Cumulative exposure to extreme heat and trajectories of cognitive decline among older adults in the USA

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ABSTRACT

Background The projected increase in extreme heat days is a growing public health concern. While exposure to extreme heat has been shown to negatively affect mortality and physical health, very little is known about its long-term consequences for late-life cognitive function. We examined whether extreme heat exposure is associated with cognitive decline among older adults and whether this association differs by race/ethnicity and neighbourhood socioeconomic status.

Methods Data were drawn from seven waves of the Health and Retirement Study (2006–2018) merged with historical temperature data. We used growth curve models to assess the role of extreme heat exposure on trajectories of cognitive function among US adults aged 52 years and older.

Results We found that high exposure to extreme heat was associated with faster cognitive decline for blacks and residents of poor neighbourhoods, but not for whites, Hispanics or residents of wealthier neighbourhoods.

Conclusion Extreme heat exposure can disproportionately undermine cognitive health in later life for socially vulnerable populations. Our findings underscore the need for policy actions to identify and support high-risk communities for increasingly warming temperatures.

WHAT IS ALREADY KNOWN ON THIS TOPIC

⇒ Extreme heat is a significant public health threat, with its frequency and severity projected to increase.
⇒ Exposure to extreme heat has been linked to a range of adverse health outcomes, including mortality and diseases.
⇒ Recent studies suggest that high temperatures may damage cognitive function. However, findings are based on momentary cognitive assessments and samples that fail to capture potential variation across the population.

WHAT THIS STUDY ADDS

⇒ This study is the first to examine the long-term impact of extreme heat on cognitive trajectories over time, and we use a nationally representative sample of US older adults.
⇒ High exposure to extreme heat can affect cognitive decline, but does so unequally across the population.
⇒ Exposure to extreme heat is associated with a faster cognitive decline for blacks but not whites or Hispanics, and for residents of poor but not wealthier neighbourhoods.

HOW THIS STUDY MIGHT AFFECT RESEARCH, PRACTICE OR POLICY

⇒ The findings call for future research examining the mechanisms linking extreme heat exposure to cognitive decline and reasons for observed disparities.
⇒ Public health strategies aimed at preserving cognitive health in older adults should consider extreme heat as an important contributing factor for cognitive ageing especially among socially vulnerable groups.
⇒ Policy actions should prioritise protecting at-risk populations and building resilient communities to rising temperatures.

INTRODUCTION

Extreme heat is a serious public health threat,[1] with its impact expected to worsen as the frequency and intensity of heat exposure increase. The average number of heat waves per year has tripled from two in the 1960s to six in the 2020s. In 2021, an alarming 46% of Americans endured at least three consecutive days of heat ≥100°, and by 2053, two-thirds of the population are projected to face perilous heat waves.[2] The severity of extreme temperatures has exacted a substantial toll on mortality rates, positioning extreme heat as the leading cause of weather-related deaths in the USA.[3]

As extreme heat events become more frequent and intense, it is increasingly important to understand their cumulative effects among older adults. This demographic faces an elevated risk of heat-related health problems due to reduced thermoregulatory function associated with ageing, which hampers blood circulation and may lead to inefficient sweat gland activity. Furthermore, older adults are more likely to experience chronic conditions such as heart, lung and kidney diseases and take prescription medicines that can impact their ability to perspire effectively. These factors heighten their susceptibility to hyperthermia and heat stroke following exposure to high temperatures,[4] which can have a range of severe neurological consequences.[5]

Cognitive decline may not manifest immediately after a single heat event but may ensue following repeated or prolonged exposures to extreme heat. Cumulative exposure to such heat conditions can trigger a cascade of detrimental effects in the brain, including cellular damage, inflammation and oxidative stress, which can exhaust cognitive reserve

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at a faster rate and accelerate cognitive decline.[6] Yet, previous studies have focused primarily on the immediate effect of hot temperatures on older adults' cognitive performance within experimental[7] or cross-sectional settings.[8] These findings are also restricted to specific samples from single states or hospitals, which limits our understanding of population-level implications of heat exposure.

