Revisiting Robinson: The perils of individualistic and ecologic fallacy

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Background	W S Robinson made a seminal contribution by demonstrating that correlations for the same two variables can be different at the individual and ecologic level. This study reanalyzes and historically situates Robinson's influential study that laid the foundation for the primacy of analyzing data at only the individual level.
Methods	We applied a binomial multilevel logistic model to analyse variation in illiteracy as enumerated by the 1930 US. Census (the same data as used by Robinson). The outcome was log odds of being illiterate, while predictors were race/nativity ('native whites', 'foreign-born whites' and 'negroes') at the individual-level, and presence of Jim Crow segregation laws for education at the state-level. We conducted historical research to identify the social and scientific context within which Robinson's study was produced and favourably received.
Results	Empirically, the substantial state variations in illiteracy could not be accounted by the states' race/nativity composition. Different approaches to modelling state-effects yielded considerably attenuated associations at the individual-level between illiteracy and race/nativity. Furthermore, state variation in illiteracy was different across the race/nativity groups, with state variation being largest for whites and least for foreign-born whites. Strong effects of Jim Crow education laws on illiteracy were observed with the effect being strongest for blacks. Historically, Robinson's study was consonant with the post-World War II ascendancy of methodological individualism.
Conclusion	Applying a historically informed multilevel perspective to Robinson's profoundly influential study, we demonstrate that meaningful analysis of individual-level relationships requires attention to substantial heterogeneity in state characteristics. The implication is that perils are posed by not only ecological fallacy but also individualistic fallacy. Multilevel thinking, grounded in historical and spatiotemporal context, is thus a necessity, not an option.
Keywords	Black, ecologic fallacy, epidemiologic methods, history of science, illiteracy, Jim Crow, methodological individualism, multilevel, race, social production of science, WS Robinson, United States

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Introduction

It is almost 60 years since WS Robinson showed, in 1950, that differing results could be obtained when the same data set is analysed at individual and aggregate levels.[1] Analysing the 1930 US census, Robinson found a correlation of 0.77 between percent black and percent illiteracy at the state-level, while the correlation between illiteracy and race (black vs rest) at the individual-level was 0.20.[1] He showed an even more striking discrepancy between ecological and individual correlations between illiteracy and nativity (foreign-born vs rest), such that the state-level correlation was negative ($r=-0.53$), while the individual correlation was positive ($r=0.12$).[1] The incongruous empirical correlations at the aggregate- and individual-level led Robinson to conclude that: 'the purpose of this paper will have been accomplished if it prevents the future computation of meaningless correlations and stimulates the study of similar problems with use of meaningful correlation between the properties of individuals' (p. 357).[1] Use of ecological analysis since Robinson has been charged with the methodological crime of 'ecological fallacy', a term coined in 1958 by Selvin,[2] referring to 'the invalid transfer of aggregate results to individuals'.

Although others had made similar observations in the 1930s on the discordance in correlations at different levels,[3,4] Robinson's 1950 paper became the standard reference point for subsequent discussions about the primacy of individual-level data. Attesting to the enduring impact of Robinson's paper, as of June 2008 it has been cited over 1150 times, in articles spanning from the 1950s to the present, and in disciplines ranging from the social sciences to the public health and biomedical sciences.[5] As noted by Firebaugh, a prominent quantitative social scientist[6]:

> It would be difficult to overstate the impact Robinson's article has had on social science research during the second half of the twentieth century. The use of ecological correlations to study individual-level relationships had been commonplace before Robinsons article, and the article sharply curtailed that practice. The article also served to motivate the development of survey research. If aggregate data are not adequate to study individuals, then social scientists need data on individuals. One efficient way to gather data on individuals is to ask them questions. So in this way Robinson's message about the need for individual-level data to study individuals no doubt played a role in the amassing of the large survey data sets that have become standard fare in social science research in the twenty-first century' (p. 4024).

In epidemiology, dire warnings about 'ecological fallacy' have appeared for decades in many widely used epidemiology textbooks (p. 74)[7] (pp. 466–471, p. 480)[8]

(pp. 259–263)[9] (pp. 196–198)[10] (pp. 42, 125–126)[11] (p. 194)[12] (pp. 24, 269)[13] (pp. 204–206)[14] (pp. 18–19)[15] (pp. 12, 13, 18)[16] (pp. 157–158)[17] (pp. 290–296)[18]. Conversely, the issue of 'individualistic fallacy' that Alker identified in 1969,[19] referring to when 'ideologically motivated social scientists try to generalize from individual behavior to collective relationships' (p. 78), and which Susser warned epidemiologists about in 1973 (using the terminology 'atomistic fallacy') (p. 60),[20] has only recently begun to receive attention in epidemiologic textbooks (p. 158)[17] (pp. 296–301)[18] (pp. 62,63, 333–334)[21] (pp. 241–242)[22] (p. 217)[23] (pp. 317–318)[24] (pp. 18–19)[25]. Rejecting Robinson's emphasis on ecologic fallacy and disregard for individualistic fallacy, Alker instead argued that a simultaneous awareness of these two fallacies (generalized through the idea of 'cross-level' fallacies) should lead to a 'natural' interest in multilevel thinking and modelling cross-level processes.

To date, critiques of Robinson's study have largely been technical,[26] like finding statistical conditions when there might be equivalence between aggregate- and individual-level associations,[27–30] or using a multivariable regression approach to reduce specification bias in aggregate models such that there is a greater congruence between individual and ecological associations.[31] For instance, including a measure of availability of educational services in the ecological or aggregate, model yielded estimates of illiteracy rates among groups other than US-born whites, which approached their illiteracy rates based on individual-level data.[31] Langbein and Lichtman[26] argued in terms of the combined effects of misspecification due to an important omitted variable (educational provision which covaries with illiteracy and ethnicity), and grouping (by state, which maximizes the effect of the omitted variable, that is state educational provision). Conversely, Firebaugh, also in 1978, showed that the individual-level relationship between black and illiteracy is subject to as much mis-estimation as the ecological relationship between percent black and percent illiteracy;[30] net of regional differences, and an interaction between region and race, being black raised the probability of being illiterate by only 0.02, thus challenging the significance of the individual relationship. Another line of research, following Robinson's study, has been to discover solutions that approximate individual-level relationship based on the information that bounds them at the aggregate level.[32,33] In summary, a defining characteristic of prior studies is their implicit or explicit acceptance of Robinson's conclusion that the target of inference for research is always and only individuals.

Crucially, none of the prior engagements with Robinson's study heeded Alker's advice to test for cross-level effects,[19] by appropriately using both individual and ecologic data. Using a historically informed multilevel approach, we critically re-examine

Robinson's empirical and substantive conclusions that only individual correlations are 'meaningful'. Specifically, using an explicit multilevel analytical framework,[34–43] we reanalyse the same 1930 US Census data on illiteracy and race/nativity that Robinson used in his study. We newly supplement these data with publicly available state-level data on 1930 state-level policies regarding legally racially segregated education ('Jim Crow' laws), i.e. data that would have been available to Robinson and which have not previously been used in critiques of his work. Motivating these additional analyses are conceptual frameworks concerned with the social and historical context within which individual risk and diseases—and their population levels and distributions—are expressed.[21,44–53] We then take the argument to the next level, by considering the societal context in which Robinson wrote his paper and its reception. To do so, we draw on the eco-social perspective with its explicit attention to accountability and agency of not only who and what drives health inequities, but also of scientists for their theories, methods and assumptions and their real-world impact on population health, disease and well-being.[45,53–57] Accordingly, the specific aims we address are:

(1) Is there state patterning in the individual likelihood of being illiterate once we account for the differential distribution of individual race/nativity by states?
(2) Does the strength of the individual association between being illiterate and race/nativity modify depending upon whether we condition this association on membership of individuals to their respective states?
(3) Does the relationship between illiteracy and race/nativity at the individual level vary by state?
(4) Does adding additional data on 1930 state-level policies regarding legally racially segregated education ('Jim Crow' laws) enhance our understanding of illiteracy variation (overall and by race/nativity)?
(5) Finally, we critique the paradigm of methodological individualism which arguably received considerable fillip as a result of Robinson's work.

