, and location data on suicide from death certificates. Data on living individuals in the same county (the "zeroes" or controls) were obtained from the US Census Bureau's American Community Survey (ACS) Public Use Microdata Sample (PUMS), which gathers demographic and socioeconomic information formerly obtained on the decennial census long form. NVDRS data on individuals dying by suicide were matched with parallel data on living individuals from ACS PUMS using geocoded information available in both. This constitutes the backbone of the Multilevel Suicide Data for the United States (MSD-US). Federal guidelines for acquiring and merging these data required special permissions, careful file construction, statistical corrections, specialized analyses, and federal agency cooperation. Institutional review board approval for the present study is held at Indiana University (protocol 1204008487).

The NVDRS has incrementally funded states since its formal inception in 2002, only recently having funding to cover the entire United States. Restricted-access data were obtained for 16 states that participated with fully operational

investigative systems from 2005 to 2011 (Alaska, Colorado, Georgia, Kentucky, Maryland, Massachusetts, New Jersey, New Mexico, North Carolina, Oklahoma, Oregon, Rhode Island, South Carolina, Utah, Virginia, and Wisconsin). While not a random sample of US states, they do represent states with wide variation in suicide rates, regions of the country, and sociodemographic characteristics. Selected person file records of residents in NVDRS states, 15+ y, whose deaths were classified as suicide were merged with parallel micro data for living persons using the ACS 1-y PUMS from 2005 to 2011. We created observation weights that match values of Public Use Microdata Areas units to values of county units using Geographic Correspondence Engine developed by the Missouri Census Data Center [i.e., Geocorr 2014 (28)]. A weight of 1 was assigned to NVDRS cases, yielding the overall suicide rate (11.99/100,000) almost identical to the suicide rate (12.1 per 100,000) reported by Compressed Mortality Files for the same states and time period.

Data integration required the resolution of discrepancies in structure and content of similar information types. Variables were harmonized and checked across datasets (see *SI Appendix, Table S1*, for descriptive statistics) across seven variables by matching community characteristics to individuals for each category (e.g., assign percentage male to male, percentage female to female). Standardized variables were constructed by subtracting means and dividing by SDs for effective comparison across different groups (see *SI Appendix, Fig. S1*; standardization creates similar distributions of demographic homogeneity measures across categories).

Contextual data were obtained from three sources. First, constructed observation weights aggregate individual-level data to county levels on seven variables: sex (male, female), age (in four categories); race [White, Black, American Indian, or Alaska Native (AI/AN), Asian, or Pacific Islander], ethnicity (Hispanic, non-Hispanic), national origin (born in United States, not born in United States), marital status (married, widowed, divorced, separated, never married), employment status (unemployed, not unemployed), and physical health status (problem noted, problem not noted). Second, to avoid misspecification errors, we merged aggregated data from the Small Area Income and Poverty Estimates, Census Geodatabase, County Population Estimates, County-to-County migration flow from the Internal Revenue Service, all provided by the Census Bureau (29) and known to be important controls in suicide analysis: percentage living in poverty, migration rate, and population density. Third, county-level counts of congregations for 236 religious organizations were obtained from the Longitudinal Religious Congregations and Membership Study (RCMS) (30) file for the most recent year available (2010), and aggregated into the Steensland et al. (31) religious tradition categories (Evangelical Protestant, Mainstream Protestant, Black Protestant, Catholic and Orthodox, Jewish, and Other). After listwise deletion of missing data, 7.8% of NVDRS cases and 4.67% of ACS cases were lost to the analysis (NVDRS Effective $n = 61,715$; ACS = 11,017,092; detail in *SI Appendix, Tables S2 and S3*).

Overview of Analyses. The MSD-US allows the specification of cross-level interactions, assuming that no ACS individual appears as an NVDRS death by suicide. Given the low suicide rate, contamination is likely to be low. The constructed observation weights are used to estimate weighted logistic regression models for a binary outcome (1 = suicide death, 0 = living individual) while adjusting for state-level clustering of SEs in the following models:

$$y_{ij} = \log\left(\frac{p}{1-p}\right) = \beta_0 + \beta_1 X_{ij1} + \beta_2 X_{ij2} + \dots + \beta_k X_{ijk} + \lambda_s + \varepsilon_{ij},$$

where p is the probability that an individual dies by suicide, X_{ijk} is an independent variable, λ_s accounts for state-fixed effects, and ε_{ij} is an error term. X_{ijk} can be either an individual-level variable (for an individual i) or a county-level variable (for a county j), or a cross-level product of two parallel variables (for an individual i living in j). The model controls for year dummies to account for potential year-specific idiosyncrasies, which produce results that are almost identical to those without year controls. Clustering across counties was considered in calculating SEs of the estimated β_k values. Robust clustered SEs were computed using the linearized variance estimator using `svy` command in Stata and compared to random intercept multilevel logistic regression models (very similar estimates; only results from the former reported).