Furthermore, no research has explicitly examined differential vulnerability to extreme heat, although certain subgroups of older adults may be more vulnerable due to social and structural circumstances.[9] For instance, black older adults may be at an increased risk relative to white older adults because, growing up in the early and mid-20th century, social conditions were vastly different due to discriminatory policies, residential segregation and limited access to quality education.[10–12] These disadvantages, along with persistent exposure to discrimination, poverty and chronic stress, can contribute to cumulative wear and tear on the body and decreased cognitive reserve,[10 11 13] potentially increasing the physiological susceptibility of black older adults to the impacts of extreme heat.

Another factor that can increase the vulnerability of extreme heat on older adults is neighbourhood socioeconomic status (SES). Neighbourhoods with higher levels of disadvantage often have poorly maintained built environment, limited access to resources and higher levels of stress due to crime activity, all of which can further exacerbate cognitive decline when coupled with exposure to extreme heat. Conversely, affluent neighbourhoods, often characterised by the large share of highly educated adults in professional occupations, may have more protective factors against extreme heat. Affluent neighbourhoods tend to foster a certain set of beneficial commercial conditions and institutions (eg, well-maintained green space, air-conditioned local commercial venues and cooling centres),[14 15] which can mitigate the adverse effect of extreme heat. In the studies on the 1995 Chicago heat wave, individuals living in more affluent neighbourhoods were less likely to die from the heat due to viable commercial activity.[16 17] While the 1995 Chicago heat wave renewed concern about extreme heat in health disparities among older, poor and black residents,[16 17] it remains unknown whether the cognitive consequences of extreme heat exposure are exacerbated among these subgroups of the older American population.

In this study, we explore whether cumulative exposure to extreme heat is associated with faster cognitive decline and how the consequences of extreme heat exposure may differ by race/ethnicity and neighbourhood SES. We use the Health and Retirement Study (HRS), one of the largest nationally representative longitudinal data sources that includes assessments of changes in cognitive function and residential environment. We hypothesise that exposure to extreme heat is associated with faster cognitive decline in later life and that the association of extreme heat with faster cognitive decline is more pronounced among racial/ethnic minorities and residents of poor neighbourhoods.

METHODS

Data

We used data from the 2006 to 2018 waves of the HRS, a national biennial panel survey of US adults aged 50 and older. Information on extreme heat days was obtained from the Centers for Disease Control and Prevention National Environmental Public Health Tracking Network (NEPHTN).[18] Data on socioeconomic conditions for each census tract were from the US Census Bureau's American Community Survey 5-Year estimates (2006–2010).[19] A total of 14 454 community-dwelling HRS respondents aged 52 and older completed the cognitive function assessment in 2006 and at least one follow-up assessment. After omitting 307 participants missing data on census tract, we limited the sample to those who had not moved to another tract over the study period, resulting in 9673 respondents. We also restricted the sample to non-Hispanic white, non-Hispanic black and Hispanic respondents, as sample sizes in other racial/ethnic categories (n=201) were too small for subgroup analyses. Further, those missing

