SOCIAL SCIENCES

Policies to influence perceptions about COVID-19 risk: The case of maps

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Choropleth disease maps are often used to inform the public about the risks posed by coronavirus disease 2019 (COVID-19). In a survey conducted in the U.S. state of Georgia in June 2020, we randomly assigned respondents to view either of two maps. The first map reported county-level COVID case counts; the second displayed case rates per 100,000 people. Respondents who saw case rate maps were less likely to perceive COVID as mostly an urban problem and reported higher levels of concerns about the virus. Case rate maps also increased support for policies aimed at mitigating the spread of the virus, although, for this outcome, the effect was quantitatively small and the maps did not change individuals' self-reported behavior. For several outcomes, the impact of the case rate map was strongest for rural residents and self-identified Republicans, both of whom were less worried about the virus and more skeptical about public health measures to mitigate its spread.

INTRODUCTION

Despite the availability of effective and safe vaccines against coronavirus disease 2019 (COVID-19), a large share of the American population is reluctant to be inoculated. As of 30 November 2021, 59.4% of the U.S. population had been fully vaccinated, according to the Center for Disease Control and Prevention. As a result, the percentage of fully vaccinated individuals remains well below thresholds that public experts deem necessary to reach "herd immunity." At least part of the hesitancy to get vaccinated is driven by the spread of false information about the vaccine, both on social media and among prominent public figures. Since the beginning of the pandemic, several prominent elected officials have publicly cast doubt on the effectiveness and safety of vaccines and the importance of masks and social distancing. Convincing the public about the effectiveness and the safety of vaccines and the importance of precautions, such as masks and social distancing, has thus emerged as one of the most daunting challenge for American policy makers. These issues are not specific to the United States but are shared by most other developed countries. Governments around the world have engaged in massive information campaigns to influence public opinion, but little systematic evidence on the effects of these policies exists, especially in environments where public health information is viewed through the lens of partisan polarization.

Accurate information about the risks of a dangerous virus might be especially important in the early stages of a pandemic, before perceptions and attitudes have had the chance to solidify. This paper examines the role of disease maps—the most common visual tool used by governments and the media to inform, and potentially misinform, the public about the risks associated with a virus as it begins to spread. As first demonstrated by Snow's (1) famous depiction of cholera in London, disease maps are powerful. In a representative sample of 1751 residents of the U.S. state of Georgia that we fielded in June 2020, 67% of respondents reported that they had consulted a choropleth COVID map produced by the Georgia Department of Public Health (DPH). It is likely that the information conveyed by these maps shaped individuals' perceptions about the risks posed by the virus and influenced their behavioral response, including support for and compliance with policies designed to limit the spread of the virus.

For this reason, good map design is important. The choice of the graphical format to communicate risk influences decision-making (2–4). Classic (5–7) and contemporary (8, 9) works by geographers have developed a set of best practices for designing disease maps. Likewise, principles for map-based risk communication have been suggested (10–13). Although maps play a large role in communicating the impact of COVID-19 (14, 15), these design principles are often ignored (16). Poor design choices not only violate cartographic guidelines but also carry the danger of misrepresenting the spread and threat of COVID (17–19).

According to Monmonier (20), every map tells a story, and, sometimes, that story is misleading. This was true of some prominent COVID maps produced by U.S. state governments and updated daily on their web pages as the COVID pandemic was spreading in the spring and summer of 2020. The left-hand column of Fig. 1 reproduces county-level maps of COVID case counts featured on the Georgia DPH COVID dashboard from mid-March to mid-May 2020. County-level maps of case counts convey very little useful information since they are almost indistinguishable from maps of population density. Atlanta-area counties displayed more COVID cases simply because they contain more people. Moreover, using equal intervals to form breaks between color categories, Georgia's mapping approach created the false impression of stasis and urban concentration of the COVID threat, even as the virus was spreading and hospitals were overwhelmed in one of the nation's most severe outbreaks in rural Southwest Georgia.

After experiencing growing criticism from public health experts, the Georgia DPH partially relented. While still featuring the misleading raw case count maps exclusively on its dashboard, it started to include a link to an alternative per capita case map on 12 April 2020 as well. This mapping approach is reproduced in the right-hand column of Fig. 1. These maps allow viewers to better assess the geography of the COVID threat in Georgia on a given day and, for frequent website visitors, its evolution over time.