We dropped a small number (0.2%) of cases with missing information on sex, age, race, nativity status since predicting ascribed characteristics is not scientifically valid (see *SI Appendix, Table S2* for missing patterns and *SI Appendix, Table S3* for comparison between the dropped and analytic sample). To address missing data for achieved characteristics (i.e., marital status, unemployment, physical problem), we ran multivariate imputation by chained equations within each county and year using `mice` package in R (32). We used multiple imputation analysis with survey weights based on 10 imputed datasets,

*Other matched cross-level interactions, not only possible but of great interest, cannot be assessed because of data limitations.

constructed in the same manner from the imputed individual-level measures, using `mi svy` in Stata. We report results from multiple imputation models for unemployment and physical problem because they have significant missing data (e.g., 50% unemployment, 10% physical problem). We report logistic regression model results for other demographic characteristics without controlling for unemployment and physical problem to avoid posttreatment biases and missing problems.

Finally, since odds ratios are known to be problematic for comparison across models and not easily interpretable (33), we calculated 1) the marginal effects of a change against the reference group in categorical variables at the individual level, and 2) the marginal effects of maximal change in continuous variables at the county level. For cross-level interactions, we plotted the predicted suicide rate of the independent (contextual) variables across different (individual) categories to maximize interpretability.

Results

Fig. 1 reports the marginal effects of the individual and county-level factors on US suicide. On the individual level, well-known effects are replicated. Women (compared to men) and other race/ethnic groups except AI/AN (compared to Whites) have a significantly lower risk of suicide while all older age groups (compared to those 15 to 24 y of age) have higher risk. Native-born individuals, those not married, who are unemployed, or who report physical problems have a higher suicide risk. On the county level, the results, controlled for individual risk factors, have some parallels with individual level results; areas that have higher percentages of divorced individuals or who were unemployed increase suicide risk. However, some county-level factors show the opposite direction of influence; areas with more individuals over 65, who were widowed, or never married decreases suicide risk while those with a greater share of native born, Blacks, or AI/AN population increases suicide risk. Furthermore, some factors typically seen as significant in individual-level analyses of suicide rates (e.g., female, physical problems) are not in evidence at the county level.

The inconsistency between individual- and county-level factors support the need to identify effects of one level while accounting for another (34). *SI Appendix, Fig. S2* shows that individual-level effects are robust against controlling for community-level counterparts, but county-level effects are not, most notably the effects of race. While a recent ecological analysis of county-level suicide rates finds that areas with a greater share of non-Hispanic Whites have higher rate of suicide (35), this analysis cannot tell us whether

this reflects the higher suicide rate among that group or captures contextual influence beyond individual-level factors. Fig. 2 begins to do so, presenting the marginal effects of sameness on US suicide. Having more individuals of the same age group, marital status, or physical problems decreases individual risk; having social similarity for US nativity, however, increases suicide risk. While like-others on unemployment and race/ethnic group increases risk and social similarity for sex decreases risks, none significantly do so.

Fig. 3 drills down on the cross-level interaction effects of social similarity at the county level. Fig. 3*A* reveals the standard effect for age groups. Sameness decreases suicide risk for the younger age groups (15–44), has little influence on the risk in middle age, and increases the risk for the oldest individuals. Ethnic and race effects are similarly complicated: For Whites and Blacks, sameness decreases individual suicide risk while for all other groups, and especially AI/ANs, the risk increases with sameness (Fig. 3*B*). Fig. 3*C* reveals that the presence of non-native-born residents decreases the individual risk of suicide among non-native-born individuals. Conversely, the pattern is reversed among US-born individuals where sameness dramatically increases individual suicide risk.

Fig. 3*D* initially shows the expected pattern of higher individual risk among those divorced or widowed; those never married with moderate risk; and those married with the lowest risk. However, sameness has very different effects on the risk, most dramatically for those who are widowed (similarity lessens risk) or who have never married (similarity increases risk). There is a moderate decrease in risk among married and separated individuals living among those who are socially similar but no cross-level interaction among the divorced. Fig. 3*E* reveals a curious effect where the risk for both individuals at higher risk (with physical problems) and those at lower risk (no physical problems) decreases with greater sameness. Fig. 3*F* shows that sameness decreases suicide risk for those who are unemployed with only a slight increase among the employed living with those who are socially similar.

