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RESEARCH ARTICLE

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Age-race-ethnicity segregation in the United States: Where do minority older adults stand?

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Abstract

A recent study shows that among the three age groups of youth, adult and older adult, youth-older adult has the highest age segregation while youth-adult has the lowest. Similar to many previous age segregation studies, racial-ethnic differences, an important population axis in segregation studies, were not considered. Prior studies are also limited to using two-group measures, failing to compare multiple groups together. We explore the complexity in measuring intersectional segregation focusing on the two axes of age and race-ethnicity and propose a conditional approach to measure age segregation by racial-ethnic groups, and racial-ethnic segregation by age groups. Using this approach, we empirically study the 2010 age-race-ethnic segregation at the county and state levels in the United States, using census tracts as the basic units. Both the two and multigroup dissimilarity indices were used. Results show that the racial-ethnic axis had been a stronger force in segregation than the age axis. Results also show disparities of racial-ethnic segregation across age groups with the highest levels present among older adults and in urban counties. For all three age groups, segregation levels involving Natives and Asians tend to be higher than those without them. In contrast, age segregation was the highest between youths and older adults, and the levels varied across racial-ethnic groups with Natives at the highest levels. Although age segregation was significantly different between urban and rural counties, higher segregation in urban areas were mostly involving Whites as opposed to higher segregation in rural counties involving minority racial groups. Studying age segregation should not be colour blinded, as nonwhite older adults in rural counties were more likely to experience higher levels of age segregation than other groups.

KEYWORDS

age segregation, dissimilarity index, intersectionality, multigroup dissimilarity index, racial-ethnic segregation, urban-rural context

1 | INTRODUCTION

Segregation may simply refer to the spatial separation of population groups defined by socio-demographic characteristics such as race-ethnicity, income, age, gender and religion. This separation may occur in different socio-geographical spaces such as residential, school, work and entertainment spaces. Thus, types of segregation may be cross-defined by the socio-demographic characteristics of population and the socio-graphical spaces where segregation takes place (Oka & Wong, 2019). However, traditional segregation studies most often have considered a single population characteristic and one specific socio-geographical space with the most intensive scrutiny accorded to racial-ethnic segregation in the residential space partly because of its potential to negatively impact one's well-being (e.g., Clark, 1986; Galster, 1988).

In contrast, studies on age segregation of the United States remain limited although this type of segregation studies were initiated at least four decades ago (e.g., Cowgill, 1978; La Gory et al., 1980). Most early studies include only a subset of the population, failing to fully assess intergenerational relations between older adults and all other age groups. A recent study by Das Gupta and Wong (2022) divides the population into youth (14 and younger), adult (15–64) and older adult (65 and older) and assesses age segregation among these groups over the two decades from 1990 to 2010. Results show that older adults were the most segregated among the three age groups. An additional finding of this study was that age segregation in the United States has been declining, contrary to the conclusion forwarded in Winkler (2013).

Despite the above contributions, Das Gupta and Wong (2022), similar to most previous studies of US age segregation, assumed that older adults of diverse racial-ethnic characteristics are segregated in the same magnitude, thereby failing to recognise the disproportional vulnerability of minority older adults (Ferrer et al., 2017; Zubair & Norris, 2015). But a study published more than two decades ago had highlighted a significantly higher level of segregation among African American older adults (Rogerson, 1998). Thus, focusing only on the age axis may overlook the compounding of segregation burdens from being in the marginalised groups of both the racial-ethnic and age axes or the intersectionality of racial-ethnic and age segregation. In fact, as noted in Hopkins (2019, p. 943), 'reference to intersectionality within the debates about residential segregation remains curiously absent', as using a 'single categorical axis' has been the dominant approach (Crenshaw, 1989, p. 140). As the demography of the US continues to become not only more racially-ethnically diverse but also older, an intersectional perspective on the segregation of age-race-ethnic groups is overdue (Frey, 2010). However, an assessment of age-race-ethnic segregation is lacking from the literature but assumes critical importance to inform future conceptual frameworks on segregation. A research question we therefore address in our study is—how do marginalised age-race-ethnic groups or groups at the intersection of the marginal categories of both the race-ethnic and age axes experience segregation burdens from the two axes?

Another limitation in most studies of age segregation has been the focus on urban or metropolitan areas (e.g., Cowgill, 1978; La Gory et al., 1980; Rogerson, 1998) ignoring the potential geographical disparities of age segregation between urban and rural settings. Some recent studies of age segregation included the entire United States (urban and rural included) but did not assess differences between urban and rural settings (Winkler, 2013). Only one prior study of the United States (Das Gupta & Wong, 2022) report rurality/urbanity of counties to be of significance to older adult segregation while the urban/rural dimension has been a central theme of research in the broader literature on place and aging (National Academies of Sciences [NAS], 2018; Shiode et al., 2014; Singh & Siahpush, 2014). Urban-rural differences in age segregation was also detected in the case of other countries, such as in England and Wales (Sabater et al., 2017). Thus another research question we address in our study relates to an examination of potential urban-rural differences in age-race-ethnic segregation.

Last, the literature is also deficient in providing guidance on how to systematically evaluate intersectional age-race-ethnic segregation. In our study, we therefore explore how segregation can be measured with population groups defined by age and race-ethnic characteristics and evaluate how an intersectional approach may extend our understanding on segregation of age-race-ethnic groups across US states, counties and urban/rural settings. Methodologically, we demonstrate that intersectionality between age and race, two of the many possible population axes, may be evaluated in segregation studies from two differing perspectives—age segregation by race-ethnicity and conversely, racial-ethnic segregation by age.

Consistent with previous segregation studies (e.g., Dupont, 2004; Johnston et al., 2016) and recent age segregation works (e.g., Das Gupta & Wong, 2022; Winkler, 2013), the current study includes both states and counties because segregation results are scale-dependent (Yao et al., 2019). Patterns exhibited on one geographical scale may not be found on another scale, and segregation has been recognised as a multiscalar phenomenon (Fowler, 2016). In our context, evaluating age segregation by race-ethnicity and racial-ethnic segregation by age will reveal whether these two types of segregation (age vs. racial-ethnic, conditioned on the other axis) may operate differently at the state and the county levels. The relative strengths of the two axes in determining segregation may be different between the state and county levels. In addition, assessing segregation at the county level will allow us to compare and contrast urban and rural segregations and add to previous age segregation studies that focused on urban areas exclusively. Therefore, it is imperative to assess segregation at both the state and the county levels. However, state–county differences will be highlighted only when these differences bear significance to the two research questions we stated earlier.

2 | AGE SEGREGATION INTERSECTED WITH RACE-ETHNICITY

The recent literature has highlighted the potential importance of space in facilitating and limiting intergenerational relations (Hagestad & Uhlenberg, 2006; Vanderbeck, 2007). Researchers have started

studying age segregation based on the residential locations of population more than one-half century ago, with the focus resting on vulnerable populations, mostly older adults but occasionally also children. Although segregation studies have traditionally focused on the separation between racial-ethnic groups in the residential space (Oka & Wong, 2019), most studies have ignored the differences in racial-ethnic segregation across age groups. Similarly absent is an intersectional approach to study segregation involving age and race-ethnicity. In its original conceptualisation, the term intersectionality emphasised the intersecting axes of race and gender 'to look at how specific forms of inequality are mutually constitutive' (Crenshaw, 1989; Hopkins, 2019, p. 938). But, in a broader sense, this idea is also useful to represent, define or identify population groups by simultaneously using multiple identifying characteristics or axes, in our case age and race-ethnicity (Crenshaw, 1989; Hopkins, 2019; Parker, 2016).

While a particular population group may belong to the marginalised category on the race-ethnic axis, it may not however belong to the marginalised category on the age axis. But belonging to the marginalised categories on both the race-ethnicity and age axes, such as minority older adults in our study, may signify disproportional segregation burden (Ferrer et al., 2017; Zubair & Norris, 2015). The utility of the intersectional approach is of particular relevance to reveal the segregation burden of a/any population group characterised by marginalised identities on multiple axes, for instance the age and the race-ethnicity axes in our study. Thus, whereas segregation assessment based on one single axis will overlook segregation burdens from other axes, an intersectional approach will likely provide a more inclusive assessment. Below, we summarise prior literature on age segregation and, in connection, trace the handful of studies that imbue an intersectional perspective in age segregation analysis.