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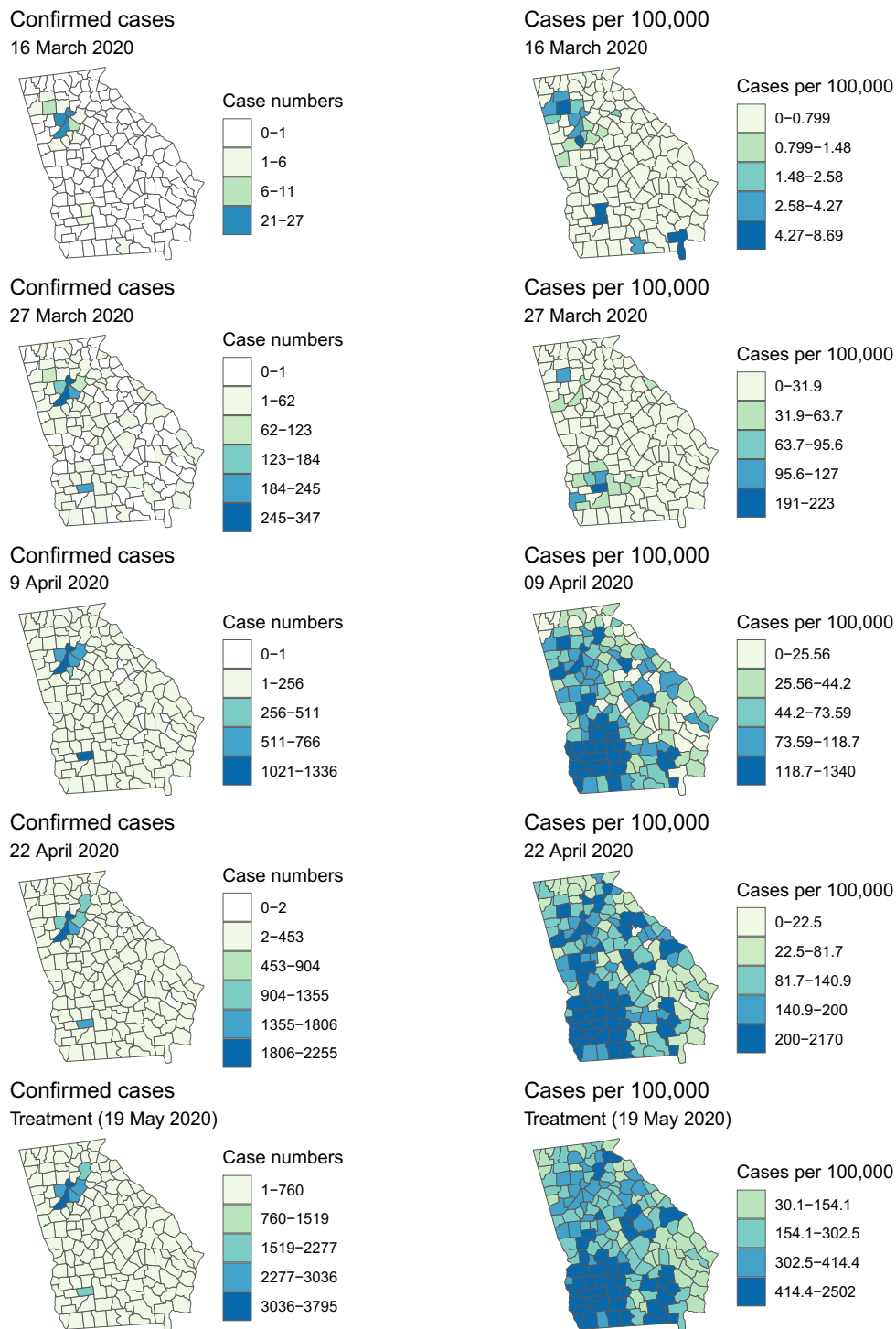
Fig. 1. Maps on the left are county-level case count maps, reproduced as they appeared on the Georgia DPH web page on various dates. Maps on the right are case rate maps constructed using the approach adopted by the DPH beginning on 12 April. The color palettes of the bottom two maps were those used in our study. The maps used in the experiment also included a dot corresponding to each of the following cities (with the city name): Albany, Athens, Atlanta, Augusta, Columbus, Macon, Savannah, and Valdosta.

Here, we study how a different map representation of the same underlying data can shape individuals' risk perceptions and their support for public health measures aimed at containing the virus. We conducted an online survey experiment, administered to a representative sample of Georgia residents between 12 and 19 June 2020.

Respondents were randomly selected to be shown a map using either the raw case count displayed at the bottom left of Fig. 1 or the case rate displayed at the bottom right. The maps viewed by respondents in our sample also included a labeled dot corresponding to each of the following cities (with the city name): Albany, Athens, Atlanta,

Augusta, Columbus, Macon, Savannah, and Valdosta. More than 95% of respondents reported that they either had a "pretty good sense of" or knew "exactly where" their county was located on the map. Respondents were then asked a variety of questions about (i) their understanding of the geography of the virus, (ii) their level of concern about the virus, (iii) appropriate public policy responses, and (iv) appropriate individual behaviors. We examine within-county differences in survey responses between those who saw the raw case count map and those who saw the case rate map.

We contribute to a growing experimental literature aimed at understanding how people interact with and learn from maps. Existing studies use small samples to explore, for example, the impact of different aggregation techniques or break points on map-reading accuracy, (21) or whether some ways of displaying darker and lighter colors are more intuitive to users than others (22). We take this literature in a new direction by randomly assigning actual current disease maps used by public health authorities to a large representative sample in the midst of a pandemic. This approach maximizes both internal and external validity and yields insights about the ways in which seemingly innocuous design decisions might shape perceptions and beliefs about public health. Since all respondents in the experiment were presented with either type of map, our results should be interpreted as the effects of viewing one of two different representations of the same underlying data, conditional on viewing a map in the first place. Given that a large majority of respondents reported consulting choropleth COVID maps, this is the relevant population of interest for policy makers in our context.