Collectively, realizing these aims demonstrates how bringing a multilevel perspective (conceptual and methodological) to Robinson's study highlights the potential fallacies of considering relationships at only one level, including Robinson's claim that individual correlations are 'meaningful' and ecological correlations are 'meaningless'. We show that by bringing a multilevel perspective, we circumvent the problems created by restricting analyses to only one level, and instead open up the possibilities for richer cross-level approaches that enable discerning the relative contribution of different levels to the scientific question of interest. Our aim in this study is not to question the empirical finding of Robinson's investigated,

i.e. ecological correlations cannot be used as substitutes for individual correlations. Rather, using the same data that Robinson had and also extending them, we apply a multilevel perspective to critique the idea of conceptualizing and analysing data at one level by ignoring other important levels.

Methods

For the empirical analyses, we used the same 1930 US census data on illiteracy and race/nativity that Robinson employed (pp. 7, 13, 35, 36).[58] Race/Nativity was categorized by the US Census as: 'white native' (meaning US-born), 'foreign-born white' and 'negro' (with no distinction between 'negroes' born in vs outside the USA). We note that we use the terminology 'negro' when referring to Robinson's data, and otherwise use the term 'black' to describe this population. Illiteracy in the US Census was defined as the inability to read and write for those aged 10 years and over (pp. 35, 36).[58] We have shown elsewhere how aggregate routine census data can readily be adapted to a multilevel data structure.[59,60] We specified a two-level structure of 147 'cells' at level-1, representing three groups based on their race/nativity, nested within 49 states at level-2. The cell contains the counts of people who are illiterate (numerator) together with the total number of people (denominator) in a particular cell. The proportion of illiterates was the response variable, while the cell characteristic (race/nativity) was the individual predictor variable. Illiteracy proportion (p) in each cell i in state j was modelled using a two-level binomial logistic model, with allowances made for the varying denominators.[34]

We first estimated a single-level logistic model assuming a binomial error distribution for the response, p_{ij}, as: logit $(\pi_{ij}) = \beta_0 + \beta(B_{ij}) + \beta(FBW_{ij})$ (Model 1), where p_{ij} is the underlying propensity for illiteracy for group i in state j, and what is being modelled is the log odds of p_{ij}. The parameter β_0 represents the log odds of being illiterate for native whites (the reference category), while parameters $\beta(B_{ij})$ and $\beta(FBW_{ij})$ represent the differentials in the log odds of being illiterate for blacks and foreign-born whites (FBW), respectively. This model effectively replicates Robinson's individual-level association. We then extended the single-level Model 1 to include fixed effects for different states (i.e. states were specified as categorical predictors as opposed to levels) as: logit$(\pi_{ij}) = \beta_0 + \beta(B_{ij}) + \beta(FBW_{ij}) + \beta(State_j)$ (Model 2). A comparison of the effect size associated with $\beta(B_{ij})$ and $\beta(FBW_{ij})$ between Models 1 and 2, meanwhile, assesses the extent to which individual race/nativity effects alter when conditioned on states (β (State$_j$)) (Aim 2). We then estimated a model that specified states as random effects as opposed to fixed effects: logit$(\pi_{ij}) = \beta_0 + \beta(B_{ij}) + \beta(FBW_{ij}) + u_{0j}$ (Model 3). The state random effects (u_{0j}) are assumed to be normally distributed with variance σ_{u0}^2 quantifying

the between-state variation in the log odds of being illiterate, conditional on individual race/nativity. The magnitude and precision associated with σ_{u0}^2 enables us to address Aim (1).

Aim 3 was realized by specifying a random coefficients model with race/nativity effects allowed to vary across states as: $\mathrm{logit}(\pi_{ij}) = \beta_0 + \beta(\mathrm{B}_{ij}) + \beta(\mathrm{FBW}_{ij}) + u_j(\mathrm{NW}_{ij}) + u_j(\mathrm{B}_{ij}) + u_j(\mathrm{FBW}_{ij})$ (Model 4). Assuming a joint multivariate normal distribution, the random effects will have the variance–covariance structure:

$$\Omega_u \sim \mathrm{N}(0, \begin{bmatrix} \sigma_{u\mathrm{NW}}^2 & & \\ \sigma_{u\mathrm{NW}u\mathrm{B}} & \sigma_{u\mathrm{B}}^2 & \\ \sigma_{u\mathrm{NW}u\mathrm{FBW}} & \sigma_{u\mathrm{B}u\mathrm{FBW}} & \sigma_{u\mathrm{FBW}}^2 \end{bmatrix})$$

This model provides a test whether the state variation is different for the three groups, such that $\sigma_{u\mathrm{NW}}^2$ estimates the between-state variation in illiteracy for native whites; while the between-state variation in illiteracy for blacks and foreign-born whites is given by $\sigma_{u\mathrm{B}}^2$, and $\sigma_{u\mathrm{FBW}}^2$, respectively.[41,59,61] We also assess the geography of illiteracy by race/nativity by plotting the state-specific residuals in illiteracy for the three groups based on Model 4.[59]

Two models were estimated to realize Aim (4): $\mathrm{logit}(\pi_{ij}) = \beta_0 + \beta(\mathrm{B}_{ij}) + \beta(\mathrm{FBW}_{ij}) + \beta(\mathrm{JC}_j) + u_j(\mathrm{NW}_{ij}) + u_j(\mathrm{B}_{ij}) + u_j(\mathrm{FBW}_{ij})$ (Model 5).

We estimate the effect of Jim Crow education laws (JC) (a state-level indicator variable: $1 = \mathrm{JC}$ states, $0 = $ otherwise; see Appendix 1 for the list of JC and non-JC states),[62] $\beta(\mathrm{JC}_j)$, over and above the effects of race/nativity, and in Model 6 we specify a combined effect of belonging to a particular race/nativity and being in a JC state of the following form: $\log \mathrm{it}(\pi_{ij}) = \beta_0 + \beta(\mathrm{WJC}_{ij}) + \beta(\mathrm{BNJC}_{ij}) + \beta(\mathrm{BJC}_{ij}) + \beta(\mathrm{FBWNJC}_{ij}) + \beta(\mathrm{FBWJC}_{ij}) + u_j(\mathrm{NW}_{ij}) + u_j(\mathrm{B}_{ij}) + u_j(\mathrm{FBW}_{ij})$ which allows an assessment if Jim Crow states affected different groups differentially. We also specified the above model with main effects for race/nativity and JC and an interaction, and found the interaction effects to be highly significant. We present the above specification for ease of interpretation.

We also tested the association between state per capita expenditure for public elementary and secondary schools (p. 116),[58] and illiteracy substantiating what had been either postulated before,[26,30] or tested using an ecologic/aggregate model.[31]

The above models were fitted using Bayesian estimation procedures as implemented via Monte Carlo Markov Chain (MCMC) methods using Metropolis-Hastings algorithm in *MLwiN 2.1* software.[63] Bayesian estimation procedure was used for two reasons. First, it is known that estimates of random effects in binomial models using maximum-likelihood procedures tend to be biased.[64] Second, we needed a measure so that we can compare the relative effectiveness of different models in accounting for the variations in illiteracy. Such an overall goodness-of-fit of the models is the Deviance Information

Criterion (DIC) coefficient,[65,66] which is a by-product of the MCMC procedure. The DIC statistic is a combination of the fit to the data and complexity. The 'badness of fit' is determined by the deviance statistic while complexity is a function of the number of degrees of freedom consumed by the model. A model with many parameters will provide a very good fit to the data, but will have fewer degrees of freedom and be of limited utility. As the DIC statistic accounts for the number of parameters in any model, a larger DIC suggests a worse performance. A small difference in DIC between models indicates that they are empirically equivalent. This balanced approach discourages over-fitting. The DIC statistic is a generalization of the Akaike Information Criterion (AIC), for which general rules of thumb have been developed such that a difference of less than 2 between models suggests essentially no difference between models; while differences greater than 10 suggest substantial support for the model with the smaller value.[67]

The basic principle of the MCMC approach is to simulate values and to use empirical summaries of these simulated values to describe the distribution.[68] There are two stages to the simulation. The first is an initial 'burn-in', which if the simulation is run long enough, will find its way to equilibrium of the correct distribution. Once this convergence has been achieved, these simulations must be discarded, as they will contain biased estimates possibly far away from the correct distribution. In the second stage, further simulations form a 'random tour'. Summarizing these simulations provides a description of the estimate and its distribution. Then length of run determines the quality of estimate, longer runs giving increased precision, once convergence has been achieved. Here we used the MLwiN 2.1 software to obtain maximum-likelihood estimates for starting values of the distribution, then 500 simulations as discarded 'burn-in', then 50 000 further simulations to get the distribution of interest. We used default diffuse priors, meaning that we did not favour a priori any particular values of the estimates. The results are based on the mean of the simulated values, and the standard error is the standard deviation of the simulated distribution. For ease of interpretation, we present these results as odds ratios (ORs) or predicted probabilities along with 95% credible intervals (CIs).