Cowgill (1978) conducted one of the earliest age segregation studies focusing on the US metropolitan areas between 1940 and 1970. Population was divided into two age groups: under 65 and 65 and older and segregation was evaluated using the dissimilarity index *D*. Based on findings, Cowgill argued that older adults tended to concentrate in inner cities partly due to aging in place, but age segregation level was strongly influenced by the pace and patterns of urban expansion. Smaller in scope than Cowgill's study, Kennedy and De Jong (1977) studied 10 US central cities from 1960 to 1970 using the dissimilarity index *D*. Kennedy and De Jong also recognised the importance of aging in place and the suburbanisation process in affecting age segregation. La Gory et al. (1980) added to this discussion by explaining the age segregation process in terms of competition between groups for space. Similarly, La Gory et al. (1981) concluded that besides some regional variables, the competitive housing market structure was the main factor affecting age segregation. Last, a study by Tierney (1987) assessed the segregation of two age groups (65–74-year-olds and 75 and older) in the residential space of 18 metropolitan areas between 1970 and 1980. Findings showed that the older group had higher segregation than the younger. All these studies examining age segregation in prior decades have several characteristics in common: the dissimilarity index *D* was the adopted segregation measure; population was divided into two groups and some included only a subset of the entire population; racial-ethnic differences were not considered when assessing age segregation; and only urban population was included.

In a more recent study by Winkler (2013), two age groups were compared: 20–34 versus 60 and older. The study used population count data in multiple geographical units (blocks, subcounties, counties and states) to compute *D* across a hierarchy of geographic levels, covering two decades (1990 to 2020) and the entire United States. Thus, Winkler is another study that used only a subset of the population, failing to provide a more comprehensive assessment of intergenerational relationships. In addition, like all studies reviewed above, as well as a recent study by Das Gupta and Wong (2022), Winkler (2013) treated each age group as homogeneous, ignoring the potential that age segregation levels may vary across racial-ethnic groups.

Closest to our objective, Rogerson (1998) focused on 15 largest metropolitan areas covering approximately 36% of the US population in 1990. Rogerson's study was motivated by the increasing attention on population aging and therefore made no explicit reference to intersectionality. Nevertheless, expecting disparities in age segregation across racial groups, population was divided into elderly (75 and over) and non-elderly (under 75) for White (W) and African American (AA). Then four pairs of comparison by age and race were conducted using the dissimilarity index *D* (AA elderly vs. AA nonelderly; W elderly vs. W nonelderly; AA elderly vs. W elderly; AA vs. W).

Thus, despite limitations that include dated results from the 1980s and a study focus on only 15 metro areas, Rogerson highlighted several important issues in studying the intersectionality of age and race segregation in the United States. Results show that levels of age segregation vary across racial groups and levels of racial segregation vary across age groups. More importantly, segregation between Whites and African Americans were higher among older adults than for all other age comparisons. This finding underscored the compounding segregation burden that minority older adults may experience due to their intersectional memberships. In this specific case, being an African American older adult was akin to being among the disadvantaged of the disadvantaged population group. Methodologically, Rogerson's study suggests that one may evaluate age segregation by race-ethnicity and evaluate racial-ethnic segregation by age. These comparative perspectives, which are adopted in the current study, are logical to address in intersectional segregation.

Some non-US segregation studies involved multiple population axes. For instance, Silm et al. (2018) measured segregation between Russian- and Estonian-speakers in Tallinn, Estonia in 2011. This study computed the dissimilarity index *D* for the two population groups for different age groups and for different types of activity space (residence, work and others). Between the two language groups, Silm et al. (2018) found younger people are more segregated by languages than older people. Silm's perspective may be characterised as evaluating ethnic segregation by age. Race-age segregation was also addressed by Boterman (2020). Populations in Amsterdam city and region were classified into eight age groups (between 0 and 35-year-old), five ethnic groups (Turkish, Moroccan, Surinamese,

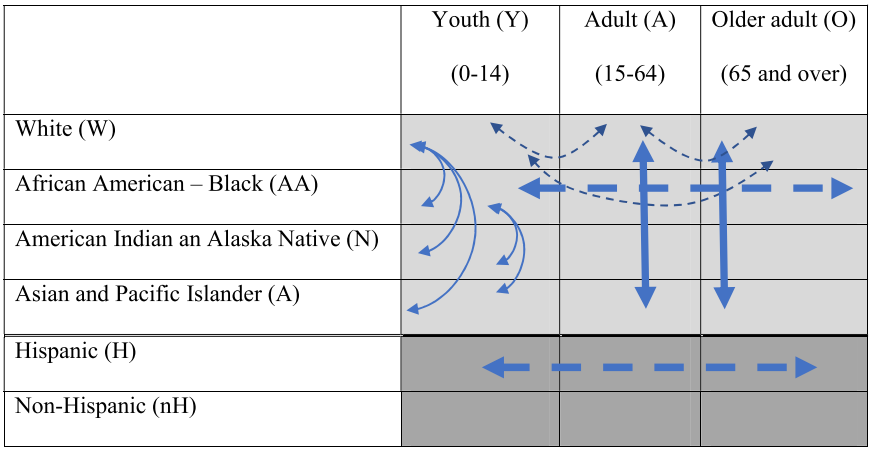

FIGURE 1 Population cross-classified by race-ethnicity and age groups with their abbreviations. Curvy thin solid arrows across rows: two-group racial-ethnic comparisons by age; curvy thin dash arrows across columns: two-group age comparisons by race-ethnicity; straight thick solid arrows across rows: multi-group racial comparisons by age; straight thick dash arrows across columns: multi-group age comparisons by race. Not all applicable comparisons are shown here.

natives-Dutch and Western), and four income groups (by quartiles). Age segregation levels were computed by income groups and by ethnic groups separately. Levels of ethnic segregation were also computed for primary school-age children. While considering age, ethnicity and income but comparing only selected sub-groups cross-defined by these population characteristics, this study fails to provide an organised framework to handle multiple-group comparisons and intersectional segregation.

The literature reviewed above provides the following limiting points. Several older studies examined age segregation only in urban/metro areas of the United States in prior decades (e.g., Cowgill, 1978; Gory et al., 1981). These studies are dated and leave out rural parts of the United States. Many existing studies of age segregation include only subgroups of the entire population, failing to assess intergenerational relationships inclusively. No prior United States study, except Rogerson (1998) has evaluated segregation involving age and race-ethnicity. While Rogerson considered only White and African American with two age groups, increasing racial-ethnic diversity of the United States dictates that other racial and ethnic groups should be considered in age segregation studies. Last, most prior studies have relied exclusively on the dissimilarity index *D*, which compares only two groups at a time. When studying age-race segregation, age can be divided into more than two groups and age groups can be cross-classified with race to derive multiple groups. In this study, we therefore undertake an evaluation of segregation in the United States by considering both race-ethnicity and age, demonstrating how to handle two intersecting population axes in measuring segregation at both the state and county levels. In turn, we also summarise segregation burden by age-race-ethnic groups in the United States. We also assess if there was any urban-rural differences in age-race-ethnic segregation levels.

3 | DATA AND METHODS

We use 2010 US decennial census data at the census tract level. The decennial census tract data report population counts cross-classified by five-race categories (White, African American, American Indian and Alaska Native, Asian and Pacific Islander and other race) and detailed age groups. However, 'other race' is not an identifiable race and therefore we do not include 'other race' in our study. Population counts are also reported by ethnicity (Hispanic and non-Hispanic) and in detailed age groups. Different from the age groups used in some of the previous studies, we adopt three age groups, labelling them as youth (0–14), adult (15–64) and older adult (65 and over). These three age groups have been used in population and demographic studies, particularly in computing dependency ratios and assessing economic burden of the young and the old on the adult population in the United States and in various other countries (Das Gupta & Wong, 2022; Jahan et al., 2014; Lau & Tsui, 2020; Sanderson & Scherbov, 2015). Population counts were aggregated into these three age groups, first by the four race categories, and then by the two ethnic groups. The 2010 tract level population count data were obtained from the National Historical GIS Centre (Manson et al., 2021).

Figure 1 shows the cross-classification of these population groups. When considering race (4) and age (3), a total of 12 groups can be formed. When considering ethnicity (2) and age (3), six groups can be formed. How these sub-groups are evaluated for segregation are partly dependent on the segregation measures adopted, more specifically whether they are two-group measures or multigroup measures.

As the dissimilarity index *D* has been used in most previous studies of age segregation, we also use *D* in the analysis. The dissimilarity index *D* considering a younger and older group is defined as:

$$D = \frac{1}{2} * \sum_i \left| \frac{y_i}{Y} - \frac{o_i}{O} \right|,$$

where y_i and o_i are the population counts of the younger and older groups, respectively, for census tract *i*, and Y and *O* are the total counts of the two groups in a region. The value of the index ranges from 0 to 1, with 0 indicating 'no segregation' with 1 representing 'perfect segregation'.[1] The value of *D* can also be interpreted as the

[1]The two extreme conditions need elaborations. No segregation does not require the two populations evenly distributed across subunits within the study region. If the two groups distributed across subunits in the same patterns (such as 0.25, 0.3, 0.2, 0.25 for both groups across four subunits), then *D* is 0. When each unit is exclusively occupied by one group, *D* will be 1, indicating perfect segregation.

proportion of population that needs to be reallocated to other subunits to achieve no segregation.