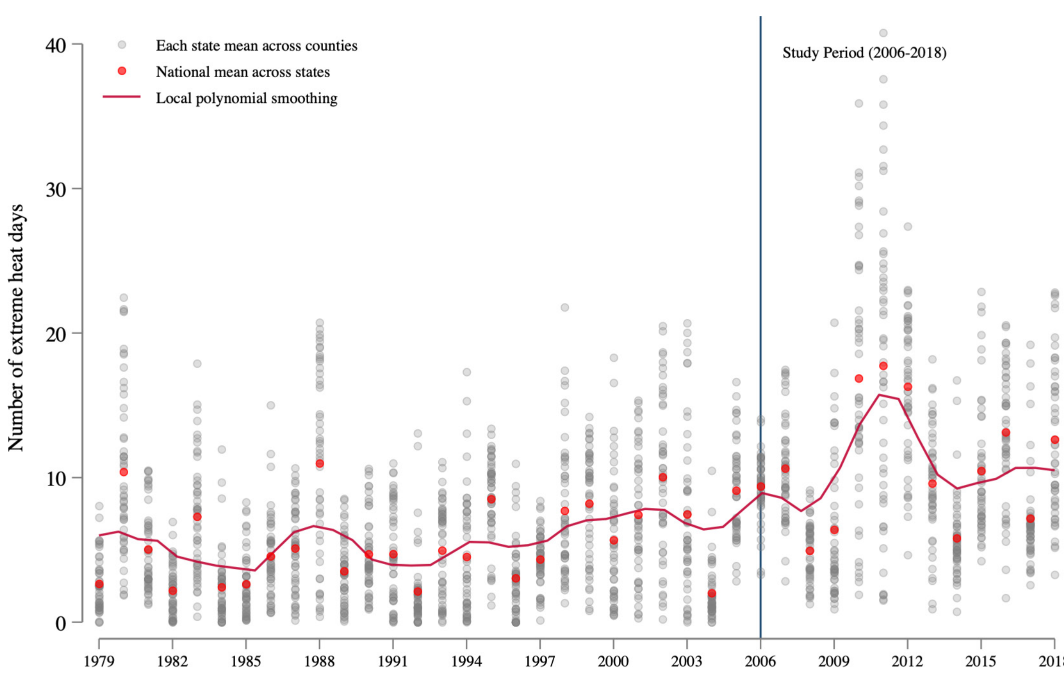

Figure 1 Yearly average number of extreme heat days, USA, 1979–2018. Note: Data were not available for Alaska and Hawaii.

data on the other variables were excluded (n=24), leaving an analytical sample of 9448.

Measures

Extreme heat refers to temperatures substantially higher than usual for a given area. A relative threshold is preferred in the heat-health literature because it accounts for the variability in absolute temperatures across climate zones and human acclimatisation to warmer temperatures.[20] The total number of extreme heat days from May to September for each census tract was obtained from the NEPHTN for 2006 to 2018. An extreme heat day is defined as a day when the maximum heat index reached or exceeded the location-specific 95th percentile threshold based on historical observations from 1979 to 2021.

To assess cumulative exposure to extreme heat, we created a measure representing the average number of extreme heat days per year over the course of each HRS participant's follow-up period up to the year preceding the last assessment. For example, if one's last cognitive assessment was 2014, we calculated the average number of extreme heat days per year from 2006 to 2013. Higher values of this measure indicate that the participant experienced a higher cumulative exposure to extreme heat. For analysis, we used a binary measure of extreme heat exposure due to its non-linear association with cognitive outcomes.[21 22] High exposure is coded as a level that falls within the highest quintile, which corresponds to 13.1 days or more of extreme heat. We also conducted sensitivity analyses using a continuous measure of extreme heat.

Cognitive function was measured with an adapted version of the Telephone Interview for Cognitive Status (TICSm) with three domains: (1) immediate and delayed 10-noun recall tests to assess episodic memory, (2) a serial seven subtraction test to assess working memory and (3) a counting backward test to assess speed of mental processing.[23] The composite scores range from 0 to 27, with higher scores indicating better function. The TICSm has been validated as a measure of cognitive function across different populations and is widely used in large-scale surveys of older adults.[24 25]

Moderating subgroups were based on individual race/ethnicity and neighbourhood SES. For neighbourhood SES, we used a three-tier categorisation for each census tract: average, disadvantaged and affluent. The classification of disadvantaged neighbourhoods was derived through a z-scored composite of five census tract-level indicators (Cronbach's alpha=0.80): % of households on public assistance, % of persons with below poverty-level income, % unemployed, % of female-headed households with children and % without high school degree. Neighbourhoods were classified as disadvantaged if their composite score was greater than or equal to 1 SD above the mean. Affluent neighbourhoods were determined by two census tract-level indicators (Cronbach's alpha=0.93): % of adults (25 years and older) with at least 16 years of education and % of professionals and managers. Those with a composite score equal to or higher than 1 SD above the mean were classified as affluent. Average neighbourhoods include all remaining census tracts not defined as either disadvantaged or affluent.

Covariates included sex, living arrangement (living alone, not married/partnered; living with someone else), educational attainment (some college or above; high school or below), household wealth (sum of all non-housing wealth components less debt), urbanicity (urban, rural) and years of follow-up. We also controlled for region to account for potential confounding by the concentration of black populations and hot days in the South. Due to the highly skewed distribution, household wealth was transformed using an inverse hyperbolic sine transformation in the growth curve models (GCMs). Living arrangement and household wealth were time-varying.