Discussion

As a complex human behavior, suicide is riddled with inconsistencies. While factors such as social disadvantage (unemployment)

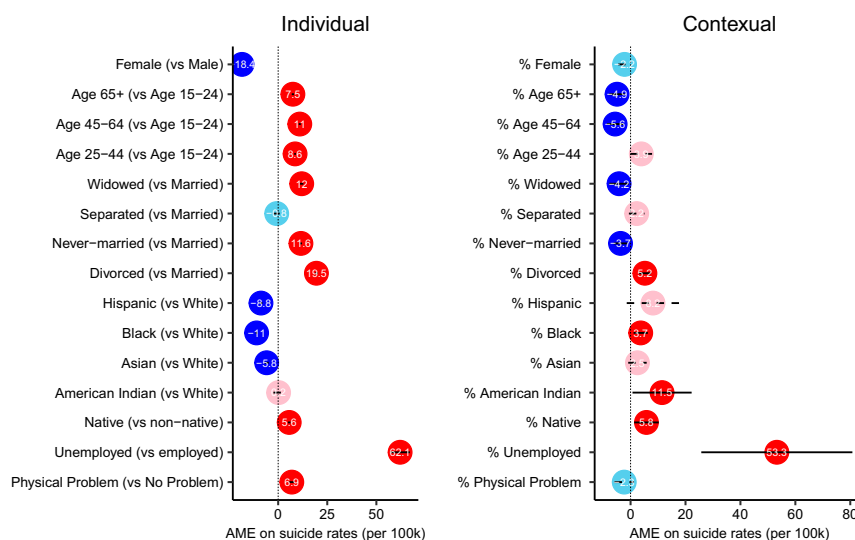


Fig. 1. Effects of individual and contextual factors on suicide risk at the county level. Note. We plot the average marginal effects (i.e., the predicted change of suicide death) with 95% confidence intervals of individual and contextual factors on suicide risks based on logistic regression models. We employ multiple imputation logistic models ($M = 10$) for unemployment and physical problems to account for missingness (*SI Appendix, Table S4*). For contextual factors, we show the maximal marginal effect by calculating the margin between minimum and maximum values (i.e., range). The dark red and blue dots with solid lines show positive and negative change, respectively, and the sky blue and pink dots with dotted lines show insignificant effects.

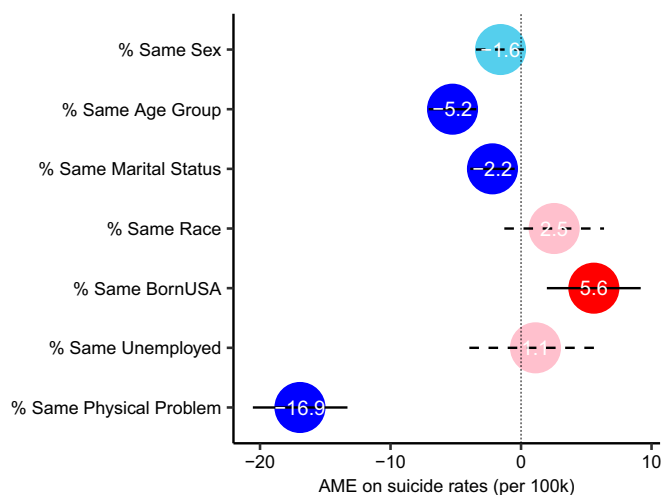


Fig. 2. Effects of social similarity on suicide risk at the county level. Note. We plot the average marginal effects (i.e., the predicted change of suicide death) with 95% confidence intervals of social similarity based on logistic regression models (*SI Appendix, Table S5*). We employ multiple imputation logistic models ($M = 10$) for unemployment and physical problems to account for missingness. We show the maximal marginal effect by calculating the margin between minimum and maximum values (i.e., range). The dark red and blue dots with solid lines show positive and negative change, respectively, and the sky blue and pink dots with dotted lines show insignificant effects.