This paper demonstrates that the visual display of quantitative geographic information can play a substantial role in altering perceptions and beliefs about public health. This was true even in an environment where attitudes toward the virus were rapidly polarizing along partisan and geographic lines and among subgroups of the population that had already likely been exposed to rhetoric from partisan officials and media personalities urging skepticism about the severity of the virus. We show that a more meaningful visual display of information can cause at least some of the perceptions and beliefs of partisan opponents to converge.

Our study also reveals a gradient in the effects of maps across the outcomes we study. Case rate maps were most effective in reducing the (incorrect) perception of the virus as mostly an urban problem. Likewise, individuals' concerns about the spread of the virus were substantially affected by case rate maps. In both cases, the impact of case rate maps estimated in our work is as large as that of gender and partisanship—two among the most important determinants of perceptions about the virus and attitudes toward policies aimed at containing its spread (23, 24). Case rate maps led to relatively small but statistically significant changes in individuals' policy preferences, with a magnitude about half that of gender or Democratic identification, and had no discernible impact on reported behavior.

Together, our results have important policy implications for the design of future efforts to communicate disease risk to the public. They indicate that public officials should prioritize the provision of information through accurate and meaningful visualizations. However, they might need to combine these with more comprehensive policies, such as information campaigns or economic incentives, if they are to transform individuals' support for public health policies and their willingness to abide by them.

RESULTS
The geography of the virus
In the United States, the COVID-19 pandemic first emerged in large, dense cities such as New York, Detroit, and New Orleans. Images on nightly news featured overrun hospitals and long lines of people seeking testing in large cities. A strong initial perception emerged that the dangers of the virus were limited to dense places that relied on public transportation. However, it subsequently became clear that viral spread was facilitated by large, tightly packed indoor gatherings, such as at bars, concerts, and church services, which are just as likely to occur in rural areas.

During the period when our survey was in the field, the virus was spreading rapidly in rural Georgia, especially in the Southwest of the state, where a large outbreak was traced to a funeral service in the town of Albany. As can be seen in the right-hand column of Fig. 1, cases per 100,000 were higher in much of rural Georgia than in the metro area of Atlanta. However, the Georgia DPH published county-level case count maps that generated the false impression that cases were concentrated in metro Atlanta.

We asked respondents whether the virus was "mostly an urban problem, mostly a rural problem, or both." Among those who were randomly assigned to view a raw case map, 53.2% believed that the virus was either "mostly an urban problem" or "somewhat more urban than rural." Among those who viewed the case rate map, only 44.5% had this belief. These patterns are confirmed in statistical analysis. We estimate probit models (which are commonly used when the outcome is a dummy variable) that control for a number of individual-level covariates and account for any county invariant characteristic through the inclusion of county fixed effects (see the Supplementary Materials for more details).

In models that include county fixed effects, we compare individuals within the same county who were randomly assigned to a different map treatment. We find that the effect of viewing a case rate map (as opposed to a raw case map) is almost 9 percentage points, with a P value below 0.001 (table S3, column 3). Figure 2 demonstrates that case rate maps have a very similar effect for individuals living in Atlanta and those living outside Atlanta. Our results are quantitatively large and comparable to those of gender or Democratic identification, two of the most important drivers of attitudes and behavior about the virus (23–25). Figure S2 presents the magnitudes of our estimated effects (for all outcomes), comparing them with those for partisanship and gender.