Results

Table 1 shows the distribution of US population in 1930 by race/nativity along with the number and percent illiteracy in each group. It should be noted that Robinson presented correlations based on either nativity (i.e. native whites and negroes vs foreign-born whites) or race (i.e. native and foreign-born whites vs negroes), which is misleading, given the marked differences in illiteracy levels between natives and foreign-born whites, as well as between native

whites and blacks. Blacks had the highest levels of illiteracy (16.2%) followed by foreign-born whites (9.8%) and native whites (1.4%).

Table 2 shows the effect of being black or foreign-born white on the odds of being illiterate, under different model assumptions about the effects of state. When we ignore the state context (Model 1, Table 2), compared with native whites, blacks were almost 12 times, and foreign-born whites were more than seven times, more likely to be illiterate. Conditioning this association on the fixed effects of states substantially altered the magnitude of the ORs of being illiterate for the two groups, and also changed the pattern, with foreign-born whites now being the group with the highest risk for illiteracy (Model 2, Table 2). These results are similar when we consider states as random effects, as opposed to fixed effects (Model 3, Table 2). When account is taken of the state-level variation in the relationship between race/nativity and illiteracy, the pattern changed yet again (Model 4, Table 2). It should be noted that the race/nativity coefficients between Models 1or 2 cannot be compared with Models 3 or 4, because the latter models do not

have marginal interpretation and were estimated with the explicit purpose of modeling state variation,[69] rather than considering state variation as a nuisance.

Table 2 also gives the DIC values for the four models and the change in this value from model to model. Introduction of state effects [either via fixed (Model 2) or random (Model 3)] to Model 1 (the regression equivalent of Robinson's individual correlation) results in a very substantial reduction in the DIC statistic, indicating that a great deal of the variation in illiteracy between individuals can be attributed to states, conditional on race/nativity. The DIC statistic did not change depending upon whether states are specified as fixed or random effects. Introducing random coefficients for race/nativity (Model 4) reduce the DIC statistic dramatically, indicating that allowing the individual relationship between race/nativity and illiteracy to vary across states leads to a substantially improved fit to the data.

Figure 1 presents the between-state variation in the log odds of being illiterate under three model specifications. We compared the magnitude of state variation before (Null, Figure 1) and after (Model 3, Figure 1) accounting for the states' differential race/nativity composition. The results indicate that state's race/nativity composition did not account, whatsoever, for the state variation in illiteracy. Furthermore, the extent of state variation substantially differed by race/nativity (Model 4, Figure 1). State variation was greatest for native whites, followed by blacks, while for foreign-born whites it was the least.

Figure 2 maps the state-specific residuals (from Model 4), expressed as the odds of being illiterate for native whites, foreign-born whites and blacks across different states, conditional on the effects of race/nativity in the fixed part (see Appendix 1 for state labels). First, there is substantial variation in the odds of being illiterate by states with the variation being greatest for native whites (OR range: 0.15–6.39) followed by blacks (OR range: 0.24–4.87) and least for foreign-born whites (OR range: 0.41–3.28) suggesting substantial state effects. With the exception of Vermont and Maryland (for native whites) and

Table 1 Distribution and percent illiteracy by race/nativity in the United States, 1930 (for the population 10 years old and over)

	Illiterate N (%)	Total N
Native White	1 103 134 (1.48)	74 773 962
Foreign Born White	1 304 084 (9.85)	13 233 609
Black	1 513 892 (16.27)	9 302 988
Robinson's grouping		
Nativity		
Native (White and Black)	2 617 026 (3.11)	84 076 950
Foreign Born Whites	1 304 084 (9.85)	13 233 609
Race		
White (Native and Foreign Born)	2 407 218 (2.74)	88 007 571
Black	1 513 892 (16.27)	9 302 988

Table 2 Odds ratios (OR) and 95% Credible Interval (CI) for illiteracy by race/nativity under different model conditions, along with the DIC for the different models

	Model 1		Model 2		Model 3		Model 4	
	OR	(95% CI)	OR	(95% CI)	OR	(95% CI)	OR	(95% CI)
Native White (Reference)	1		1		1		1	
Foreign Born White	7.31	(7.29–7.33)	13.63	(13.58–13.67)	13.63	(13.58–13.67)	5.71	(5.18–6.29)
Black	11.66	(11.63–11.69)	5.86	(5.84–5.88)	5.86	(5.84–5.88)	5.95	(5.42–6.53)
DIC	1 862 752.2		264 904.17		264 904.27		2223.12	
Differences in DIC	–		1 597 848		−0.10		262 681.15	

Note: Model 1: Single-level model with race/nativity fixed effects; Model 2: Model 1 + state fixed effects; Model 3: Two-level model with race/nativity fixed effects and state random effects; Model 4: Model 3 + random coefficients for race/nativity.
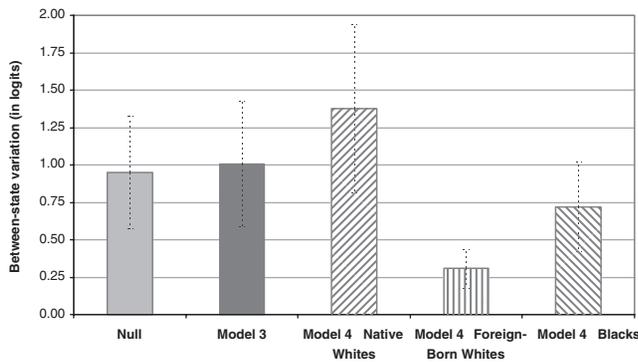
Figure 1 Between-state variation in illiteracy (in logits) along with 95% credible intervals under different model specifications. Null, Two-level model with state random effects but without fixed effects of race/nativity; Model 3, Two-level model with race/nativity fixed effects and state random effects; Model 4, Model 3 + random coefficients for race/nativity
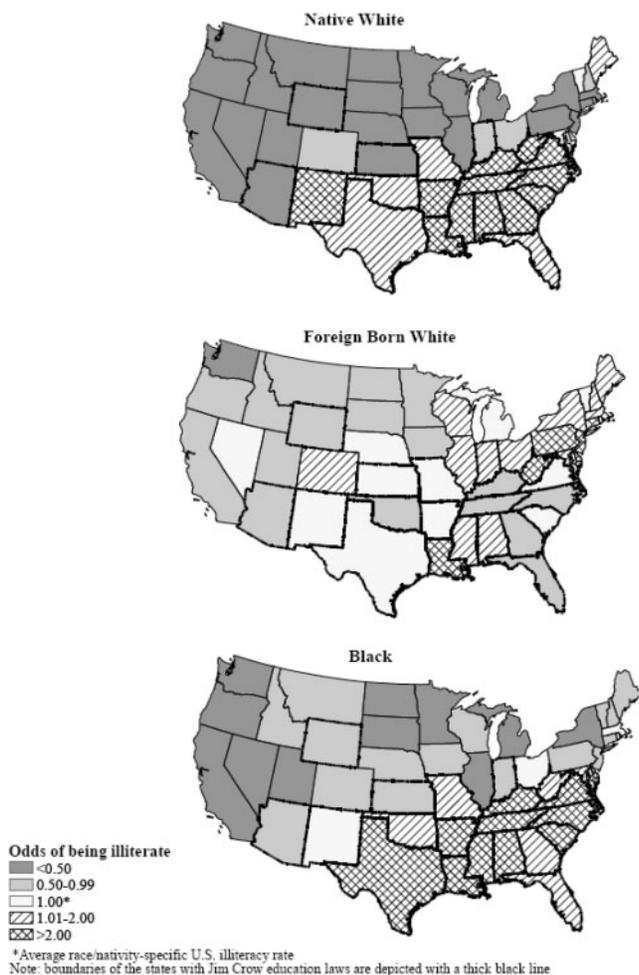