or personal trauma (divorce) remain a bedrock of psychological, medical, and social understandings, findings that those with more social advantage (e.g., whites, men) die by suicide are curious. Furthermore, while individual-level traumas form the central focus of medical and psychological epidemiology, the continued, strong influence of social context advanced by public health, sociology, and social geographers remains remarkably intact. Some researchers suggest that this bifurcation of efforts and the resulting stalled progress in understanding and reducing suicide in the United States is methodological, resulting from insufficiently progressive, innovative, or accumulative approaches (4). We argue that, at least for completed suicide, a longstanding challenge has been in data accessibility, not in methods to analyze them. Research considering multiple levels or cross-level interactions in suicide is rare, recent, and provocative, especially in the US case (36). Findings from societies with registries, while generalizable internally, may not hold insights for the American case since these societies are more homogenous, have universal health care systems, and provide broader welfare state provisions. In sum, despite decades of suicide research, we know little about how multilevel factors work together or in opposition in the United States.

Ostrom (37) recommends embracing such complexities rather than trying to explain them away. Complex systems, composed of heterogeneous units interacting have emergent properties that cannot be understood by reference to individual units alone as they adapt to changing circumstances (ref. 15, p. 357), are viewed as open systems, with units interacting via flows of resources (both material and nonmaterial) through networks embedded in an environment (38). Here, we conceptualize the environment, itself, defined by geography as one of those key, interacting social units holding the unique potential to shape the structure and culture of social connectedness. We do not have direct measures of networks here, and it is unlikely that measuring individuals' networks at this scale will ever be feasible. However, precisely because social network formation is largely driven by self-selection processes such as homophily and propinquity, we can theorize about the influence of connectedness on suicide. Specifically, we can speculate how sameness taps into structural ties, normative climates, and social diffusion processes (39).

In this first effort, we merged and harmonized existing datasets to provide US data on the individual risk of dying from suicide by comparing decedents (included in the CDC's NVDRS) to living US residents (included in the ACS) from 2005 to 2011. We find that individual-level risks often remain the same even after controlling for social context; however, the effects of social context sometimes do not remain the same. More importantly, some of the most robust suicide research findings at the individual level are dramatically moderated by a consideration of their social environmental counterpart.

In a simple way, our findings align with traditional theories of social comparison theory (i.e., greater unemployment in an area decreases the perception that those around them are better off), relative deprivation (i.e., greater unemployment or widow in an area decreases the perception of an unfair disparity between oneself and others), or status integration (i.e., greater unemployment or widow in an area increases the likelihood of similar status configurations) theories. However, to suggest that "otherness" (i.e., being socially different) is the only insight into the role of connectedness and to new directions in identification, prevention, and treatment misses the critically important opposite effect for marginalized minority populations (e.g., American Indians and Alaska Natives). In general, while suicide rates in these populations have been previously documented, the role that economic, social, and cultural circumstances play in these groups has been neglected or based on unexamined assumptions (40, 41). We find that for populations that have been coerced or restricted to small, isolated geographical areas, the protective effect of ethnic culture reverses to produce high suicide rates among that cultural group. It may be that isolation intensifies social contagion processes, that the insular culture of communities with historical trauma reverses the traditionally protective effect of ethnic cultures, or that a concentrated environment of deprivation predisposes individuals to suicide (42–44).

These seemingly conflicting findings on connectedness fit more easily with classic sociological and more recent social network-based theories of suicide (3, 45). Connectedness is not always a mechanism of protection from suicide. Sociology's dominant theory of suicide, developed by Emile Durkheim over a 100 y ago, anticipated extreme conditions of connectedness where too insular ties are just as deadly as too few ties. These circumstances create cultures that may inflate the beliefs of the group, whether in line with or against the dominant culture, to such a degree that the individual life has little value. Especially when isolation is also present, they can facilitate social contagion processes (41).

Traditional theories fall short in understanding the critical role that social embeddedness (i.e., the individual in social context) plays in the connections between the personal and the public. Under the network principle of homophily (i.e., the tendency for "like to choose like" in social interactions), increasing like-others opens up the potential for social network ties, the social incubator for a community's social integration, social regulation, and cultural belief system (9). In places with a community of like-others, risk factors to suicide can be moderated, to a point. Where there are too few others at risk (e.g., the unemployed in an upper middle-class community), the ability to form or perceive a community of support is impossible. When others share the same fate, the sense of individual failure transforms into structural failure (e.g., the unemployed in a rust-belt community). However, when that sense of despair or fatalism engulfs the community as a whole, the ability to see any future is restricted in isolated and historically stigmatized communities. Trauma is stressful when others do not share the same fate, but it is devastating when all members of the community share the same fate. Power or advantage is not as potent when the profile of an area changes toward those with less power.