However, a major limitation of D is that it can compare only two groups. In the current context involving groups cross-defined by multiple racial-ethnic and age groups (Figure 1), the D index can be applied to assess the segregation of one pair of groups at a time, consequently multiple comparisons will be required (Boterman, 2020; Rogerson, 1998). Using the two-group D index, racial segregation between any two racial or ethnic groups (e.g., White vs. African American, American Indian and Alaska Native vs. Asian and Pacific Islander, non-Hispanic vs. Hispanic) can be assessed, conditioning on the age axes (youth, adult or older adult). This type of comparison within each age group is represented by the curvy thin solid arrows across rows in Figure 1. Thus, given an age category or conditional on age, the pairs of racial group comparisons are W-AA, W-N, WA, AA-N, AA-A and N-A, and the pair of ethnic comparison is H-nH. Alternatively, age segregation between any two age groups (youth vs. adult, adult vs. older adult and youth vs. older adult) can be assessed conditioning on the racial-ethnic dimension. This type of segregation within each racial-ethnic group is represented by the curvy thin dash arrows across columns in Figure 1. Given a race or ethnic category or conditional on race-ethnicity, the pairs of age group comparisons would be youth-adult (YA), adult-older adult (AO), and youth-older adult (YO). The abbreviations for population groups presented in Figure 1 will be used henceforth.

With three age groups, four racial groups, and 12 age-racial groups involved, employing measures that can assess segregation for more than two groups seems desirable. Segregation can be computed for multiple groups simultaneously using a multi-group version of D (Sakoda, 1981), which can be defined as:

$$D_m = 0.5\frac{\sum_i\sum_j\left|O_{ij} - E_{ij}\right|}{N\sum_j p_j(1 - p_j)},$$

where O_{ij} is the observed counts in group j in subunit i, p_j is the proportion of the total population found in group j, and N is the total population of the study region. E_{ij} is the expected count in group j and unit i, which is defined as:

$$E_{ij} = \sum_i O_{ij} * \sum_j O_{ij}/N.$$

Similar to the two-group D index, D_m also ranges from 0 to 1, indicating no segregation to perfect segregation, respectively. Values of the D_m can also be interpreted in the same way as the two-group D index: the proportion of population to be moved to other units to attain no segregation.[2]

The two-group D and multigroup D_m will be used in this study to compare population groups defined by race-ethnicity and age. Specifically, D will be used to assess segregation levels between pairs of racial-ethnic groups within each age group (racial-ethnic segregation by age) and between pairs of age groups within each racial-ethnic group (age segregation by race-ethnicity). In the context of considering both race-ethnic and age segregation, the multigroup D_m can be used in the following settings:

(1) racial segregation considering all four racial groups for each age group separately (straight thick solid arrows across rows in Figure 1);
(2) age segregation considering all three age groups for each racial and ethnic group separately (straight thick dash arrows across columns in Figure 1);
(3) age-ethnic segregation by considering all three age groups and two ethnic groups together (the lower block with six cells in Figure 1); and
(4) race-age segregation by considering all three age groups and four racial groups together (the upper block with 12 cells in Figure 1).

We use census tracts for both the state- and county-level analyses. Population distributions within states can be highly uneven and state-level analysis may conceal some important intra-state variabilities. Thus, the above group comparisons will be assessed both at the state and county levels using 2010 census tracts as the basic areal units. The county-level analysis will not only show the intra-state variability that would be of interest to local authorities, but it will also facilitate the assessment of the differences in segregation between urban and rural contexts. To evaluate urban/rural disparities in segregation, we apply a methodology similar to that in a previous study and define a county as urban if the percent of population defined as rural in 2010 was less than 50%, and rural otherwise (Das Gupta & Wong, 2022).[3] The means of D values between urban and rural counties were compared using the t-test with unequal variance assumption.

4 | ANALYSIS RESULTS USING TWO-GROUP DISSIMILARITY D

4.1 | Racial-ethnic segregation by age

The two-group D index was computed for each pair of racial-ethnic groups in *each age category* (youth, adult and older adult) for each state. D for each racial-ethnic comparisons was also computed with all age groups combined to obtain the starting reference unconditional on age ('All' in Figure 2). Vertical bars in Figure 2 show the mean D values across all states by pairs of racial-ethnic comparison for each of the three age groups. Standard deviation of D values for each comparison is also shown by a dot. Despite a few minor differences, the age-combined (All)

[2]Another popular segregation measure for multigroup setting is the entropy-based diversity index. However, 'no-segregation' is defined as all groups having equal share of the total population. Because such a definition cannot accommodate the much smaller minority groups, while the multi-group can, the diversity index is not adopted in this study.

[3]https://www2.census.gov/geo/docs/reference/ua/County_Rural_Lookup.xlsx (last access on May 12, 2022).

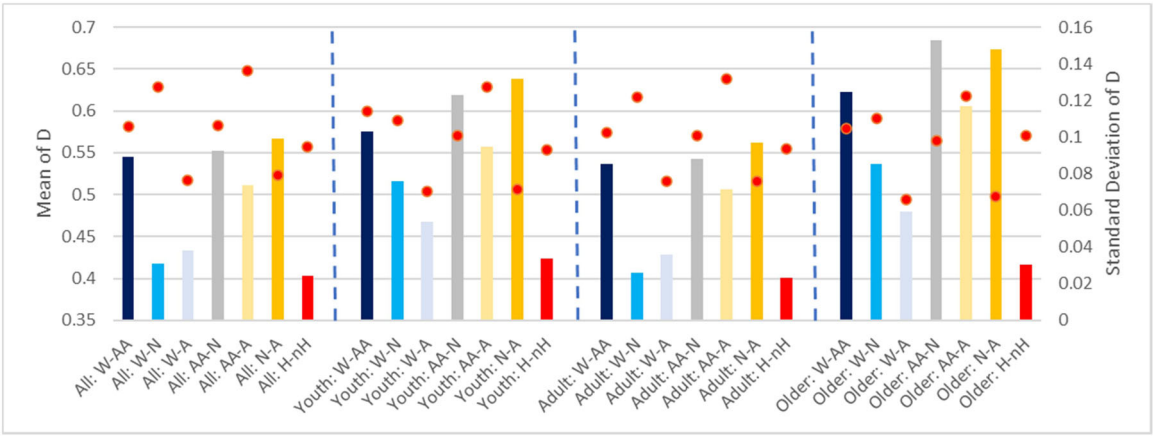

FIGURE 2 Racial-ethnic segregation by age by states: averaged *D* values (vertical bars) and standard deviations of *D* (dots) for the following population groups: W, White; AA, African American; N, Native; A, Asian; H, Hispanic; nH, non-Hispanic.

pattern of racial-ethnic segregation is similar to the patterns for the three age groups, with the highest levels among older adults and lowest among adults. Across all three age groups, the highest segregation levels consistently involved racial minorities such as AA-N for older adults and N-A for youths. For ethnic segregation, youths had a slightly higher level than older adults. Many youth and older adult minority groups had higher segregation levels than other groups and youths and older adults are regarded as the two marginal groups in the study of age in geography (Hopkins & Pain, 2007).

Figure 2 also shows that both W-A and N-A segregations across all age groups have smaller standard deviations than other types of segregations, indicating that the segregation levels of these two group-comparisons were relatively consistent across states regardless of age while other types of comparisons had larger variabilities across states. Variabilities across states will be addressed later with maps. Using census tract data, the *D* index was also computed at the county level to address intrastate variabilities and results are shown in Figure 3.[4]

When comparing the counties results in Figure 3 with those at the state level (Figure 2), one recognisable difference is that the overall racial-ethnic segregation levels at the county level were slightly lower than those at the state level. A straightforward explanation is that the respective population groups were more unevenly distributed within states than within counties. Smaller regions (counties) tend to have lower variability in population compositions and thus smaller *D* values than larger regions (states) with larger composition variabilities and thus larger *D* values. This was the argument provided by Krupka (2007) to explain the observation that larger regions have higher segregation levels than smaller regions. Besides these absolute differences in the average *D* values, results from the county and state levels were mostly consistent across age groups. Older adults had the highest racial-ethnic segregation levels among the three age groups while adults had the lowest levels. Within each age group, segregation for AA-N, AA-A and N-A again had higher segregation levels than other racial group comparisons. On the other hand, across all age groups, W-AA segregation levels were moderate to relatively high. In sum, the state and county analyses offered consistent results and older adults, particularly AA and N, experienced higher racial segregation. However, the variabilities of segregation levels across states and counties need to be examined.

Maps in Figures 4–6 show the *D* values by states in each of the three age groups: youth (Figure 4), adult (Figure 5) and older adult (Figure 6). Each of these figures is a matrix of choropleth maps with each map showing the levels of racial-ethnic segregation between the two groups represented in the respective row-column labels. All maps across the three figures use the same class breaks such that colours and patterns across maps are comparable. While there are many details one may be able to extract from these maps, we highlight the most noteworthy results.