Figure 2 State-specific residuals (from Model 4), expressed as the odds of being illiterate for the native whites, foreign-born whites and blacks across different states, conditional on the effects of race/nativity in the fixed part, using the 1930 US Census data

Vermont, New Mexico, Ohio and Rhode Island (for blacks), which were not significantly different from the US average odds of being illiterate for native whites and blacks, respectively, the remaining states had a significantly higher or lower odds of being illiterate compared to the US average for the respective groups. The top five states that had significantly lower odds of being illiterate for native whites were Nevada, District of Columbia, California, Oregon and Washington and for blacks it was Nevada, Minnesota, South Dakota, New York and Oregon. Meanwhile the bottom five states that significantly increased the odds of being illiterate for native whites were New Mexico, Louisiana, Kentucky, North Carolina and Tennessee, and for blacks it was South Carolina, Alabama, Louisiana, Mississippi and North Carolina. There was no close correspondence, thus, between the geographies of illiteracy for native whites and blacks and even less of a correspondence for foreign-born whites.

There was a strong effect of Jim Crow laws (a state-level attribute) on the individual odds of being illiterate (OR = 1.92, 95% CI = 1.81–2.03), controlling for individual-level race/nativity. Furthermore, there was an interaction effect between race/nativity and JC states (Figure 3a). Compared to native whites residing in non-JC states, blacks in JC states were almost 30 times, and blacks in non-JC states were seven times more likely to be illiterate; additionally, whites in JC states were seven times more likely to be illiterate compared to their counterparts in non-JC states. In Figure 3b, we plot the predicted probability of being illiterate. JC laws clearly had substantially greater effect on blacks; for instance the predicted probability for blacks in non-JC states and JC states was 0.04 (95% CI = 0.033–0.049) and 0.132 (95% CI = 0.123–0.141), respectively. Meanwhile, the predicted probability for whites in non-JC states and JC states was practically 0 [0.005, 95% CI (0.004–0.006)] and 0.029 (95% CI = 0.027–0.031), respectively. For foreign-born whites, JC laws had no additional negative effect. Not only do JC states have higher probability of being illiterate for native whites and blacks, but the differentials are also greater. While state-variation in illiteracy by race/nativity remained, even after accounting for the presence of JC laws, it was substantially reduced, by 70% for native whites and blacks (Figure 4). The effect of JC laws on illiteracy (and its interaction with being black) did not alter when we additionally conditioned on state per capita expenditure for public elementary and secondary schools and state per capita net income (data not shown).

Discussion

Using a historically informed multilevel perspective, we reanalysed the same data set that Robinson used and report four major findings. First, there were
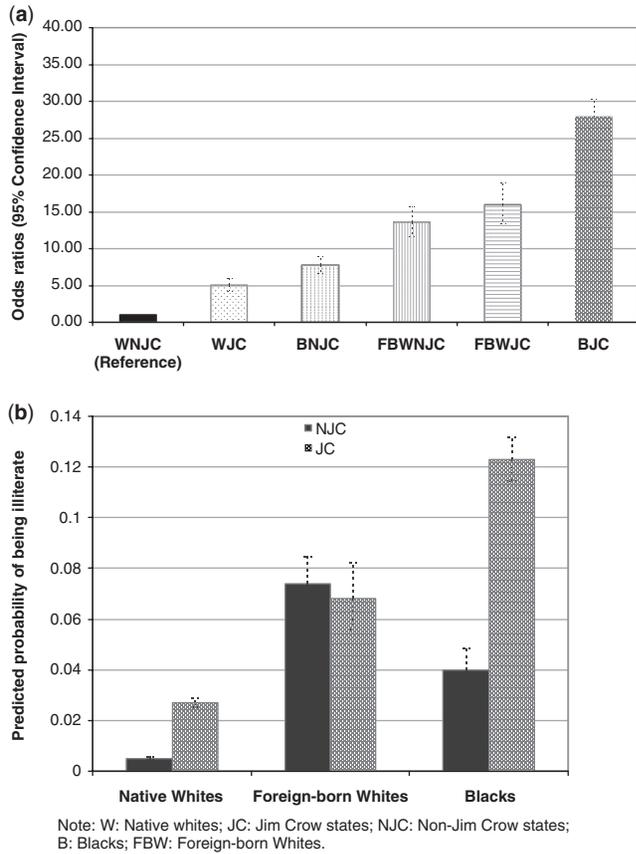
Note: W: Native whites; JC: Jim Crow states; NJC: Non-Jim Crow states; B: Blacks; FBW: Foreign-born Whites.

Figure 3 Odds ratios and 95% credible intervals for the likelihood of being illiterate by combinations of individual race/nativity and presence of Jim Crow laws at the state level (**a**); and predicted probabilities and 95% credible intervals showing differences between Jim Crow and non-Jim states for different race/nativity groups (**b**).
Note: W, Native whites; JC, Jim Crow states; NJC, Non-Jim Crow states; B, Blacks; FBW, Foreign-born whites
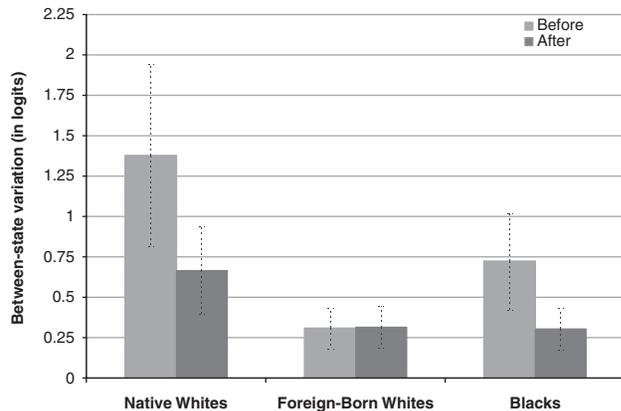

Figure 4 Between-state variations in illiteracy (in logits) and 95% credible intervals for native whites, foreign-born whites before and after accounting for Jim Crow Laws and interaction of Jim Crow Law individual with race/nativity

substantial state variations in illiteracy that could not be accounted by the states' race/nativity composition. Second, taking account of state substantially reduced the effects associated with individual race/nativity, thereby suggesting that individual-level effects are not unambiguously determined and depend on model specification. Third, state variation in illiteracy was not constant across the three groups, further undermining the significance of individual-level relationships in the absence of a description of the substantial state-heterogeneity. Finally, by adding to the data set a state-level variable related to the presence of JC laws affecting education, we found strong and independent state effects of JC laws on illiteracy, with the effect being strongest for blacks.

Before we interpret and discuss the meaning, historical context and implications of our findings, the following caveats are noted. First, the empirical relationships we report, like those of Robinson's, are subject to omitted variable bias. By this we mean that important determinants of illiteracy such as one's socioeconomic position are not included due to data limitations (e.g. the 1930 census records on illiteracy and race/nativity does not further tabulate the data by education, income or occupation). This problem of omitted variables, however, is not germane to the motivation of this study. One can still argue that within the context of the data that Robinson had, when we restrict our focus only on one level of analysis (be it individual or ecological), rather than use both levels, we obtain a distorted picture of the potential multilevel processes at play. Thus, while omitted variable bias is a critical issue for causal inference in observational studies, it is not particularly relevant here, as our objective is not to draw substantive inferences about either levels of analysis (or specific variables). Rather it is to demonstrate the pitfalls of Robinson's argument that only individual-level analyses are 'meaningful'. Second, we deliberately focus on the overall state context—rather than specific state variables—since any 'specific ecological effect'[40] is likely to be influenced by the omitted variable bias at the individual-level. Our aim, consequently, is to focus on the 'common ecological effect',[40] either through estimating state-effects in general or state-effects identifying via broad political/policy context.