Moving explanation in this direction has a certain parsimony. However, it raises additional questions. Why is there a tendency for

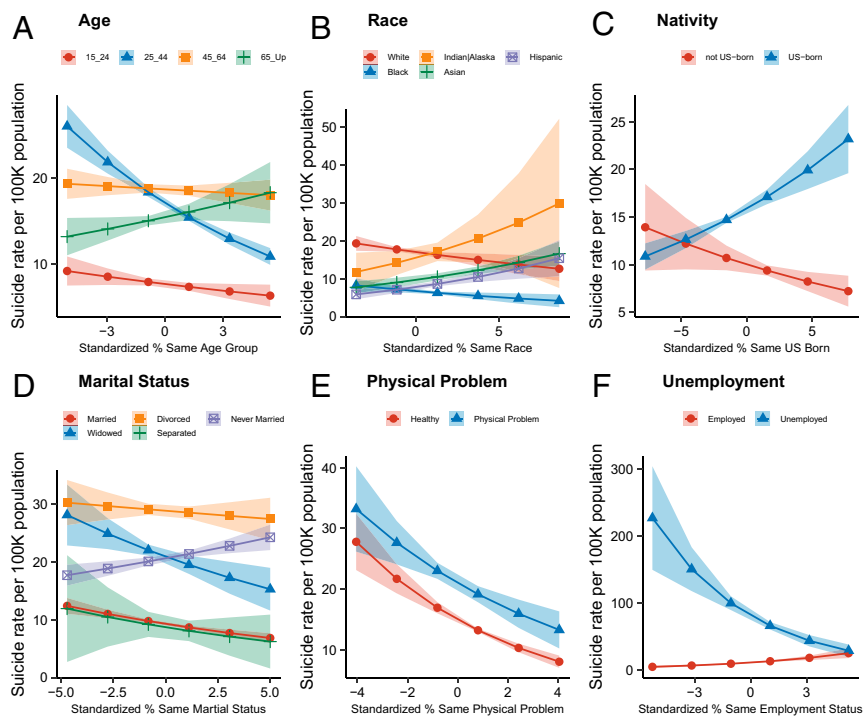


Fig. 3. Cross-level interaction effects of social similarity at the county level. Note. We predict the suicide rate per 100,000 population across different subgroups (A: Age, B: Race, C: Nativity, D: Marital status, E: Physical problem; F: Employment status) across the range of social similarity at county levels. We employ multiple imputation logistic models ($M = 10$) for unemployment and physical problems to account for missingness; otherwise, we use logistic regression models (*SI Appendix, Table S6*).

those in a “favorable” comparison group (e.g., US-born) to have an increased probability of suicide as the at-risk profile of an area changes? In the face of decreased network density among the more powerful groups, are their social ties challenged by the ability to construct networks with sufficient integration and regulation? Such interpretations have been advanced across the sciences. At the cellular level, social interaction among cells is essential for multicellular complexity. Conflict between individual and population-level interests are resolved by novel molecular mechanisms that stabilize cooperation among cells by creating diverse social interaction motifs (46). In social ecology, social space contingencies allow social systems to organize and structure themselves into local clusters of consensus in attitudes, values, and practices (47).

Between physical and psychological space is social space, defined by association with those with whom individuals come into contact. However, we know little about the effect of cross-level demographic similarity on human behavior, in part because early social theory linked population density to social pathology and disadvantages in simple ways, became paralyzed by conflicting findings, and fell out of favor (48). Recent work has begun to conceptualize more complex nonlinearities of spatial interdependence (49). Hamilton’s (50) early rule that cellular behavior cooperation can evolve if individual units favor other related individuals parallels Newman and Park’s (51) view that human networks are characterized by nontrivial clustering (i.e., network transitivity) and positive correlations (i.e., assortative mixing) whenever groups differ in size.

Our findings have clear limitations and are suggestive. The data are not dynamic, limiting causal inference. The data we do have are limited primarily to sociodemographic characteristics, less powerful compared to the network structures and cultures that they proxy. Our findings do point to the importance of a multilevel understanding and assembling relevant data from databases that are statistically representative of populations. In our case, the importance of both the ACS and the NVDRS cannot be

overstated, particularly given the absence of national data registries. Even as we move toward electronic health data, only about 45% of individuals who die by suicide visit the health care system in the months before their death (52). Population-based data are essential to scientific progress and building the scientific foundation for personalized medicine. Finally, we cannot conclude that these findings are representative of US suicides since data required for our analyses come from earlier phases of the NVDRS program. However, there are no clear biases in terms of region, wealth, or suicide rates among the set we use.