In all age groups, W-A and H-nH have the lowest segregation levels (the lightest colour tones) and the least variations across states, but segregation between these groups involving older adults (Figure 6) were higher compared to the other two age groups (Figures 4 and 5). The relatively high concentrations of Native Americans in the upper Midwest and southwest may have influenced the higher segregation levels between this group and other groups found in these regions.[5] Asian immigrants have a

[4]Dissimilarity index *D* cannot be determined if counties have only one census tract. These counties (240 out of 3143 total counties) are excluded in the county-level analysis. Counties were also excluded if one of the two groups was missing in the county for a two-group comparison. Remaining counties were used to tabulate the statistics of *D* reported here. Our results were highly consistent with results using a minimum threshold of a group of 100 persons per county, a criterion adopted by the County Health Rankings and Roadmaps programme (CHR&R, https://www.countyhealthrankings.org/) to ensure that dissimilarity values are robust, and not severely affected by small population counts. Readers with concerns about the reliability of the *D* index may refer to Carrington and Troske (1997) and Allen et al. (2015).

[5]https://minorityhealth.hhs.gov/omh/browse.aspx?lvl=2&lvlID=26 The 'Minority Population Profiles' site describes the concentrations of minority populations in specific states across the US mentioned in this paragraph.

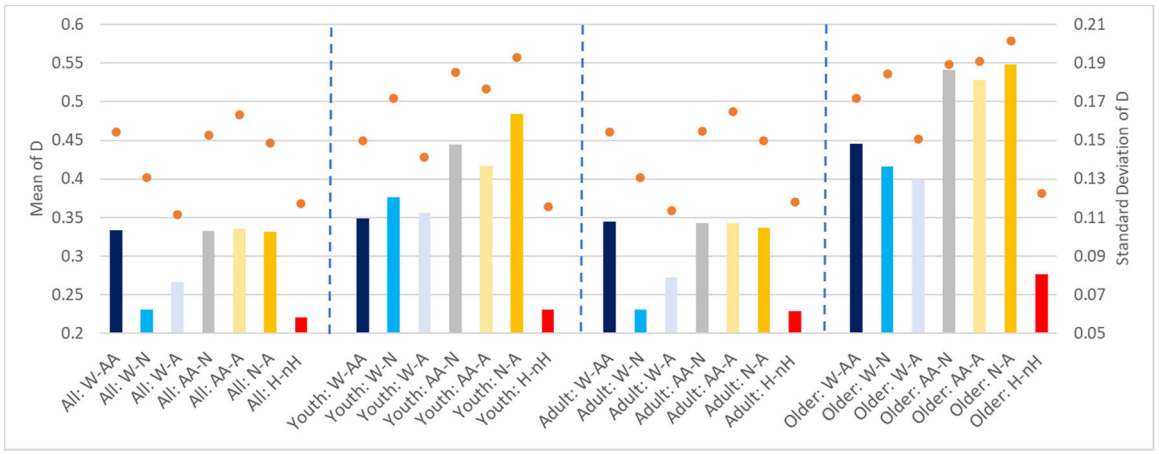

FIGURE 3 Racial-ethnic segregation by age: averaged *D* values (vertical bars) and standard deviations of *D* (dots) by counties for the following population groups: W, White; AA, African American; N, Native; A, Asian; H, Hispanic; nH, non-Hispanic.

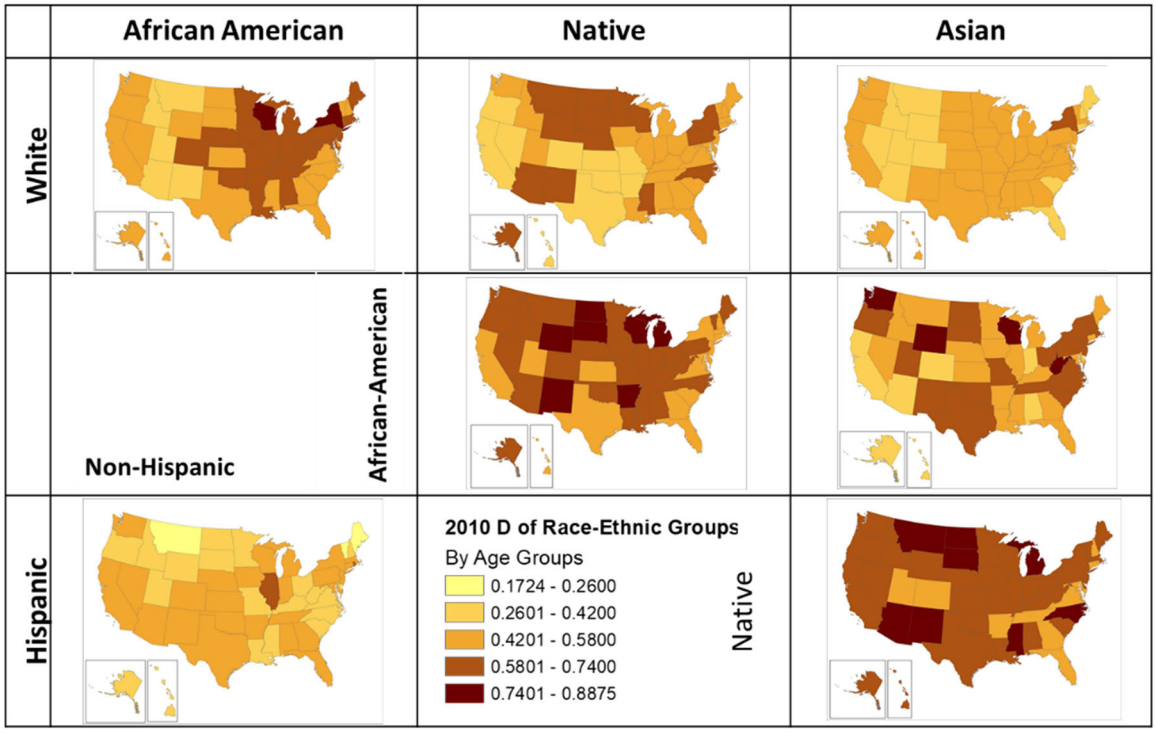

FIGURE 4 Racial-ethnic segregation (*D*) of states: youth

general preference to reside in and around large cities, many of which are found on the east of Mississippi River (e.g., New York, Philadelphia, Chicago, Washington, DC) and along the West Coast (e.g., San Francisco and Los Angeles). Such preference might have produced slightly higher segregation levels for W-A in eastern US and along the West Coast. Similarly, the high concentrations of Hispanics along the southern boarder (California, Arizona, New Mexico and Texas), in Florida, New York and Illinois may have been correlated with the higher segregation levels for H-nH in those states. The correlations of each pairwise racial-ethnic segregation at the state-level across the three age groups range from 0.98 (W-AA between youth and adult) to 0.76 (N-A between youth and older adult). Thus, relative differences in racial-ethnic segregation levels across states have been quite similar between age groups, although older adults had the overall highest levels.

D values computed for the county level provide detailed intra-state spatial variations of racial-ethnic segregation levels by the three age groups. While a comprehensive interpretation of county-level results is beyond the scope of this paper, maps showing the details are available from the corresponding author. With regard to