Figure 3 plots within-group means (with corresponding 95% confidence intervals) for the probability of considering the virus mostly an urban problem, separately by partisanship of respondents. It reveals a partisan cleavage in perceptions of the virus. Self-identified Republicans were far more likely than Democrats or independents to perceive the virus as an urban problem. However, all three groups were less likely to consider the virus as an urban problem after viewing the case rate maps. Although Republicans remained more likely than both Democrats and independents to view the virus as an urban problem, the perceptions of Republicans moved in the direction of those of Democrats. This pattern has important policy implications. First, it suggests that at least part of the partisan divide in risk perception may be influenced by the sources used by people to gather information. Second, it indicates that providing the public with elucidative displays of information might correct important misperceptions.
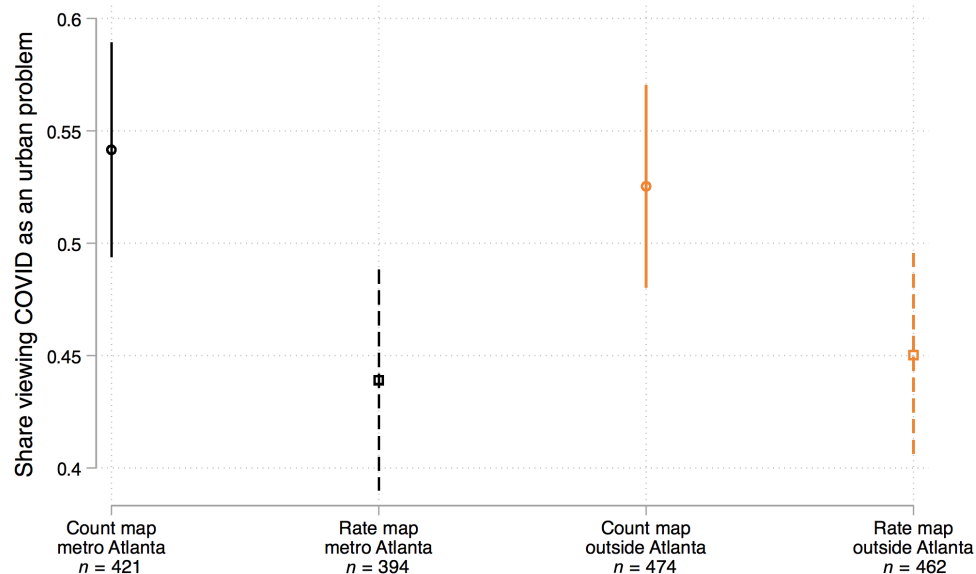
Fig. 2. These are within-group means and 95% confidence intervals for a dummy variable that takes on the value 1 for those reporting that COVID was mostly an urban problem or somewhat more urban than rural.
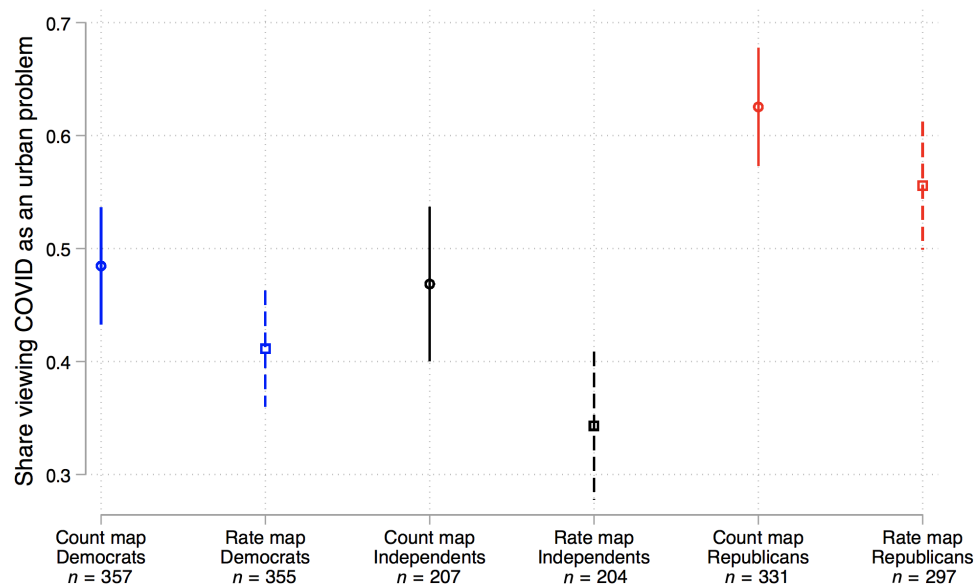
Fig. 3. These are within-group means and 95% confidence intervals for a dummy variable that takes on the value 1 for those reporting that COVID was mostly an urban problem or somewhat more urban than rural.

Concerns about the virus

Next, we examine the impact of the type of data visualization on the level of respondents' concerns about the virus. We asked respondents to use a slider ranging from 1 to 10 to communicate how worried they were about different aspects of the virus. First, we asked questions not specific to the respondent's residential location: How worried are you about the spread of infection in Georgia? How worried are you about the economic impact of the virus? For these questions, we anticipated a higher level of concern among those who saw the case rate map regardless of the individual's residential location.

We then presented respondents with a set of questions for which we anticipated that the treatment effects would be location specific.

We elicited participants' level of concern about becoming infected, about a member of their family, church, or friends becoming infected, and about the spread of the virus in their county. For these questions, we anticipated the treatment effect to be concentrated among respondents living in counties that were presented with the lightest color in the raw case map—that is, counties other than metro Atlanta or Dougherty County (Dougherty County, which is home to Albany, is the only non-Atlanta county that was not in the lowest color category in the DPH case map and hosts only 13 respondents in our sample). In these mostly rural counties, the raw case map conveyed a low case prevalence, but the case rate map told a very different story. For residents of Atlanta and Dougherty County, the two maps do not communicate different levels of local risk, and we do

not expect a treatment effect. On the other hand, we expect to observe a treatment effect among residents of the rest of the state. In addition to geography, we also test for heterogeneous effects by partisanship.

Figure 4 displays group means and 95% confidence intervals for the 10-point scale for each separate question. In table S11, we present results of ordinary least squares (OLS) models in which the map treatment indicators are interacted with indicators for the respondent's region. As anticipated, regardless of geography, relative to the case count map, respondents who saw the case rate map were substantially more worried about the spread of the virus in Georgia. The difference was over one-half of a point on the 10-point scale, both in urban and rural Georgia. This effect is roughly the same as the extent to which women (respectively Democrats) were more worried than men (respectively independents). Those who saw the rate map also reported being more worried about the economy. This effect was substantively smaller, and while statistically significant in the full sample (table S7), it was not statistically significant at conventional levels among some subgroup (tables S12 and S17), which, we suspect, can be explained in part by ceiling effects since more than 80% of respondents classified themselves as a "10" on the worry scale along the economic dimension.