Despite these limitations, these findings suggest potential new directions for social and medical responses to suicide. Traditionally, suicide is considered a psychological problem and individual-based manualized treatments are the gold standard. However, there is increasing tension between manual-based interventions and broader notions of precision or personalized medicine (53). While manualized treatments have been shown to improve client outcomes and promote replicability on average, there is an increasingly recognized need to tailor efforts to the individual. However, there are few guides for adapting empirically supported, manualized prevention and intervention programs. The ones that do so tend to target sociodemographic populations such as age or race/ethnicity. Our results suggest that an unconsidered factor in such adaptations is geographic context. Our results, for example, suggest that a treatment plan for medical, psychological, and psychiatric intervention should look very different for those at risk for suicide because of unemployment depending on the employment profile of where they live. It is a one thing to be unemployed in Dekalb County, Georgia, where unemployment is high (and the suicide rate low), compared to Bleckley County, Georgia, where unemployment is low (and the suicide risk high). Even for prevention efforts, a recent report on mental illness and stigma from the National Academies of Sciences, Engineering, and Medicine (54) concluded that prevention only at the individual level can be limiting or even counterproductive. Considering an individual’s

risk factors in light of the community social environment becomes an essential ingredient in developing intervention and prevention strategies under a personalized model of care and concern.

Data Availability. The ACS PUMS data are available via the US Census Bureau's ACS website (<https://www.census.gov/programs-surveys/acs/data/pums.html>), the FTP site (<https://www2.census.gov/programs-surveys/acs/data/pums/>), and IPUMS USA (<https://usa.ipums.org/usa/>). NVDRS data are restricted and require application to the CDC and an approved project-specific Data Use Agreement (<https://www.cdc.gov/violenceprevention/datasources/nvdrs/datapublications.html>). The longitudinal RCMS data are available at <http://www.thearda.com/Archive/Files/Descriptions/RCMSMGCY.asp>. The county-puma link files are downloaded from MABLE Geocorr 2014 (<http://mcdc.missouri.edu/applications/geocorr2014.html>). Other county-level data sets (i.e., population count, in-and-out migration rate, land area size, poverty) are obtained from the following US census website: land area (<https://www.census.gov/library/publications/2011/compendia/usa-counties-2011.html>),

poverty (<https://www.census.gov/data/developers/data-sets/Poverty-Statistics.html>), migration rate (<https://www.census.gov/topics/population/migration/guidance/county-to-county-migration-flows.html>), and population count (<https://www2.census.gov/programs-surveys/popest/datasets/2010-2019/counties/totals/>, <https://www2.census.gov/programs-surveys/popest/datasets/2000-2010/intercensal/county-co-est00int-tot.csv>). Replication code and all other publicly available data can be accessed at <https://dataverse.harvard.edu/dataverse/bk> (<https://doi.org/10.7910/DVN/351V23>).

ACKNOWLEDGMENTS. We acknowledge funding from the National Institute of Mental Health (Grant 5R01MH099436) and the Indiana University College of Arts and Sciences to the Indiana Consortium for Mental Health Services Research. We thank Alex Capshew, David Boulifard, Brian Aronson, and Sam Harbison for their contributions on various phases of this project and Peter Bearman for comments. We also thank Dawn McDaniel, Emiko Petrosky, and the NVDRS team at the Centers for Disease Control and Prevention for their assistance in obtaining the data. Finally, we thank Bethany Deeds, National Institute of Drug Abuse, for believing in the potential of this project to improve the health of Americans.