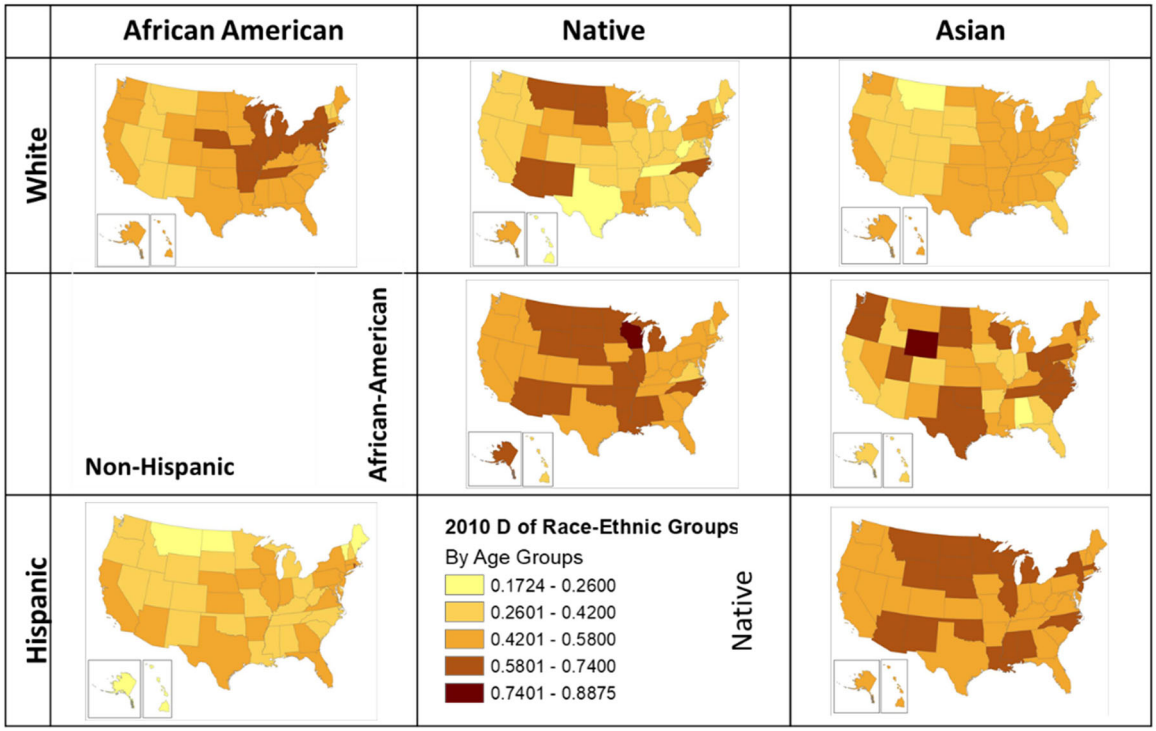

FIGURE 5 Racial-ethnic segregation (*D*) of states: adult

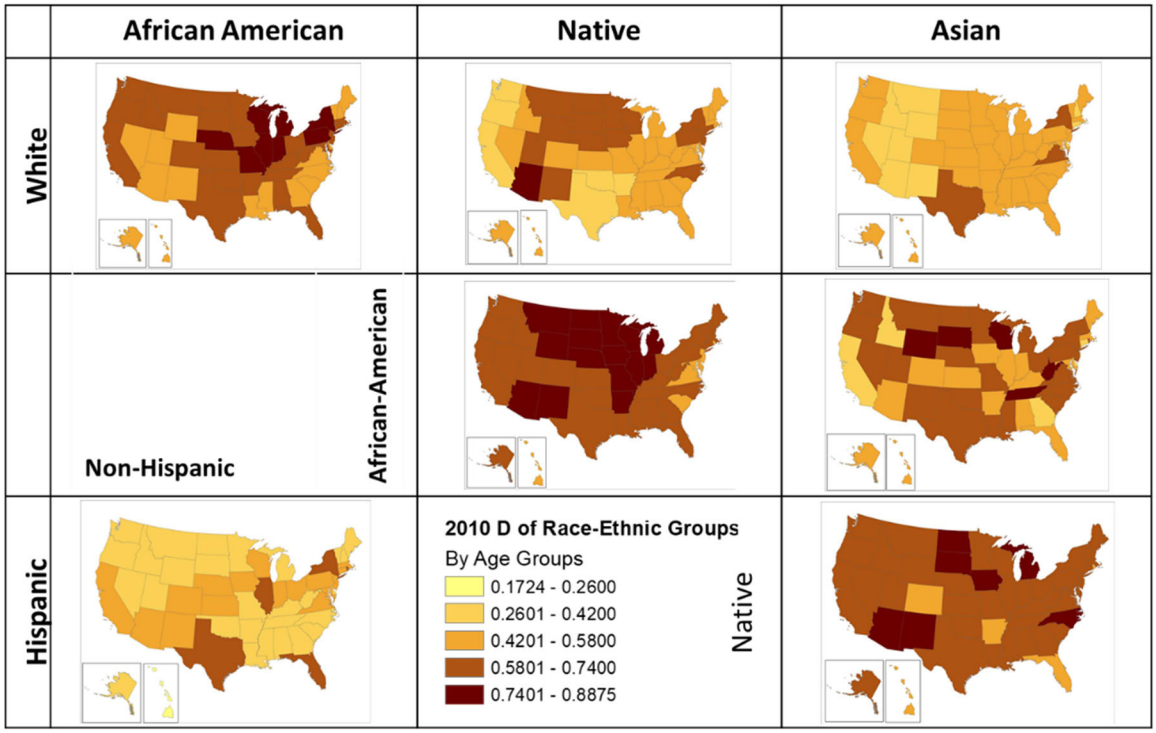

FIGURE 6 Racial-ethnic segregation (*D*) of states: older adult

urban-rural disparities, most racial-ethnic comparisons had means of *D* higher in urban counties than the means of rural counties (Table 1). The *t*-tests showed that the means were mostly statistically different. As indicated in Table 1, selected groups of youth and older adults experienced higher racial-ethnic segregation in the rural than in the urban environment, but this was not the case for adults. We also assessed the correlation between the percent urban population in a county and the racial-ethnic

TABLE 1 Comparing the means of racial-ethnic segregation levels in urban and rural counties by age groups

Age: race-ethnic groups	Urban mean	Rural mean	*t*-test
Y: W-AA	0.39	0.32	***
Y: W-N	0.37	0.38	
Y: W-A	0.35	0.36	***
Y: AA-N	0.43	0.46	***
Y: AA-A	0.43	0.41	***
Y: N-A	0.47	0.49	**
Y: H-nH	0.27	0.20	***
A: W-AA	0.38	0.32	***
A: W-N	0.25	0.22	***
A: W-A	0.29	0.26	***
A: AA-N	0.34	0.34	
A: AA-A	0.37	0.32	***
A: N-A	0.37	0.31	***
A: H-nH	0.26	0.20	***
O: W-AA	0.47	0.42	***
O: W-N	0.44	0.40	***
O: W-A	0.37	0.42	***
O: AA-N	0.55	0.53	***
O: AA-A	0.52	0.54	**
O: N-A	0.55	0.55	
O: H-nH	0.29	0.26	***

Note: Y, youth (0–14 years), A, adults (15–64 years), O, older adults (≥65 years). W, Whites, AA, African Americans, N, Natives, A, Asians; H, Hispanics; nH, non-Hispanics. Grey shaded cells: Rural mean greater than urban means. $^{**}p < 0.05$, $^{***}p < 0.01$.

segregation levels by age.[6] All types of racial segregation are positively and significantly correlated with the percent of urban population in a county, but the strengths of correlation vary from mild (e.g., W-AA and H-nH for all age groups with a range of 0.28–0.44) to very weak (W-A for youths [0.11] and older adults [0.04]). Racial-ethnic segregation has been traditionally viewed as an urban phenomenon (Massey & Denton, 1993). But when the age axis intersects with race-ethnicity, the geographical disparities of segregation across urban and rural areas become far from clear.

[6]Full correlation results are not reported in the article. Interested readers may contact the corresponding author.

The results above show that segregation levels between non-whites were higher than those involving whites. Racial segregation patterns across the country seemed to have been influenced by the spatial mismatches of minority group concentration patterns, but segregation levels were higher for older adults than for the other age groups. Urban-rural differences in racial-ethnic segregation levels were not uniform across age groups. Thus, the age-race-ethnic intersectional approach highlighted the segregation burdens of minority older adults.

4.2 | Age segregation by race

Figure 7 shows the distributions of mean age segregation across states by racial-ethnic groups. Segregations of adult-older adult for different racial-ethnic groups (bars in the middle batch) are higher than the two other age-group comparisons overall (youth-adult and youth-older adult), and the youth-older adult segregations (bars in the last batch) for most racial-ethnic groups were relatively low. These results are surprising as youth-older adults are expected to have larger generational distance than other age-group comparisons (Das Gupta & Wong, 2022; Luszcz & Fitzgerald, 1986) and thus should have higher segregation levels than those for the other two age-group comparisons. In general, Whites (W) and Asians (A) have the lowest age segregation levels and the age segregation for Natives (N) and African Americans (AA) were in general high, particularly between adult and older adult, and their *D* values varied largely across states. However, both Hispanic and non-Hispanic (last two bars in each batch) have moderate to high age segregation for all age-group comparisons.