Disentangling Robinson's fallacies: A multilevel perspective
Our findings provide a basis to critique Robinson's position on dichotomizing between 'individual' and 'group' and considering the former as being superior. Affirming his commitment to these ideas, Robinson tellingly opened his paper with two definitions that he treated as axiomatic:

(1) 'An individual correlation is a correlation in which the statistical object or thing described is indivisible . . . In an individual correlation the

variables are descriptive properties of individuals'; whereas

(2) 'In an ecological correlation the statistical object is a group of persons...the variables are percentages' (p. 351).[1] followed by the assertion that 'ecological correlations are used simply because correlations between the properties of individuals are not available' (p. 353).[1]

Interestingly, these definitions are imbued with important ambiguities. First, many phenomena, including but not restricted to individual persons, meet Robinson's criteria for being a 'statistical object or thing' that is 'indivisible'. For example, in the context of the United Nations, individual nations cast their vote as indivisible entities. In Robinson's paper, however, his abstract definition of 'individual correlation' quickly assumes the more specific and familiar form of correlations based on individual-level data obtained from or describing individual persons. His definition of 'ecological correlation' similarly contains an unwarranted conflation, whereby 'ecological' is equated with 'aggregate'. By referring to the 'ecological' 'statistical object' as 'a group of persons', Robinson's terminology makes it difficult to disentangle the idea of aggregate variables from contextual variables which cannot be reduced to a lower level (and which in fact, by his definition, constitute 'individuals' because they are indivisible).

While it is correct that aggregate analysis is incapable of distinguishing the contextual (the difference a place makes) from the compositional (what is in a place),[49,70–72] Robinson was wrong to conclude that 'meaningful' relationships are those that are based on individual data, in contrast to 'meaningless' relationships based on groups. It is for this reason Susser argued that the coupling of 'ecological' and 'fallacy' has brought the ecological approach into disrepute,[73] such that he advocated instead for use of the more accurate term 'aggregative fallacy'.[20] Put simply, ecological explanations can be important (and ecological units might well be the target of inference) and should not be dismissed, but they cannot be evaluated through aggregate analysis at a single level. Consequently, Robinson conflated in his conclusion the proper formulation and specification of statistical association with appropriateness of data and target of inference.[31]

The above discussion underscores the need for multilevel thinking; i.e. we need to simultaneously examine the circumstances of individuals at one level, in the context of the different levels shaping their circumstances.[21,37,40,45,47,48,57,72,73] Figure 5 identifies a typology of designs for data collection and analyses;[40,74,75] where the rows indicate the level or unit at which the outcome variable is being measured [i.e., at the individual level (y) or the aggregate, or ecological, level (Y)], and the columns indicate whether the exposure is being measured at the individual level (x) or the ecological level (X).

		Exposure	
		x (measured at individual level)	X (measured at ecological level)
Outcome	y (measured at individual level)	{y, x} Traditional risk factor study	{y, X} Multilevel study
	Y (measured at ecological level)	{Y, x}*	{Y, X} Ecological study

Figure 5 Typology of Studies.[40] Asterisk represents that this type of study is impossible to specify as it stands. Practically speaking, it will either take the form of {Y,X}, i.e. ecological study, where X will now simply be central tendency of x. Or, if dis-aggregation of Y is possible, so that we can observe y, then it will be equivalent to {y,x}

Study-type {y,x} is most commonly encountered when the researcher aims to link exposure to outcomes, with both being measured at the individual level. Study-type {y,x} not only ignores ecological effects (either implicitly or explicitly), but also with its individualistic focus resonate with the notion of health as solely a matter of individual responsibility.[72]

Conversely, study-type{Y,X}—referred to as an 'ecological study'—may seem intuitively appropriate for research on population health and ecological exposures. However, study-type {Y,X} conflates the genuinely ecological and the aggregate or 'compositional',[72] and precludes the possibility of testing heterogeneous contextual effects on different types of individuals. Ecological effects reflect predictors and associated mechanisms operating solely at contextual level. Aggregate effects, in contrast, equate the effect of a place with the sum of the individual effects associated with the people living within the place. In this situation the interpretative question becomes particularly relevant. If common membership of a state by a set of individuals brings about an effect that is over and above those resulting from individual characteristics, then there may indeed be an ecological effect. Distinctions of this type were pointedly raised by Alker when he asked: 'When, for example, do national and/or regional factors dominate election behavior? And when do they reflect, via aggregation, the summation of local and individual decision?' (p. 85).[19] As Alker rightly concluded, answering these types of questions would require developing modelling frameworks that take account of the 'rich variety of effects due to geopolitical context and the socio-ecological environment' (p. 86).[19]

The type of multilevel approach suggested by Alker is provided by a study-type {y,X}, i.e. in which an ecological exposure is linked to an individual outcome.

A more complete representation would be type {y,x,X} whereby we have an individual outcome, individual confounders (x), and ecologic exposure reflecting a multilevel structure of individuals nested within ecologies. A fundamental motivation for study-type {y,x,X} is to distinguish 'ecological differences' from 'the difference an ecology makes'.[72] Stated differently, ecological effects on the individual outcome should be ascertained after individual factors that reflect the composition of the places (and are potential confounders) have been controlled. Indeed, compositional explanations for ecological variations in health are common. It nonetheless makes intuitive sense to test for the possibility of ecological effects, besides anticipating that the impact of individual level, compositional factors may vary by context. Thus, unless contextual variables are considered, their direct effects and any indirect mediation through compositional variables remain unidentified. Moreover, composition itself has an intrinsic ecologic dimension; the very fact that individual (compositional) factors may 'explain' ecologic variations serves as a reminder that the real understanding of ecologic effects is complex.

There has been considerable debate over the importance of contextual effects (those related to the characteristics of an area) and compositional effects (those related to the characteristics of the individuals who reside in an area),[76] However, the multilevel analysis we have undertaken is more sophisticated than that, allowing complex heterogeneity in terms of differential ecological geographies for different groups of people. It is not simply a matter of individual vs ecological, nor of compositional vs contextual but considering both simultaneously. Indeed as Figure 1 shows the between-state variations increase as we move from the null model to include individual characteristics in Model 2, and the between place variation is different for individuals with different characteristics (Model 3).

The multilevel framework with its simultaneous examination of the characteristics of the individuals at one level and the context or ecologies in which they are located at another level accordingly offers a more comprehensive framework for understanding the ways in which places can affect people (contextual) or, alternatively, people can affect places (composition). It likewise allows for a more precise distinction between aggregative fallacy vs ecologic effects.

Applying a multilevel perspective highlights the problematic nature of Robinson's mutually exclusive distinction of the level of 'individual' vs the level of 'ecological'. It is intriguing that when faced with the discordance between the individual-level and group-level correlations, Robinson decreed the former as 'meaningful' and the latter as 'meaningless'. In Robinson's defence, his conclusions were narrowly intended and specifically directed to those researchers who were routinely using ecological correlations as substitutes for individual correlations, given a lack of the relevant individual-level data. Yet such a stance has to reckon with the predominant interpretation of his widely influential paper which, as we have previously noted,[6] was taken to mean that individual data are what count and implicitly that ecological data should be avoided. To understand the ready acceptance and profound impact of Robinson's paper, we accordingly next situate Robinson's study within its historical context (Table 3).

Robinson's paper in context: USA in 1950, the Cold War and methodological individualism

Robinson tellingly published his paper on 'Ecological correlations and the behavior of individuals' in the USA in 1950. Just prior to his paper appearing, during the latter part of the 1940s, social sciences, especially in the USA, overtly embraced, both conceptually and quantitatively, the stance of methodological individualism. As defined in the International Encyclopedia of the Social Sciences, 'methodological individualism' refers to[77]:

> ...the explanatory and modeling strategies in which human individuals (with their motivations) and human actions (with their causes or reasons) are given a prominent role in explanations and models. Social phenomena are viewed as the aggregate results of individual actions. Explanation thus proceeds from the parts to the whole: individual action has an explanatory primacy in relation to social facts, society's properties, and observed macroregularities (p. 9571).