Statistical analysis

We used a GCM to estimate baseline level of cognitive function and its rate of change with age. GCM handles partially missing data typically present in longitudinal data and performs well compared with multiple imputation methods.[26] In our data, multiple observations of cognitive function across time (level 1) are nested within persons (level 2). The mean number of observations per respondent was 5.4. Time was modelled by age and

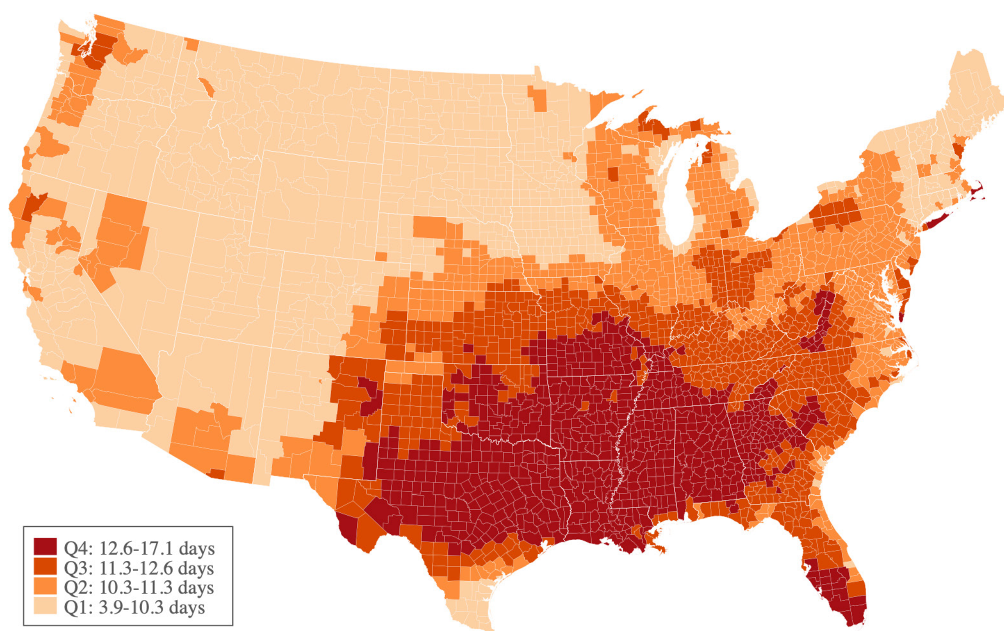

Figure 2 Geographical distribution of average number of extreme heat days, USA, 2006–2018. Q=quartile. Note: County-level average numbers of extreme heat days were categorised in quartiles, with the fourth quartile (Q4) having the most.

Table 1 Summary statistics of sample, US Health and Retirement Study, 2006

Variables	Mean (SD)	%
Outcome		
Cognitive function (range: 0–27)	16.1 (4.3)	
Exposure		
High exposure to extreme heat*		17.3
Subgroups		
Race/ethnicity		
Non-Hispanic white		83.3
Non-Hispanic black		9.3
Hispanic		7.4
Neighbourhood SES†		
Average neighbourhood		70.5
Disadvantaged neighbourhood		11.6
Affluent neighbourhood		17.9
Covariates		
Age in years (range: 52–104)	65.0 (9.5)	
Female sex		54.8
Living alone, not married/partnered		19.6
≥ Some college education		49.2
Household wealth	$377K ($1099K)	
Region		
Northeast		18.0
Midwest		26.7
South		37.7
West		17.7
Urbanicity		76.2
Years of follow-up (range: 2–12)	9.3 (3.5)	

*Exposure to extreme heat was measured as the average number of extreme heat days per year during the participant's follow-up period, up to the year preceding their last cognitive assessment. High exposure was defined as a level that falls within the highest quintile, which corresponds to 13.1 or more days of extreme heat.
†Disadvantaged neighbourhoods refer to census tracts scoring 1 SD above the average on a composite index of area socioeconomic disadvantages (eg, % residents living in poverty). Affluent neighbourhoods are defined as census tracts scoring 1 SD above the mean on a composite index of socioeconomic advantages (eg, % residents with college education). Average neighbourhoods include all other census tracts not classified as either disadvantaged or affluent; all statistics were weighted.
SES, socioeconomic status.

centred at age 65. Preliminary analyses showed a curvilinear pattern of cognitive decline with age, so all models included an age-squared term.