The *D* index was also computed for age segregation by racial-ethnic groups at the county level and results are reported in Figure 8. Comparing the county results with those at the state level (Figure 7), several differences are recognisable. The state-level results show that adult-older adult comparisons for all races had the highest segregation, but at the county level, youth-older adult (last batch of bars in Figure 8) had the highest segregation, followed by adult-older adult and youth-adult. The orders of these three age-group comparisons at the county-level are more aligned with the expectations based on generational distances between these three age groups. Across all age-group comparisons, Natives had the highest segregation, followed by Asians, African Americans and Whites. Also, Hispanics had higher age segregation than non-Hispanics. These county-level patterns are not consistent with the state-level patterns depicted in Figure 7. A curious pattern is also revealed in Figure 8. All non-White racial groups had higher age segregation levels at the county than at the state level. Also, Hispanics had lower segregation than non-Hispanics at the state level, but the situation is opposite at the county level. These inconsistencies between the state and county level analyses reveal the nature of age segregation at different geographical scale. States are relatively large such that they likely encompass multiple groups, and thus not segregated. Counties are relatively small such that some groups are not well represented, allowing other group(s) to dominate, and thus more segregated. In other words, age segregation was relatively pronounced at the local scale, partly due to the significantly smaller

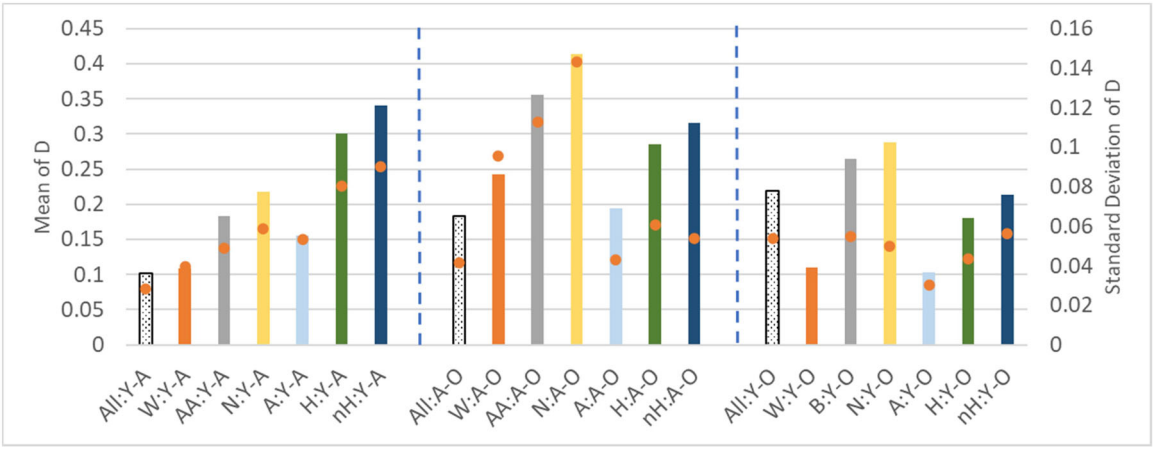

FIGURE 7 Distributions of age segregation levels (*D*) and standard deviations of *D* (dots) by racial-ethnic groups at the state level, 2010. (Y, youth; A, adult and O, older adults) and racial-ethnic groups (W, White; AA, African American; N, Native; A, Asian; H, Hispanic; nH, non-Hispanic).

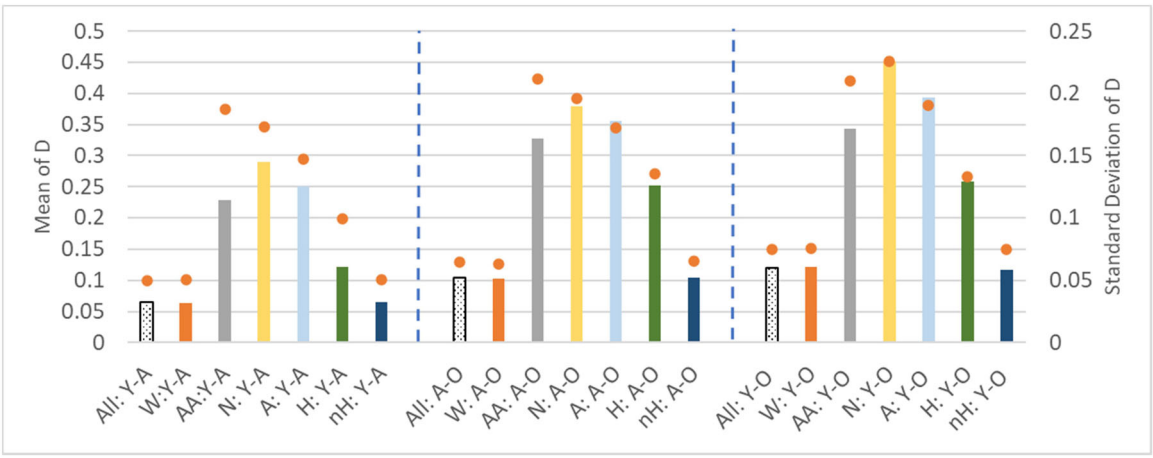

FIGURE 8 Distributions of age segregation levels (*D*) by racial-ethnic groups at the county level, 2010. (Y, youth; A, adult, and O, older adults) and racial-ethnic groups (W, White; AA, African American; N, Native; A, Asian; H, Hispanic; nH, non-Hispanic).

sizes of certain groups. In short, age segregation results were inconsistent across state and county.

How *D* values varied across states are shown in Figure 9. Again, class break values for all maps are identical such that patterns can be compared across maps. Although regional clusters or spatial trends can be identified in most of the maps, in general, different racial-ethnic groups had different geographical patterns in age segregation levels, and given a racial-ethnic group, age segregation patterns across states are also different for different age comparisons. These variabilities imply that age segregations across racial-ethnic groups were highly heterogeneous. Nevertheless, Figure 9 demonstrates the utility of the intersectional approach to study segregation, showing the specific situations or outcomes corresponding to each age-race-ethnic context.

Age segregation in *D* values by race-ethnicity by counties are mapped. Interested readers can obtain a copy from the corresponding author. Means of age segregation for urban and rural counties for all racial-ethnic groups were statistically different based on *t*-test (Table 2). Means of age segregation of urban counties were higher than rural counties for all White, non-Hispanic, and most Native age comparisons, but the means of age segregation of urban counties were lower than rural counties for all African American, Asian and Hispanic age comparisons.

The moderate to high correlations (from 0.43 to 0.63) of age segregation of Whites and non-Hispanics with urban level indicate that urbanity favoured greater age segregation for Whites and non-Hispanics. However, correlations between age segregation and urbanity for other racial-ethnic groups were low (Natives and Hispanics: between 0 and 0.25) or even negative (Asians and African Americans: between −0.06 and −0.16), indicating that the role of urban-rural setting in influencing age segregation of these groups is less than clear.[7] Age segregations involving older adults (A-O and Y-O) were more positively correlated with urban setting

[7]Again, full correlation results are not reported in the article. Interested readers may contact the corresponding author.