The contrast, of course, was to alternative frameworks that argued that properties of parts reflected, in part, the whole of which they were inherently a part—and also that 'wholes' might have properties irreducible to the individual-level yet nevertheless affecting individual-level phenomena.[78–83]

The academic debates regarding 'individualism' vs 'holism' were, however, more than merely academic. As is well recounted in the literature on changing ideas and ideologies in the social sciences in the post-World War II period,[84–86] these academic disputes were deeply connected to larger geopolitical conflicts, most specifically the Cold War.[87] Framed in terms of political economy, the conflict was between what was referred to as 'capitalism' vs 'communism', as respectively incarnated by USA (and its 'free world allies') vs the USSR and, starting in 1949, China. In ideological terms, the former emphasized individualism; the latter, structuralism.

Within the USA, the individualist approach not surprisingly became dominant. Its power lay not simply in what proponents considered to be the persuasiveness of its ideas but also because of the frank exercise of political power. The year 1950, when

Table 3 ''Ecological correlations and the behavior of individuals'' within its historical context

Year	The historical context in the U.S.[95–99,102]
1929	Stock market crash and start of Great Depression in the US
1930	US 1930 Census (data source for Robinson's 1950 article on ecological fallacy)
1932	Franklin D. Roosevelt elected US president
1933	Start of the US ''New Deal''
1936	Start of Spanish Civil War; US declares ''neutrality''
1939	Start of World War II
1941	Pearl Harbor; US enters WWII
1944	Myrdal G. An American Dilemma: The Negro Problem and Modern Democracy. 2 vols. New York: Harper & Brothers, 1944
1945	–US uses atomic bomb on August 6 (Hiroshima) and August 9 (Nagasaki)
	–End of World War II
	–Start of Chinese civil war
	–UN founding conference in San Francisco; issue raised of US Jim Crow laws as contrary to human rights.[98]
1946	–President Harry S. Truman establishes the ''President's Committee on Civil Rights,'' leading to the report *To Secure These Rights*, which stated that ''the separate but equal doctrine has failed'' (p. 78).[95] –First meeting of the United Nations
1948	–Feb 2: President Truman delivers the first speech to Congress by a US president on civil rights, placing it on the national agenda –Disgruntled Southern Democrats form the ''States' Rights Democratic Party,'' aka the ''Dixiecrats,'' to oppose Truman's civil rights agenda –Universal Declaration of Human Rights
1949	End of Chinese civil war; establishment of Chinese People's Republic NATO established
1950	–Publication of Robinson WS. Ecological correlations and the behavior of individuals. Am Sociol Rev 1950; 15:351–357 –Start of the Korean War –Rise of Senator Joseph McCarthy and the House Un-American Activities Committee (HUAC)
1953	End of Korean War
1954	–May 17: *Brown* v. *Board of Education*; US Supreme court nullifies Jim Crow doctrine of ''separate but equal'' –Congress censures McCarthy
1955	Montgomery bus boycott with Rosa Parks and Martin Luther King Jr
1957	Little Rock, Arkansas: use of federal troop to enforce school integration
1963	March on Washington (''I have a dream''); bombing of church in Birmingham
1964	US Civil Rights Act

Robinson published his article on ecological correlations, marked not only the start of the Korean War but also, within the USA, the rise of Senator Joseph M. McCarthy and the House Un-American Activities Committee (HUAC).[87–89] During what has come to be known as the 'McCarthy era',[87,89] US academics who seriously or publicly questioned the individualistic assumptions associated with free-market ideology found themselves variously marginalized, denied funding, or fired from their jobs (pp. 404–407),[87,89] including in economics (pp. 296–297),[85] sociology (pp. 230–232),[84] and medicine and public health.[90,91]

The impact of these ideological battles, as noted by Ross, a leading historian of the social sciences, was felt not only in the USA but worldwide[84]:

As the strongest power to emerge from the war and a society that had escaped fascism and communism, the United States promoted its ideologies and cultural products around the world. United States government agencies, private foundations, universities and disciplinary organizations supported extensive exchange of social science faculty, students, and books. American

models of social science were selectively imported into countries outside the Soviet sphere of influence, while the American model of graduate education that linked teaching and research was often emulated . . . (p. 230).

According to Ross, the theories that came to predominate in the USA and that were exported elsewhere in 'the 1950s climate of Cold War scientism and burgeoning professional practice' retained 'a basis in individualistic, voluntarist premises', whereby '[i]n line with the era's theories, behavioral social science methodologically endowed individuals with autonomy, while substantively enmeshing them in a world of increasing social complexity' (p. 231).[84] Directly relevant to Robinson's training and academic context, 'Through translation of structural-functional concepts into behavioral variables, theory was sometimes linked to these methods, notably by Robert Merton and Lazarsfeld at Columbia, thereby offering the promise of an interdisciplinary convergence in "behavioral science" ' (p. 232).[84]

It consequently should not be surprising that in 1950, and thereafter, researchers found it compelling to embrace the primacy of individual-level analysis and that groups are nothing more than aggregates of individuals. The irony that the term 'individual' originally referred to being 'indivisible' from the group of which it is a part and that recognition of 'individuality' does not require embracing the philosophical stance of 'individualism' (pp. 161–165),[55,92] is a important conceptual shortcoming of Robinson's study.

The US in 1950: Jim Crow and the saliency of states

It is also instructive to analyse Robinson's claims about the primacy of individual relationships in relation to his chosen empirical example pertaining to race/nativity and illiteracy. It is important to remember that in 1950 (the year when Robinson's study was published) states loomed large in one of the major US political divisions of the day: the highly public battle over Jim Crow (i.e. federal and state laws that permitted racial discrimination) and 'states' rights', as invoked by US southern states to justify their *de jure* discrimination against their black residents (then termed 'Negroes').[62,93–99] These Jim Crow laws spanned the gamut, enforcing racial discrimination against blacks—and racial privilege for whites—in myriad domains. As described by the historian Van Woodward[94]:

the 'segregation code' . . . lent the sanction of law to a racial ostracism that extended to the churches and schools, to housing and jobs, to eating and drinking. Whether by law or by custom, that ostracism eventually extended to virtually all forms of public transportation, to sports and recreation, to hospitals, orphanages, prisons, and

asylums, and ultimately to funeral homes, morgues, and cemeteries (p. 8).

Compounding the problem, the reach of Jim Crow extended to voting laws, thereby circumscribing the ability of disenfranchised populations from legally altering the terms of their disenfranchisement.

Notably, in 1950, the same year Robinson published his paper, the legendary US lawyer and civil rights (and later women's rights) advocate Pauli Murray[99,100] published a 746 page volume, the first of its kind, documenting every US state and local law and ordinance involving 'race' and 'colour'.[62] Examples of state laws decreeing racial segregation in education and defining 'race', still on the books in 1950, are provided in Table 4. Although a number of these Jim Crow laws (including for education) alluded to the concept of 'separate but equal'[62] (as established by the 1896 US Supreme Court ruling in *Plessy vs Ferguson*, in favour of 'separate but equal' segregation of public transportation),[62,93,95,97] the reality was one of racial inequity. For example, in 1923, a survey of education in Bibbs County, Georgia, 'found the following educational costs for 10 652 white and 8847 blacks'[95]:

Building and repairs—White: $16 941.29; Colored: none
Equipment—White: $3127.57; Colored: none
Supplies, libraries, janitors, fuels, and other expenditures – White: $85 344.27; Colored: none
Transportation—White: $14 969.93; Colored: none
(p. 70).