We fitted a series of models to test our research hypotheses with attention to model parsimony. First, we examined the association of extreme heat exposure with cognitive trajectories adjusting for covariates. This was done by modelling an interaction between the heat variable and the linear term for age. The interaction with age-squared was not significant and therefore excluded. Second, we tested whether the association between extreme heat and cognitive trajectory differs by race/ethnicity and neighbourhood SES. In addition to heat, other covariates were also interacted with linear age to allow for differences in the rate of change in cognitive function. Preliminary analyses showed no significant interactions between age-squared and all covariates and, thus, we excluded them. The full specification of our models is provided in online supplemental appendix 1. All analyses were weighted to make the estimates population-representative. Data were analysed using Stata V.17.0 (StataCorp).

RESULTS

Figure 1 displays the yearly number of extreme heat days for May–September across states from 1979 to 2018. Each grey dot represents the state-mean value across counties, revealing that the number of extreme heat days differs substantially between states. Red dots represent the national means across states, and the local polynomial smoothed line indicates the gradually increasing trend of the extreme heat days, particularly over the exposure period for our sample (2006–2018). Figure 2 shows geographical disparities in extreme heat during over the same period, with the most extreme heat days disproportionally concentrated in the southern region. There are an average of 12.6 hot days in the South compared with 10.5, 10.8 and 9.2 in the Northeast, Midwest and West, respectively.

Table 1 shows the weighted sample characteristics in 2006 and extreme heat exposure during the study period. The mean cognitive function score was 16.1. 17.3% of our sample experienced high cumulative exposure to extreme heat. This group had at least 13.1 extreme heat days per year, with a maximum of 23.3 days. A majority (83.3%) were non-Hispanic white and 11.6% lived in neighbourhoods with low SES. Online supplemental table 1 highlights differences in in extreme heat exposure by race/ethnicity and neighbourhood SES. Almost one-third of black participants faced extreme heat exposure, significantly more than their white (16.9%) and Hispanic (11%) counterparts. In addition, residents of disadvantaged neighbourhoods (22.1%) were more likely to experience extreme heat exposure than those of affluent neighbourhoods (11.7%).

Table 2 shows the estimated association between extreme heat and cognitive function trajectories. The full suite of estimates for these models, including the coefficients for interaction terms, are shown in online supplemental table 2. We found that, although heat exposure was not associated with either the baseline (at age 65) level of cognitive function ($b=-0.03$, $p=0.83$) or its rate of change ($b=0.002$, $p=0.85$) in model 1, high exposure to extreme heat was particularly detrimental to blacks and poor neighbourhood residents in model 2 and 3.

For example, model 2 shows that among blacks, extreme heat had no significant association with level of cognitive function at baseline ($b=-0.08$, $p=0.78$), but was associated with a 0.07-point faster decrease on the 27-point scale of cognitive function per each additional year of age ($p=0.001$). However, for whites, extreme heat exposure was not significantly related to either baseline level ($b=-0.04$, $p=0.77$) or the rate of change in cognitive function ($b=0.01$, $p=0.23$). Similarly, we found no significant relationship of extreme heat with cognitive function for Hispanics. Of note, our models control for region, accounting regional differences in racial composition.

Model 3 shows that the association of extreme heat and cognitive trajectories differed by neighbourhood SES. Among residents of average and affluent neighbourhoods, extreme heat exposure was not associated with levels of cognitive function or its rate of decline. For residents of disadvantaged neighbourhoods, high exposure to extreme heat was associated with a 0.06-point faster decrease on the 27-point scale of cognitive function for every additional year of age ($p=0.006$), while it was not associated with baseline cognition ($b=0.098$, $p=0.78$).