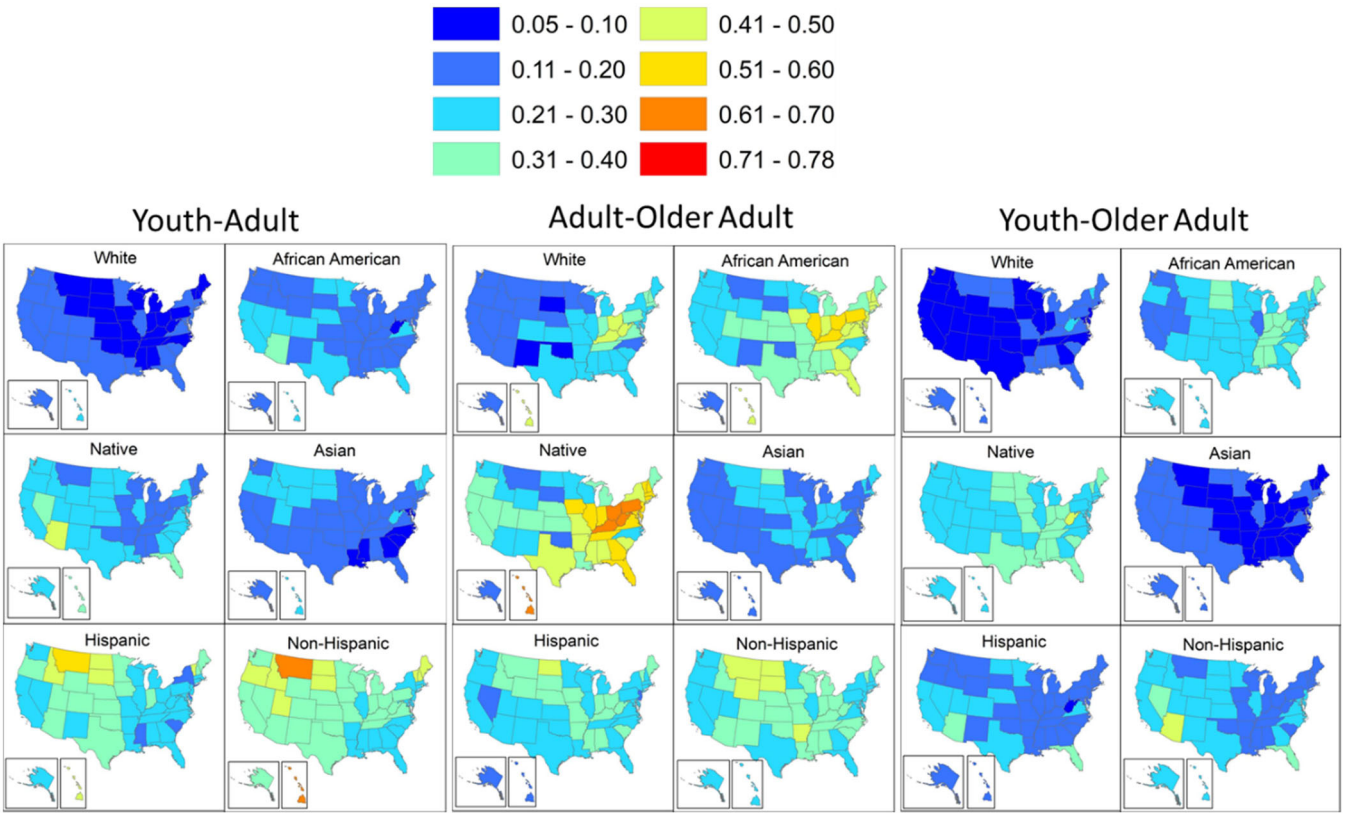

FIGURE 9 Age segregation (*D*) of states by racial-ethnic groups: 2010

than those not involving older adults (Y-A) across all racial-ethnic groups. This finding is generally consistent with a previous finding examining overall age segregation and reporting that urban areas had higher levels of age segregation than rural areas (Das Gupta & Wong, 2022). But the current study provides further details that the urban environment had the greatest influence on the age segregation of Whites and non-Hispanics involving older adults, while the rural setting was more salient for selected racial-ethnic groups, particularly African Americans, Asians and Hispanics.

Results of age segregation by race-ethnicity show that youth-older adult was the most segregated with minorities of these two age groups having the highest segregation levels. Age segregation was manifest with dissimilar geographical patterns across racial-ethnic groups at the state level, implying that the age segregation process may be racial-ethnic group specific. Similarly, the urban and rural environments revealed disparate levels of age segregation of different racial-ethnic groups.

5 | ANALYSIS RESULTS USING MULTIGROUP/GENERAL DISSIMILARITY

The D_m was used to evaluate multiple groups of racial, age, ethnic-age and race-age segregation at both the state and county levels. As these two levels yielded similar results, the following discussion focuses on the county-level results.[8] Distributions of D_m values of all types of comparison at the county level are shown in Figure 10. The first batch of bars shows racial segregation (W, AA, N and A) with all age groups combined and each age groups separately (youth-Y, adult-A and older adult-O). The second batch of bars indicates age segregation with all racial groups combined and separately. Age segregation of the two ethnic groups (H and nH) are shown by the two following bars. The last two bars are the combined ethnicity-age segregation (six groups) and race-age segregation (12 groups).

A comparison of the first two batches of bars in Figure 10 (racial segregation by age and age segregation by race) indicates the following interesting patterns. Racial segregation levels were higher than age segregation levels with racial segregation of older adults at the highest level. For age segregation, racial minority groups (AA, N and A) had much higher levels than that of Whites. With multiple groups considered together, results reveal the higher racial segregation burden of older adults and higher age segregation burden of racial minorities. While D_m is therefore useful in offering a summary on segregation levels when multiple groups are involved, it, however, fails to pinpoint the specific groups contributing to segregation.

[8]The state and county results of D_m are in general similar with racial segregations higher than age segregation among all types of comparisons. Racial segregation at the state level were at least 50% higher than that at the county level, showing that race is an important segregation driver at the state level as compared to age. State-county segregation differences are also reported earlier for the two-group measures. To streamline the presentation of results and focus on the use of the multigroup index, only county-level results are discussed here.

We mapped the D_m values at the county level and interested readers again may obtain these maps from the corresponding author. To depict the spatial patterns across the country, state-level results are shown in Figure 11, which includes three maps showing (a) racial segregation of all age groups combined (first batch-first bar in Figure 10), (b) age segregation of all racial groups combined (second batch-first bar in Figure 10), and (c) the age-racial segregation of the 12 groups cross-defined by age and race (last bar in Figure 10) at the state level. Classes in these maps were determined using the quantile method, mainly because the three types of segregation had very different ranges. Racial segregation (Figure 11a) had the highest levels (from 0.33 to 0.66) and age segregation (Figure 11b) had the lowest levels (from 0.07 to 0.22), while age-race segregation levels of the 12 groups (Figure 11c) were in between (from 0.11 to 0.51), a pattern consistent with the relative segregation levels by racial, age and age-race groups depicted in Figure 10. The quantile method puts states into five classes according to their relative segregation levels, assigning about equal number of states to each class.

States with the highest racial segregation levels were interspersed around the Great Lake region and Midwest while the three northeast New England states and several states in the west had the lowest racial segregation levels (Figure 11a). This pattern is in stark contrast, if not entirely opposite to the age segregation pattern depicted in Figure 11b where low age segregation states were found in the Appalachian and the south around the Mississippi delta and high age segregation states were mostly found in the west.

When considering age and race together (Figure 11c), it is important to note that the spatial patterns of segregation considering 12 groups are not simply a mashing together of the patterns from the two individual types of segregation in Figure 11a,b. Except the three New England states which were low in all the three maps (Figure 11a–c), the distinctive patterns in Figure 11c highlight the utility of an intersectional approach in further informing our understanding on segregation. For instance, the set of southern states (from Georgia to Louisiana) were not high on age or racial segregation, but they stood out when considering both age and race together.

Similar to previous analyses, we also assess if the urban-rural setting might have had an impact on D_m at the county level. Table 3 shows that except for age segregation of African American, the means of D_m for urban and rural counties were significantly different

TABLE 2 Comparing the means of age segregation levels in urban and rural counties by racial-ethnic groups

Race: Age groups	Urban mean	Rural mean	*t*-test
W: Y-A	0.09	0.05	***
W: A-O	0.14	0.08	***
W: Y-O	0.16	0.09	***
AA: Y-A	0.20	0.25	***
AA: A-O	0.32	0.34	***
AA: Y-O	0.33	0.36	**
N: Y-A	0.28	0.30	***
N: A-O	0.40	0.36	***
N: Y-O	0.46	0.44	***
A: Y-A	0.20	0.28	***
A: A-O	0.30	0.40	***
A: Y-O	0.33	0.45	***
H: Y-A	0.11	0.13	***
H: A-O	0.24	0.26	***
H: Y-O	0.24	0.27	***
nH: Y-A	0.09	0.05	***
nH: A-O	0.14	0.08	***
nH: Y-O	0.16	0.09	***

Note: Y, youth (0–14 years), A, adults (15–64 years), O, older adults (≥65 years). W, Whites, AA, African Americans, N, Natives, A, Asians; H, Hispanics; nH, non-Hispanics. Grey shaded cells: Rural mean greater than urban means. $^{**}p < 0.05$, $^{***}p < 0.01$.

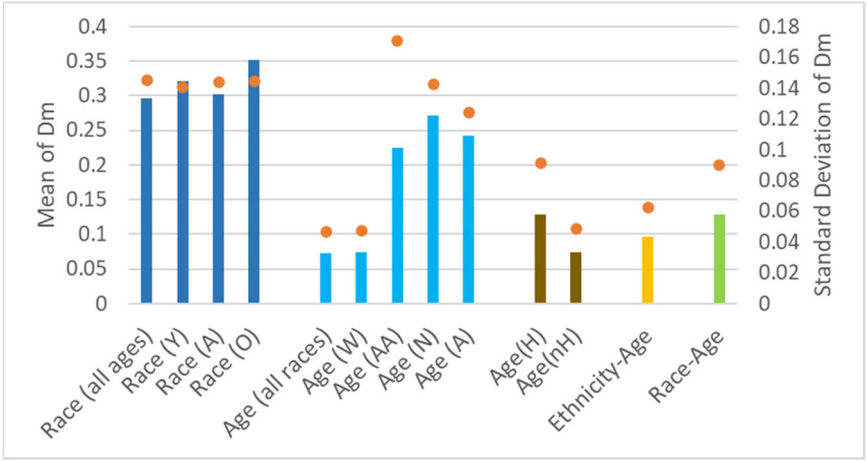

FIGURE 10 Averaged D_m values (vertical bars) and standard deviations of D_m (dots) by counties for the following population groups: racial segregation with all age group combined and separately (Y, youth; A, adult; O, older adults), age segregation with all races combined and separately (W, White; AA, African American; N, Native; A, Asian; H, Hispanic), age segregation by ethnic groups, ethnic-age segregation and segregation of 12 groups cross-classified by age and race.