These sums translated to an expenditure of $11.30 per white child, vs $0.00 per 'coloured' child. Even closer to the 1930 census, in 1927 the 'annual cost per child' in the Alabama public school system 'was $26.47 for whites' vs '$3.81 for blacks' (p. 70).[95]

The battles over Jim Crow played an enormous role in not only the US 1948 presidential elections, but also the US entry into the United Nations in 1948, its positioning as defender of the 'free world' in the emerging Cold War, and the US ratification of the 1948 Universal Declaration of Human Rights.[62,93,95–99] After all, for the US to practice racial discrimination 'at home' while preaching freedom 'abroad' was an unseemly contradiction—a problem raised not only by US African–American veterans returning home from World War II but also by the USSR, as it sought to embarrass the US on issues of civil rights to counter US charges regarding the Soviet suppression of political and civil rights.[96–99] As summarized by Frederickson[96]:

Tensions came to a head in 1948 when, in an unprecedented move, President Harry Truman placed himself squarely behind civil rights legislation. Truman advocated federal protection against

Table 4 Selected examples of US state laws on racial segregation in education and corresponding ''racial'' definitions[62]

State	Laws on racial segregation in education	''Racial'' definitions
Alabama	p. 21: **Constitution. Education. Art. XIV, Sec. 256** [Authorizes establishment of a system of public schools for children between the ages of 7 and 21 years and provides 'separate schools shall be provided for white and colored children, and no child of either race shall be permitted to attend a school of the other race']	p. 22: **Definition of ''Negro''**. Title 1, §2...The word 'negro' includes mulatto. The word 'mulatto' or the term 'person of color' means a person of mixed blood descended on the part of the father or mother from negro ancestors, without reference to or limit of time or number of generations [1927, p. 716]
Arkansas	p. 40: **Education. Public Schools – Segregation of Races** (80–509): ''The board of school directors of each district in the State shall be charged with the following powers and perform the following duties...(c) establish separate schools for white and colored persons...''	p. 39: **Definition of Negro**: [Statute related to concubinage, supra, defines 'person of negro race' as 'any person who has in his or he veins any negro blood whatever.']
Florida	p. 77: **Constitution. Education. Art. 12, §12. Separate schools for negroes**. – White and Colored Children shall not be taught in the same school, but impartial provision shall be made for both. [Const. 1885] p. 78: **Education – Segregation. Public Schools. §228.09. Separate schools for white and negro children required**. – The schools for white children and the schools for negro children shall be conducted separately. *No individual, body of individuals, corporation, or association shall conduct within this state any school of any grade (public, private, or parochial) wherein white persons and negroes are instructed or boarded in the same building or at the same time by the same teachers*. [§209, ch. 19355,1939; Comp. Gen Laws 1940 Supp., §892(29).] (emphasis added). [*Note*: This statute is mandatory and applies to both public and private schools.]	p. 78: **Definition of ''Negro'' §1.01. Definition** – ...(6) The words 'negro,' 'colored', 'colored persons', 'mulatto' or 'persons of color', when applied to persons, include every person having one-eighth or more of African or negro blood. [Rev. Gen. St. 1920, §§3939; Comp. Gen. Laws 1927, §5858.]
Georgia	p. 89: **Constitution. Education. Art. VIII. §1(6576) Paragraph I. System of common schools; free tuition; separation of races.** – The provision of an adequate education for the citizens shall be a primary obligation of the State of Georgia, the expense of which shall be provided by taxation. Separate schools shall be provided for the white and colored races. [Const. 1877, §2–6601; Const. 1945, §2–6401.]	p. 90: **Definition of ''Negro'' and ''White.'' §790103. (2177) Persons of color, who are.** – All Negroes, mulattoes, mestizos, and their descendants, having any ascertainable trace of either Negro or African, West Indian, or Asiatic Indian blood in their veins, and all descendants of any person having either Negro or African, West Indian, or Asiatic Indian blood in his or her veins shall be known in this State as persons of color. [Acts 1865–6, p. 239; 1927, p. 272.] **§55–312. ''White person'' defined.** – The term ''white person'' shall include only persons of the white or Caucasian race, who have no ascertainable trace of either Negro, African, West Indian, Asiatic Indian, Mongolian, Japanese, or Chinese blood in their veins. No person, any one of whose ancestors has been duly registered with the State Bureau of Vital Statistics, as a colored person or person of color, shall be deemed to be a white person. [Acts 1927, p. 277]
Tennessee	p. 427: **Constitution. Education – Segregation. Art 11, Sec. 12.** – ...The State taxes derived hereafter from polls shall be appropriated to educational purposes, in such manner as the General Assembly shall, from time to time, direct by law. No school established or aided under this section shall allow white and negro children to be received as scholars together in the same school... [Const. 1870.]	p. 428: **Statutes. Williams Tennessee Code Annotated, 1934. Definition of Negro. 25. Same** – The word ''negro'' includes mulattoes, mestizos and their descendants, having any blood of the African race in their veins. **8396**. 417a1 (2745a). Persons of color define. – All negroes, mulattoes, mestizos, and their descendants, having any African blood in their veins, shall be known as ''persons of color.'' [1865–66, ch. 40, sec. 1, Modified.]

lynching, anti-poll tax legislation, the establishment of a permanent Fair Employment Practices Commission (FEPC), and the prohibition of segregation in inter-state transportation. For the first time since Reconstruction, the status of African Americans had become a national issue (pp. 2–3).

To counter this 'progressive tide', 'a group of disgruntled southern Democrats formed the States' Rights Democratic Party...soon nicknamed the Dixiecrats', with their goal being to 'upset the election bid of Harry Truman'—and to keep safe the 'cherished regional "customs and institutions"' of racial discrimination (pp. 2–3).[96] Although the Dixiecrats ultimately failed in their 1948 presidential maneuverings, they did succeed in derailing much of Truman's civil rights legislation during congressional battles taking place in both 1948 and 1949 (p. 192).[96] Consequently, as stated in a 1950 lecture by the internationally renowned civil rights advocate Paul Robeson: 'Ask fifteen million American Negroes, if you please, "What is the greatest menace in your life?" and they will answer in a thunderous voice, "Jim-Crow Justice! Mob Rule! Segregation! Job Discrimination!"—in short white supremacy and all its vile works'.[101]

In light of the profound effects of Jim Crow on shaping and entrenching racial inequality in the USA, it should not be surprising that we found that there was an independent effect of presence of JC laws on illiteracy, with the effect being strongest for blacks. This finding coupled with the substantial unexplained variation at the state level suggests the simultaneous importance of states (which Robinson interpreted as simply one form of aggregation) and individuals.

We hasten to add that we do not wish to imply that Robinson was deliberate in ignoring the strong synergies between race, illiteracy and states that were present at that time. Indeed, his motivation was considerably narrower and technical. Nevertheless, the data, figures and text appearing in the 1931 census report from which Robinson drew his data[58] could have encouraged greater scrutiny of the relevance of states to the individual-level correlations of interest. For instance, if Robinson had computed state-specific individual-level correlations between race/nativity and illiteracy, the substantial heterogeneity in the individual correlations among states could well have tempered the conclusion that only individual-level correlations matter. In Appendix 2a we report the individual correlations between race/nativity and illiteracy for the different states, which substantially vary from practically zero in states such as Nevada and Connecticut to 0.31 in Alabama indicating that the US average of 0.20 reported by Robinson glossed over marked state (and hence context-dependent) variation in these correlations.[1] Furthermore, underscoring that social geography

matters for illiteracy, the US Census chapter on 'illiteracy' provided a map of illiteracy by states (p. 1221)[58] (see Appendix 2b) and explicitly stated that 'The variations in the proportion of illiterates in the several color and nativity classes reflect the educational opportunities, past and present, which have been open to them in different sections of the United States' (p. 1219).[58] It further warned that 'to make a fair comparison' between the illiteracy rates of the native white and foreign born white populations, 'statistics for individual cities and for urban and rural areas in individual States, should be examined', since 'a much larger proportion' of the former 'are found in the rural communities, where school attendance has been less general than in the cities', noting further that most of the rural foreign born white population lived 'in States where educational facilities, even in the country, are relatively good' (p. 1219).[58] Moreover, similar to Figure 2, the census chapter included a bar chart showing the 'percent illiterate in population 10 years and over, by color and nativity, by states: 1930 and 1920' (p. 1222),[58] which graphically highlighted both the state variation in illiteracy rates by race/nativity and also the partial overlap in states for high illiteracy for the 'native white' and 'negro' populations (see Appendix 2c).