- Centers for Disease Control and Prevention, "WISQARS Leading Causes of Death Reports, 1981–2018" (2020). <https://webappa.cdc.gov/sasweb/nipc/leadcause.html>. Accessed 12 February 2020.
- A. Case, A. Deaton, Rising morbidity and mortality in midlife among white non-Hispanic Americans in the 21st century. *Proc. Natl. Acad. Sci. U.S.A.* **112**, 15078–15083 (2015).
- Institute of Medicine, *Reducing Suicide: A National Imperative*, (National Academies Press, Washington, D.C., 2002).
- J. C. Franklin *et al.*, Risk factors for suicidal thoughts and behaviors: A meta-analysis of 50 years of research. *Psychol. Bull.* **143**, 187–232 (2017).
- D. M. Stone *et al.*, *Preventing Suicide: A Technical Package of Policies, Programs, and Practices*, (National Center for Injury Prevention and Control, Centers for Disease Control and Prevention, Atlanta, GA, 2017).
- US Department of Health and Human Services, *National Strategy for Suicide Prevention: Goals and Objectives for Action*, (US Department of Health and Human Services, Rockville, MD, 2001).
- G. Turecki *et al.*, Suicide and suicide risk. *Nat. Rev. Dis. Primers* **5**, 74 (2019).
- M. Wray, C. Colen, B. A. Pescosolido, The sociology of suicide. *Annu. Rev. Sociol.* **37**, 505–528 (2011).
- B. A. Pescosolido, "Bringing Durkheim into the 21st century: A social network approach to unresolved issues in the study of suicide" in *Emile Durkheim: Le Suicide–100 Years Later*, D. Lester, Ed. (The Charles Press, Philadelphia, 1994), pp. 264–295.
- T. Matthews *et al.*, Loneliness and neighborhood characteristics: A multi-informant, nationally representative study of young adults. *Psychol. Sci.* **30**, 765–775 (2019).
- L. F. Berkman, T. Glass, I. Brissette, T. E. Seeman, From social integration to health: Durkheim in the new millennium. *Soc. Sci. Med.* **51**, 843–857 (2000).
- J. T. Denney, T. Wadsworth, R. G. Rogers, F. C. Pampel, Suicide in the city: Do characteristics of place really influence risk? *Soc. Sci. Q.* **96**, 313–329 (2015).
- S. Stryker, *Symbolic Interactionism*, (Benjamin/Cummings, Menlo Park, CA, 1980).
- E. Durkheim, *Suicide*, (Free Press, New York, 1951).
- D. A. Luke, K. A. Stamatakis, Systems science methods in public health: Dynamics, networks, and agents. *Annu. Rev. Public Health* **33**, 357–376 (2012).
- L. Festinger, A theory of social comparison processes. *Hum. Relat.* **7**, 117 (1954).
- B. A. Pescosolido, The social context of religious integration and suicide: Pursuing the network explanation. *Sociol. Q.* **31**, 337–357 (1990).
- S. Feld, B. Grofman, "Homophily and the focused organization of ties" in *The Oxford Handbook of Analytical Sociology*, P. Hedström, P. Bearman, Eds. (Oxford University Press, Oxford, UK, 2009), pp. 521–543.
- J. A. Smith, M. McPherson, L. Smith-Lovin, Social distance in the United States: Sex, race, religion, age, and education homophily among confidants, 1985 to 2004. *Am. Sociol. Rev.* **79**, 432–456 (2014).
- C. W. Mills, *The Sociological Imagination*, (Oxford University Press, London, 1959).
- P. S. Bearman, The social structure of suicide. *Sociol. Forum* **6**, 501–524 (1991).
- M. McPherson, L. Smith-Lovin, J. M. Cook, Birds of a feather: Homophily in social networks. *Annu. Rev. Sociol.* **27**, 415–444 (2001).
- National Institute of Mental Health Information Resource Center, Suicide n.d. <https://www.nimh.nih.gov/health/statistics/suicide.shtml>. Accessed 30 March 2020.
- P. S. Bearman, J. Moody, Suicide and friendships among American adolescents. *Am. J. Public Health* **94**, 89–95 (2004).
- F. Van Tubergen, M. Grotenhuis, W. Ultee, Denomination, religious context, and suicide: Neo-Durkheimian multilevel explanations tested with individual and contextual data. *Am. J. Sociol.* **111**, 797–823 (2005).
- S. Zammit *et al.*, Individual- and area-level influence on suicide risk: A multilevel longitudinal study of Swedish schoolchildren. *Psychol. Med.* **44**, 267–277 (2014).
- A. V. Diez-Roux *et al.*, Neighborhood environments and coronary heart disease: A multilevel analysis. *Am. J. Epidemiol.* **146**, 48–63 (1997).
- The Missouri Census Data Center, Geocorr 2014: Geographic correspondence engine (University of Missouri, Office of Social and Economic Data Analysis, 2016).
- US Census Bureau, USA counties (2011). <https://www.census.gov/library/publications/2011/compendia/usa-counties-2011.html>. Accessed 12 February 2020.