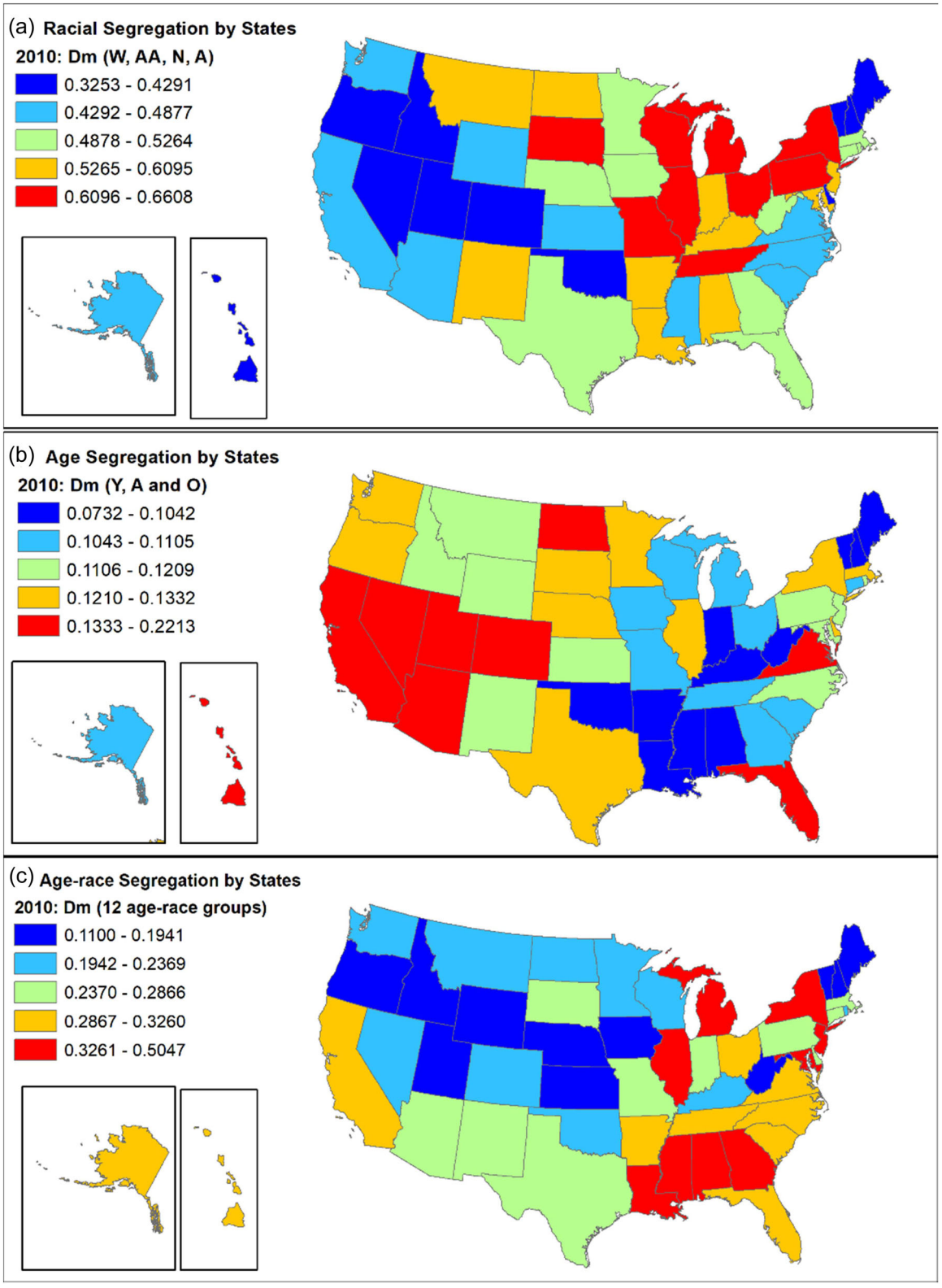

FIGURE 11 Racial segregation (a: White, African American, Native and Asian), age segregation (b: youth, adult and older adult) and age-racial segregation (c: 12 groups cross-defined by three age groups and four racial groups) as reflected by D_m by states, 2010. Quantile method was used in determining the map classes.

TABLE 3 Comparing the means of segregation levels (D_m) in urban and rural counties by race, age, ethnicity-age and race-age categories

Race-Age groups	Urban mean	Rural mean	*t*-test
Race (all ages)	0.34	0.27	***
Race (Y)	0.36	0.29	***
Race (A)	0.34	0.27	***
Race (O)	0.39	0.32	***
Age (all races)	0.10	0.06	***
Age (W)	0.10	0.06	***
Age (AA)	0.20	0.24	***
Age (N)	0.28	0.27	
Age (A)	0.20	0.27	***
Age (H)	0.12	0.14	***
Age(nH)	0.10	0.06	***
Ethnicity-Age	0.13	0.07	***
Race-Age	0.17	0.10	***

Note: Y, youth (0–14 years), A, adults (15–64 years), O, older adults (≥65 years). W, Whites, AA, African Americans, N, Natives, A, Asians; H, Hispanics; nH, non-Hispanics. Grey shaded cells: Rural mean greater than urban means. ***$p < 0.01$.

for all comparisons based on *t*-tests. In addition, urban counties had higher segregation levels for all comparisons except for age segregation of African Americans, Asians and Hispanics. In addition, D_m for age segregation and urban level were not correlated or negatively correlated for nonwhite racial groups and Hispanics. Thus, the urban environment may have played little to no role in nonwhite age segregation and Hispanic-age segregation.

6 | CONCLUSION

Methodologically, the current study demonstrates that the application of the 2-group dissimilarity *D* to measure segregation involving age and race allows either of the two population axes to serve as the conditional axis that is held constant to measure the segregation of subgroups of the other axis. This conditional approach offers a systematic framework applicable to segregation studies involving more than one population axis. Empirical results from *D* and D_m using 2010 census tract data provide detailed and mostly consistent information about group relationships. Analyses from both the two-group and multi-group indices, show that non-Whites experienced higher age segregation than Whites while older adults experienced higher racial segregation than the other two age groups. Results from both the *D* and D_m also show that the racial-ethnic axis had been a stronger force in segregation than the age axis. We also show that the multi-group dissimilarity D_m offers the convenience of summarising the segregation level of all groups of an axis, or all groups of two axes together, but the trade-off is failing to pinpoint which specific groups contribute to segregation significantly. Nevertheless, comparison of D_m results show that states with high segregation levels in one or both axes did not necessarily have high segregation levels for the 12 race-age groups

We also aimed to examine whether race-ethnic-age segregation varied between urban and rural settings. The levels of almost all types of segregation were statistically different between urban and rural areas. While higher racial-ethnic segregation levels for most group comparisons were correlated with the urban setting, the higher segregation levels of selected racial-ethnic pairs for youths (e.g., White-Asian and African American-Native) and older adults (e.g., White-Asian and African American-Asian) were associated with the rural setting. Higher age segregation involving Whites and non-Hispanic older adults were strongly associated the urban setting, but the influence of urban setting on age segregation of minority groups had been inconsequential.

Thus, the current study breaks new ground in several directions. Most studies on age segregation did not consider racial-ethnic differences within each age group, assuming that population within each age group is relatively homogeneous or within-group variability may be ignored. Our results revealed that racial-ethnic segregation can be quite different across age groups, and age segregation exhibited different patterns across racial-ethnic groups. The conceptualisation of age-race-ethnic segregation should be predicated on an empirical assessment of segregation involving these two population axes, but no prior study has conducted such an analysis. Our results based on the conditional approach and the urban-rural comparison revealed cross-sectional patterns and provide the framework for future analyses to conceptualise age-race-ethnicity segregation. An additional future direction could be to examine whether the patterns in age-race-ethnic segregation, particularly for the minority older adult group, sustained or changed over time. A third line of inquiry could further unravel factors driving urban/rural disparities for specific age-race-ethnic groups.

We also aimed to evaluate whether marginalised groups at the intersection of the race-ethnic and age axes experienced segregation burdens from the two axes. Our results point to the importance of considering intersectionality of race-ethnicity and age segregation, and to a large degree, substantiate the argument that intersectionality is a meaningful concept in studying racial-ethnic segregation involving additional axes (Hopkins, 2019; Hopkins & Pain, 2007). Among the three age groups we studied, older adults were in general the most severely impacted by racial-ethnic segregation across all racial-ethnic groups, while the segregation levels were higher when Natives or Asians were involved in the comparisons. Age segregation between older adults and youths was the highest compared to the other two age comparisons but age segregation levels for non-White groups were higher than Whites. Taking both race and age together, minority older adults had relatively larger segregation burdens than Whites and younger groups. Thus, one should not be 'colour-blind' when age is studied AND should not be 'age-neutral' when race-ethnicity is studied. The segregation of age-race-ethnicity groups,

including spatial patterns, is more than simply 'adding' age segregation and racial-ethnic segregation together. The whole is bigger than the sum of the parts.

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DATA AVAILABILITY STATEMENT

The data that support the findings of this study are available in National Historical GIS at https://www.nhgis.org/. These data were derived from the following resources available in the public domain: 2010 U.S. Census, https://www.nhgis.org/.

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