Turning to individual-specific worry about contracting the virus, Fig. 4 reveals that respondents in the areas portrayed with dark colors in both maps—the Atlanta area and Dougherty County—were not

responsive to the map treatment, just as we anticipated. However, among respondents in the remaining nonmetro counties (around half of the sample), where the maps told substantially different stories, those who saw the rate map expressed substantially greater concerns about becoming infected. The effect size among nonmetro respondents—a little under a half a point—is similar if we focus on concerns about friends, family, or church members becoming infected or concerns about the rest of the respondent's county. In all cases, the magnitudes are comparable to those associated with the gap between women and men or between Democrats and independents in our sample.

In the Supplementary Materials, we examine models that interact the regional dummies with the map treatment indicator, including county fixed effects, which absorb any county invariant characteristic and compare the responses of individuals living within the same county but randomly shown a different type of map. Even with this more stringent comparison, our results remain unchanged: The effect of seeing the rate map is comparable to that of gender or partisanship.

The bottom three panels of Fig. 4 demonstrate that pronounced regional differences in concern about the virus could only be discerned among those who saw the misleading case maps. Residents of rural Georgia were substantially less worried about themselves, their social contacts, and their neighbors than metro Atlanta and Dougherty County residents among those who saw only the case
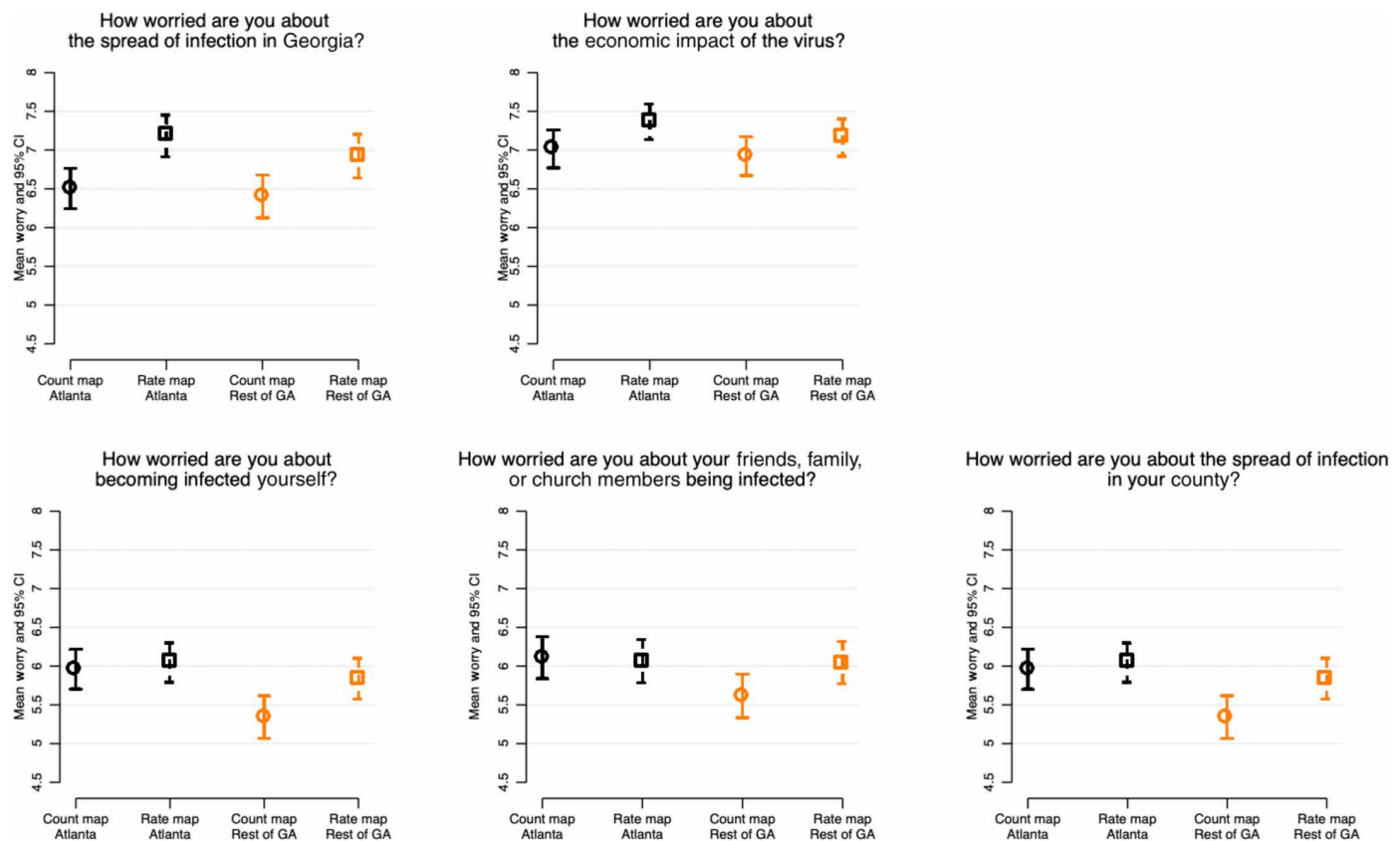
Fig. 4. These are means and 95% confidence intervals for the 1 to 10 scale of self-reported "worry" for those who saw the case map and those who saw the rate map. Respondents from Atlanta and Dougherty County are on the left, and those from the rest of Georgia are on the right. Four hundred and sixty respondents from Dougherty and Atlanta saw the case map, and 436 saw the rate map. For respondents from the rest of Georgia, 435 saw the case map, and 420 saw the rate map.

map. The difference was a little under one-half a point on the 10-point scale and statistically significant (see tables S13 to S15). However, among those who saw the rate map, the level of local-specific concern in nonmetro Georgia, where the virus was spreading rapidly, rose almost to the level of that of residents of Atlanta and Dougherty County, and the difference was not statistically significant at conventional levels in any of our models.