- R. Bacon, R. Finke, D. Jones, Merging the religious congregations and membership studies: A data file for documenting American religious change. *Rev. Relig. Res.* **60**, 403–422 (2018).
- B. Steensland *et al.*, The measure of American religion: Toward improving the state of the art. *Soc. Forces* **79**, 291–318 (2000).
- S. van Buuren, K. Groothuis-Oudshoorn, *mice*: Multivariate imputation by chained equations in R. *J. Stat. Softw.* **1**, 2011 (2011).
- T. D. Mize, Best practices for estimating, interpreting, and presenting nonlinear interaction effects. *Sociol. Sci.* **6**, 81–117 (2019).
- A. V. Diez-Roux, Bringing context back into epidemiology: Variables and fallacies in multilevel analysis. *Am. J. Public Health* **88**, 216–222 (1998).
- D. L. Steelesmith *et al.*, Contextual factors associated with county-level suicide rates in the United States, 1999 to 2016. *JAMA Netw Open.* **2**, e1910936 (2019).
- U. Hegerl, L. Wittenburg, European Alliance Against Depression Consortium, Focus on mental health care reforms in Europe: The European Alliance against Depression: A multilevel approach to the prevention of suicidal behavior. *Psychiatr. Serv.* **60**, 596–599 (2009).
- E. Ostrom, *Governing the Commons: The Evolution of Institutions for Collective Action (Political Economy of Institutions and Decisions)*, (Cambridge University Press, New York, 1990).
- A. C. Gatrell, Complexity theory and geographies of health: A critical assessment. *Soc. Sci. Med.* **60**, 2661–2671 (2005).
- D. Lee, B. Lee, The role of multilayered peer groups in adolescent depression: A distributional approach. *Am. J. Sociol.* **125**, 1513–1558 (2020).
- L. M. Olson, S. Wahab, American Indians and suicide: A neglected area of research. *Trauma Violence Abuse* **7**, 19–33 (2006).
- L. M. Wexler, J. P. Gone, Culturally responsive suicide prevention in indigenous communities: Unexamined assumptions and new possibilities. *Am. J. Public Health* **102**, 800–806 (2012).
- S. M. Manson, J. H. Shore, J. Bloom, "The depressive experience in American Indian communities: A challenge for psychiatric theory and diagnosis" in *Culture and Depression: Studies in the Anthropological and Cross-Cultural Psychiatry of Affect and Disorder*, A. M. Kleinman, B. Good, Eds. (University of California Press, Berkeley, CA, 1985), pp. 331–368.
- A. S. Mueller, S. Abrutyn, Suicidal disclosures among friends: Using social network data to understand suicide contagion. *J. Health Soc. Behav.* **56**, 131–148 (2015).
- J. Beals *et al.*, Prevalence of major depressive episode in two American Indian reservation populations: Unexpected findings with a structured interview. *Am. J. Psychiatry* **162**, 1713–1722 (2005).
- B. A. Pescosolido, S. Georgianna, Durkheim, suicide, and religion: Toward a network theory of suicide. *Am. Sociol. Rev.* **54**, 33–48 (1989).
- J. B. Xavier, Social interaction in synthetic and natural microbial communities. *Mol. Syst. Biol.* **7**, 483 (2011).
- B. Latane, J. H. Liu, The intersubjective geometry of social space. *J. Commun.* **46**, 26–34 (1996).
- R. J. Sampson, S. W. Raudenbush, Systematic social observation of public spaces: A new look at disorder in urban neighborhoods. *Am. J. Sociol.* **105**, 603–651 (1999).
- L. M. Bettencourt, The origins of scaling in cities. *Science* **340**, 1438–1441 (2013).
- W. D. Hamilton, The genetical evolution of social behaviour. I. *J. Theor. Biol.* **7**, 1–16 (1964).
- M. E. J. Newman, J. Park, Why social networks are different from other types of networks. *Phys. Rev. E Stat. Nonlin. Soft Matter Phys.* **68**, 036122 (2003).
- J. B. Luoma, C. E. Martin, J. L. Pearson, Contact with mental health and primary care providers before suicide: A review of the evidence. *Am. J. Psychiatry* **159**, 909–916 (2002).
- N. E. Goldstein, K. A. Kemp, S. S. Leff, J. E. Lochman, Guidelines for adapting manualized interventions for new target populations: A step-wise approach using anger management as a model. *Clin Psychol (New York)* **19**, 385–401 (2012).
- National Academies of Sciences, Engineering, and Medicine, *Ending Discrimination Against People with Mental and Substance Use Disorders: The Evidence for Stigma Change*, (The National Academies Press, Washington, D.C., 2016).