Thus, while Robinson importantly noted that the positive sign of both the 'individual correlation between color and illiteracy' (0.203) and the 'ecological correlation' (0.946) was 'consistent with our knowledge that educational standards in the United States are lower for Negroes than for whites' (p. 354),[1] neither Robinson nor his peers raised questions about the relevance of state-level phenomena to the analysis of correlations between illiteracy and race/ethnicity. A fitting coda is that a mere 4 years after Robinson published his paper, the US Supreme Court, in 1954, ruled that state-sponsored racial discrimination was illegal in its classic case *Brown vs Board of Education*. This case specifically put an end to legalized segregation of US public schools and more broadly was the death knell of Jim Crow.[94–99,102]

Conclusion

Robinson's study made a seminal contribution by demonstrating that correlations for the same two variables can be different depending on the level at which it is analysed. The purpose of our study is not to undermine this scholarship. Robinson's specific technical contribution, however, was overcast by the conclusions he made regarding the meaningfulness or meaninglessness of particular analyses or correlations. As we demonstrate, applying a historically informed multilevel perspective to Robinson's study facilitates a less narrow conclusion than the one Robinson made. Robinson's profoundly influential study, by default or by design, gave justification for analyses to focus only

on one level, with that one level being the individual. We showed that this was particularly problematic within the context of the example of race/nativity and illiteracy that Robinson used, where ignoring ecologies, even to explain 'individual behaviours' leads to a severely incomplete, if not misleading, knowledge. The implication is that perils are posed by not only ecologic fallacy but also individualistic fallacy. Multilevel thinking, grounded in historical and spatio-temporal context, is thus a necessity, not an option. It is not that ecological effects are unconditionally important. However, continuing to do individual-level analyses stripped out of its context will never inform us about how context may or may not shape individual and ecological outcomes. Borrowing Robinson's famous last words, the purpose of this paper will have been accomplished if it stimulates a more critical and comprehensive interpretation of analyses solely focused at one level: be it individual or ecological.

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Appendix 1 List of states with and without Jim Crow laws regarding education[62]

States Labels and Jim Crow Boundaries

Non-Jim Crow states	Jim Crow states
California (CA)	Alabama (AL)
Colorado (CO)	Arizona (AR)
Connecticut (CT)	Arkansas (AK)
Delaware (DE)	Florida (FL)
District of Columbia (DC)	Georgia (GA)
Idaho (ID)	Indiana (IN)
Illinois (IL)	Kansas (KS)
Iowa (IO)	Kentucky (KT)
Maine (ME)	Louisiana (LA)
Maryland (MD)	Mississippi (MS)
Massachusetts (MA)	Missouri (MO)
Michigan (MI)	North Carolina (NC)
Minnesota (MN)	New Mexico (NM)
Montana (MT)	Oklahoma (OK)
North Dakota (ND)	South Carolina (SC)
Nebraska (NE)	Tennessee (TN)
Nevada (NV)	Texas (TX)
New Hampshire (NH)	Virginia (VA)
New Jersey (NJ)	West Virginia (WV)
New York (NY)	Wyoming (WY)
Ohio (OH)	
Oregon (OR)	
Pennsylvania (PA)	
Rhode Island (RI)	
South Dakota (SD)	
Utah (UT)	
Vermont (VT)	
Washington (WA)	
Wisconsin (WI)	

Appendix 2a Individual-level correlations between illiteracy and race/nativity by US states based on 1930 US Census data

State[a]	Phi coefficient[b,c,d]	Phi coefficient[c,d,e]
Alabama	0.310	0.310
Arizona	0.071	0.090
Arkansas	0.219	0.220
California	0.019	0.067
Colorado	0.020	0.040
Connecticut	0.001	0.100
Delaware	0.188	0.250
District of Columbia	0.122	0.154
Florida	0.146	0.152
Georgia	0.172	0.172
Idaho[f]	0.017	0.027
Illinois	0.017	0.079
Indiana	0.069	0.092
Iowa	0.047	0.063
Kansas	0.099	0.117
Kentucky	0.113	0.114
Louisiana	0.220	0.228
Maine	0.005	0.010
Maryland	0.179	0.223
Massachusetts	0.011	0.094
Michigan	0.016	0.067
Minnesota	0.005	0.017
Mississipi	0.302	0.304
Missouri	0.114	0.131
Montana[f]	0.019	0.046
Nebraska	0.029	0.058
Nevada[f]	0.001	0.024
New Hampshire[f]	0.004	0.017
New Jersey	0.015	0.129
New Mexico	−0.006	−0.006
New York	−0.012	0.055

(Continued)

Appendix 2a Continued

State[a]	Phi coefficient[b,c,d]	Phi coefficient[c,d,e]
North Carolina	0.227	0.227
North Dakota[f]	0.005	0.013
Ohio	0.062	0.127
Oklahoma	0.132	0.135
Oregon	0.010	0.021
Pennsylvania	0.014	0.092
Rhode Island	0.018	0.112
South Carolina	0.305	0.305
South Dakota[f]	0.005	0.010
Tennessee	0.144	0.145
Texas	0.238	0.247
Utah[f]	0.015	0.028
Vermont	0.007	0.013
Virginia	0.225	0.227
Washington	0.016	0.036
West Virginia	0.082	0.098
Wisconsin	0.012	0.032
Wyoming[f]	0.032	0.063
US	**0.189**	**0.252**
Robinson's numbers	0.202	

[a] Jim Crow states are shaded in light grey.
[b] These coefficients were calculated using cross tabulation based on 'native and foreign-born whites'/'negro' and literate/illiterate, similar to what Robinson reported in his paper.
[c] All correlations were statistically significant at $p < 0.0001$.
[d] The phi coefficient is a measure of the degree of association between two binary variables. This measure is similar to the correlation coefficient in its interpretation. Two binary variables are considered positively associated if most of the data falls along the diagonal cells. In contrast, two binary variables are considered negatively associated if most of the data falls off the diagonal. The phi coefficients and p-values were calculated using VassarStats calculator: http://faculty.vassar.edu/lowry/VassarStats.html (Accessed on 10 June 2008).
[e] These coefficients were calculated using cross tabulation based on 'native whites'/'negro' and literate/illiterate.
[f] The expected frequency of one of the cells was <5, thus the Pearson Chi-square was not calculated.

Appendix 2b Map of percent illiterate in population 10 years old and over by states from the 1930 US Census Report[58] (p. 1221)
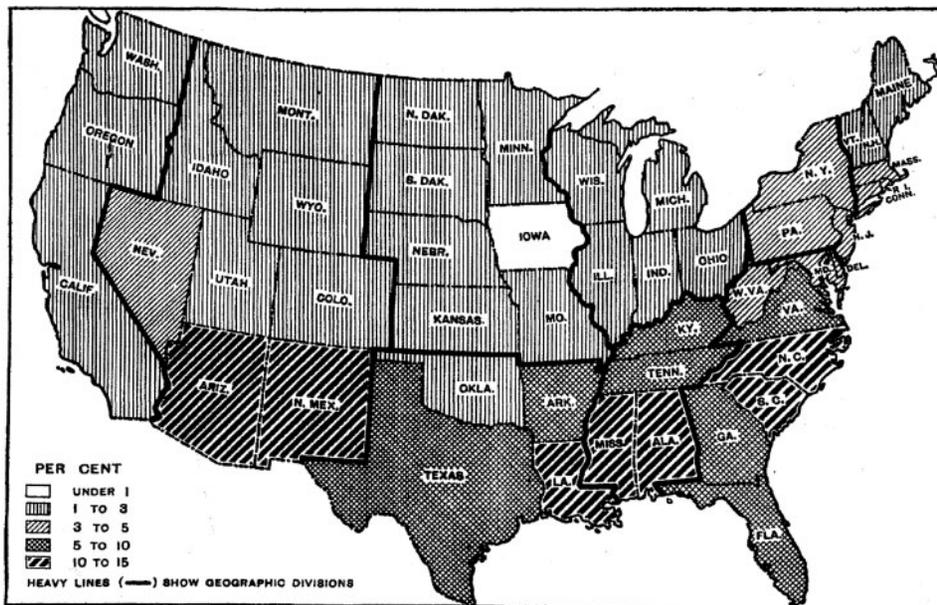
Appendix 2c Bar chart showing the 'percent illiterate in population 10 years and over, by color and nativity, by states: 1930 and 1920' from the 1930 US Census Report[58] (p. 1222)