In Fig. 5, we consider the potential for maps to have a differential effect depending on respondents' political preferences. Except for worries about the economy, Republicans and Democrats were, respectively, less and more worried than independents. In line with existing research, partisan differences were large and statistically significant even in models with county fixed effects (23). Despite the partisan divide, when asked about concerns over the spread of the virus in Georgia, respondents who saw the rate map were more worried than those who saw the count map, regardless of their political preference. Although Democrats remained substantially more worried than Republicans about the spread of the virus in the state, the effect of viewing a case rate (rather than a raw case) map was quantitatively very similar for both groups: about 0.6 points. In our regression models, within parties, the overall impact of seeing a case rate map was similar in magnitude to the estimated cross-party difference between independents and Republicans. This pattern highlights the importance of providing the public with accurate and meaningful information.

The bottom three panels of Fig. 5 display results for individual-specific and local concerns. If anything, the map treatment effect is slightly larger for self-identified Republicans. However, we suspect that this pattern may be partly driven by the relative prevalence of Republicans in rural Georgia, where the difference in the information conveyed by the two types of maps was strongest. Confirming this conjecture, when controlling for county fixed effects, the difference in the treatment effect between Democrats and Republicans is not statistically significant. We suspect that the lack of significance in these more stringent models may be due to the low variation we are left with when controlling for county fixed effects. Summing up, Figs. 4 and 5 suggest that by increasing the level of concern about the virus among nonurban Georgia residents, rate maps reduced geographic differences in levels of concern about local infection and perhaps, unexpectedly, they even led to a reduction in partisan differences.

Policy preferences
Next, we examine whether rate maps have the potential to shape respondents' views toward policies aimed to contain the spread of the virus. At the time our study was in the field, Georgia's Republican governor, Brian P. Kemp, had recently implemented a controversial push to make Georgia the first state to open a broad set of businesses, including gyms, restaurants, and tattoo parlors. We asked respondents whether they supported the move to (i) open nonessential businesses
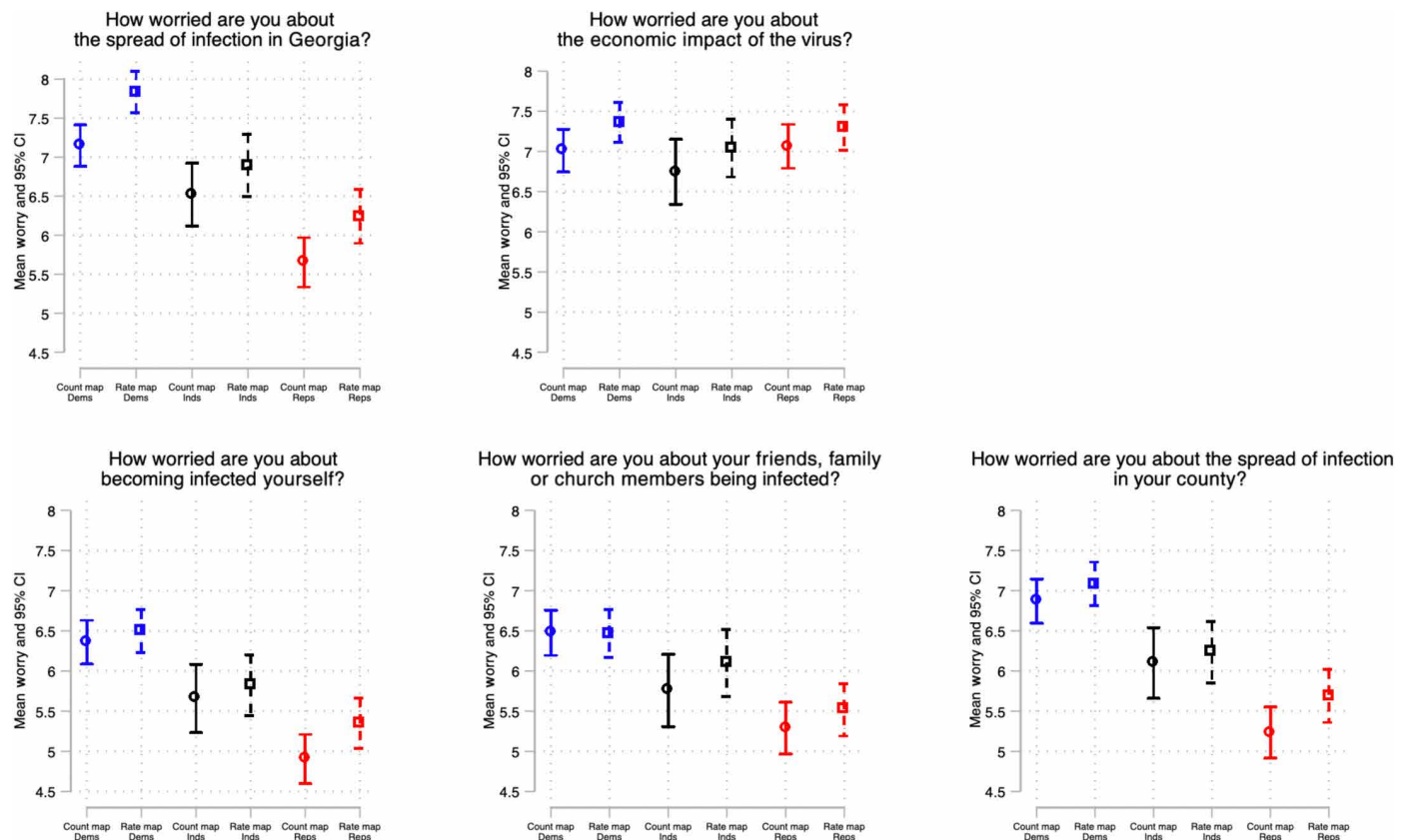
Fig. 5. These are means and 95% confidence intervals for the 1 to 10 scale of self-reported worry for those who saw the case map and those who saw the rate map. Democrats are on the left (blue font), independents are in the middle (black font), and Republicans are on the right (red font). Among Democrats, 357 saw the case map, and 355 saw the rate map. Among independents, 207 saw the case map, and 204 saw the rate map. Among Republicans, 331 saw the case map, and 297 saw the rate map.

and (ii) close those businesses once again if the spread of the virus increased. We also asked them (iii) to consider a trade-off between opening businesses and protecting lives and (iv) whether risks were greater for opening businesses too fast or too slow.

Using factor analysis, we generated an index out of the four items (i) to (iv), with higher values reflecting attitudes in favor of more cautious reopening of businesses. The index has a mean of 0 and an SD of 0.88, with substantial polarization across parties. Democrats and Republicans were 1 SD apart (with means of 0.4 and −0.48, respectively). In the model with county fixed effects, there was a small but statistically significant difference in policy preferences between individuals assigned to the two different map treatments and those who saw the case rate map expressing greater trepidation about Georgia's reopening (table S21). The difference in the overall sample is around $1/10$ of an SD or half of the effect of gender or Democratic identification (fig. S2). These patterns indicate that the effect of maps on policy preferences is substantially smaller than the one estimated above for respondents' perception of the virus as mostly an urban problem (Fig. 2) or their concerns about the spread of the virus (Fig. 4).

We do not find evidence of a difference in the size of the treatment effect on the policy index between metro Atlanta and the rest of the state (table S22), but heterogeneity is evident with respect to partisanship (table S23). As shown in Fig. 6, which displays means and 95% confidence intervals of the policy scale by partisanship, the map treatment effect was driven by Republicans. By moving the policy preferences of Republicans in the direction of independents and Democrats, the rate maps had a subtle depolarizing effect. While a substantial partisan gap remained, the case rate map effect

among Republican respondents is quantitatively meaningful and similar to the difference between men, who favored faster reopening, and women, who favored slower reopening.

The implications of this finding may be particularly relevant at a time when actual or perceived polarization between partisan voters is at historically high levels. While some authors have argued that the overall distribution of ideology in the United States has not changed much since the 1970s (26–28), many others have emphasized that ideological and especially affective polarization between partisans has markedly increased (29–32). Our analysis indicates that simply providing more meaningful information to counteract misperceptions might lead to at least some convergence in views, thereby counteracting polarization. At the same time, our results suggest that policy preferences may be stickier than perceptions or worries and that in an era of political polarization, improvements in the provision of information may not be enough to substantially change individuals' approval of specific policies.

Behavior

Last, we examine whether map design had an impact on respondents' beliefs about appropriate behavior in the face of the virus. We asked them how important it is to wash hands more frequently, reduce contact with family or friends, wear a mask in public, and limit trips to the store. We also asked how willing respondents were to risk their own health by patronizing local businesses. Again, we used factor scores to create an index, which takes on higher values as the individual sees the importance of more cautious behaviors. We found no evidence of a map treatment effect on either the index or on responses to individual questions.
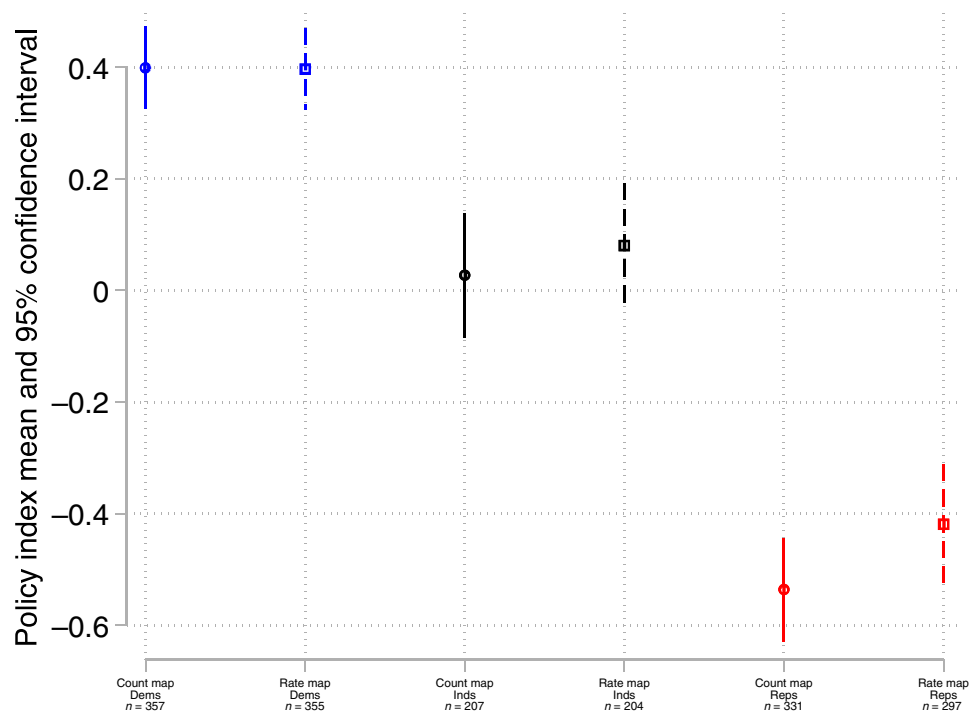
Fig. 6. These are means and 95% confidence intervals for the policy scale among those who saw the case map and those who saw the rate map. Higher numbers are associated with greater skepticism about reopening. Democrats are on the left (blue font), independents are in the middle (black font), and Republicans are on the right (red font).

DISCUSSION

Maps have always played a powerful role in shaping perceptions and understandings of the world, especially when it comes to infectious disease. Given the power in the hands of mapmakers, great care should be taken in making design decisions. Our survey experiment indicates that the choice of data represented on disease maps indeed shapes beliefs about the spatial incidence of disease, the threat of the disease to individuals and communities, and, although to a lesser extent, preferences over policies aimed at combating its spread.

Our study has high external validity, since it was conducted in the midst of a pandemic using actual disease maps that were currently available to study participants. Two in three participants in our study reported that they had consulted the maps created by the Georgia DPH. In the period leading up to our study, the Georgia DPH and local newspapers that published links to or screenshots of its maps featured only the case count maps, which conveyed the message that COVID was an overwhelmingly urban problem, with little change in spatial disease incidence over time. Our study indicates that this likely led individuals outside the Atlanta area to perceive lower levels of threat than would have been the case had DPH published more meaningful case rate maps.

The use of case count maps might also be a subtle facilitator of the extreme political polarization surrounding measures to combat COVID that has occurred in the United States. Well before the pandemic, partisan voting patterns in the United States had come to be highly correlated with population density (33). In the early days of the pandemic, the false impression that COVID was an overwhelmingly urban phenomenon may have led some rural Republican voters to believe that measures to combat the spread of the disease were designed to benefit urban Democrats while limiting rights and imposing economic costs everywhere.

In our sample, Republicans were far less concerned about the public health impact of the virus than Democrats, while both groups were equally concerned about its economic impact. As a result, policy preferences about opening businesses were starkly polarized. Respondents across the party spectrum became more concerned about the spread of the virus when confronted with the case rate maps for risks faced by Georgia as a whole. However, perceptions of individual and local risks as well as the policy preferences of Republicans who saw the case rate map moved slightly in the direction of Democrats, whose policy preferences were instead unaltered by the map treatment.

In summary, better maps might not only convey valuable information to rural residents about the risks of becoming infected but can also help combat geographic and partisan polarization about virus response. At the same time, our study reveals a gradient in the extent to which maps can move people's preferences and behavior. Case rate maps were most effective in reducing the perception of the virus as mostly an urban problem; they were also effective in changing individuals' worries about the spread of the virus. However, maps had a more limited effect on policy preferences and no impact on behavior. This pattern indicates that policy makers may need to combine meaningful visualizations with other, stronger interventions to incentives if they wish to change individuals' acceptance of disease mitigation policies and ultimately behavior.

METHODS

Our survey was fielded through a survey firm called Dynata using the Qualtrics platform and included 1751 Georgia residents, selected to be representative of the Georgia population on age, gender, region, and rural versus urban residence. Our research protocol was approved by the institutional review boards of both Stanford and Harvard University.

We ended up with observations from 109 counties. Respondents were randomly assigned to see either the case map or the rate map. In addition to the simple comparisons of means presented above, we also estimated probit models (when the dependent variable was the binary indicator for perception of COVID as an "urban problem") and OLS models (when the dependent variable was a numerical scale). The key independent variable was a dummy variable that took the value 0 if the respondent viewed the case count map and 1 if she viewed the rate map. As described above, this variable was also interacted with indicators for partisanship and geography to test for heterogeneous effects of the treatment.

We estimated models that included county fixed effects so as to control for county-specific factors that might have affected survey response. Because we did not have within-county balance on possible confounders in many of the smaller counties, we also included a set of control variables, including partisanship (dummy variables for Democrats and Republicans, with independents as the base category), a seven-point scale of self-described left-right ideology, an indicator of whether the respondent described their neighborhood as "urban," age, gender, race, and an indicator for whether the respondent had a family member living in an assisted living facility. We conducted two-tailed t tests of statistical significance. Details of these models are included in the Supplementary Materials.

SUPPLEMENTARY MATERIALS

Supplementary material for this article is available at https://science.org/doi/10.1126/sciadv.abm5106

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