Figure 3 displays the predicted trajectories of cognitive function across age based on the results of models 2 and 3. In figure 3A, regardless of heat exposure, whites started with and maintained higher levels of cognitive function over time compared with blacks. While there was no role of heat

Table 2 The estimated association of extreme heat exposure with cognitive function trajectories, US Health and Retirement Study, 2006–2018

	Model 1: average association		Model 2: by race/ethnicity*		Model 3: by neighbourhood SES*	
	Intercept	Rate of change	Intercept	Rate of change	Intercept	Rate of change
	b (p value)	b (p value)	b (p value)	b (p value)	b (p value)	b (p value)
Average heat						
High exposure to extreme heat	−0.03 (0.83)	0.002 (0.85)				
Heat X race/ethnicity						
Non-Hispanic white			−0.04 (0.77)	0.01 (0.23)		
Non-Hispanic black			−0.08 (0.78)	−0.07** (0.001)		
Hispanic			0.11 (0.84)	0.02 (0.62)		
Heat×neighbourhood SES						
Average neighbourhood					−0.06 (0.70)	0.01 (0.29)
Disadvantaged neighbourhood					0.08 (0.78)	−0.06** (0.006)
Affluent neighbourhood					−0.02 (0.95)	0.01 (0.64)

*Numbers show the estimated total effects (considering both main and interactive effects) of heat exposure for each subgroup. These estimates were calculated through linear combinations of coefficients from the growth curve models detailed in online supplemental table2; All models were adjusted for race/ethnicity, neighbourhood SES, sex, living arrangement, educational attainment, household wealth, region of residence, urbanicity and years of follow-up. **p<0.01.
SES, socioeconomic status.

for whites, extreme heat was associated with the rate of decline for blacks. For example, blacks with high exposure to extreme heat (solid red line) had an average cognitive score of 13.7 at age 65, which declined to 8.0 by age 85 (42% decrease). In contrast, blacks with lower extreme heat exposure (blue dashed line) had an average score of 13.9 at age 65, which declined to 9.4 by age 85 (32% decrease). Figure 3B shows the differential association of extreme heat with trajectories of cognitive function by neighbourhood SES. While exposure to extreme heat was not associated with the rate of decline in average neighbourhoods, it was associated with a steeper decline in disadvantaged neighbourhoods. For example, respondents in disadvantaged neighbourhoods with high exposure to extreme heat had an average cognitive score of 14.5 at age 65, which declined to 9.1 by age 85 (37% decrease). For those not exposed to extreme heat, the average score was 14.4 at age 65, which declined to 10.2 by age 85 (29% decrease).

We conducted several sensitivity analyses to assess the robustness of our findings by repeating analyses with simultaneous interactions terms for each subgroup, a continuous measure of heat exposure, a stricter threshold for extreme heat days (99th percentile), the subset of participants who completed all seven cognitive measurements (n=4379), and race-stratified models. As presented in online supplemental table 3–7, the estimates remained largely similar and did not change our conclusions.

We also assessed the effects of persistent extreme heat exposure, a concept distinct from the cumulative exposure captured by our primary measure. Cumulative exposure can, in theory, be driven by 1–2 years with many days of extreme heat. This counts towards accumulation but seems different from the notion of persistent exposure. To create a measure that quantifies persistency of exposure, we calculated the proportion of years each HRS respondent's census tract fell within the top quartile for the number of extreme heat days for a given year. As detailed in online supplemental table 8, every 10% increase in persistent exposure was associated with accelerated cognitive decline by 0.01 points annually at the population average. Interaction analyses showed stronger persistent heat effects among black participants compared with other racial/ethnic groups. However, the association of persistent heat exposure with cognitive decline was not different across neighbourhood SES groups.

DISCUSSION

By 2050, the number of extreme heat days is projected to double, affecting over 100 million Americans.[2] Extreme heat events claim more lives each year in the USA than hurricanes, tornadoes and lightning combined.[27] Leveraging historical temperature data merged with a nationally representative sample of US older adults, we examined the role of cumulative exposure to extreme heat in predicting trajectories of cognitive functioning and whether racial/ethnic minorities and those living in poor neighbourhoods are more vulnerable to these extreme weather conditions.

We found that cumulative exposure to extreme heat can affect cognitive decline but does so unequally across the population. Cumulative exposure to extreme heat is associated with faster cognitive decline, only for blacks and for residents of socioeconomically disadvantaged neighbourhoods. The findings suggest that models focusing on 'average' associations, that is, without interaction analyses, can obscure critical, heterogeneous consequences of extreme heat and fail to reveal the subpopulations at high risk.

This study is one of the first to show differential vulnerability to extreme heat by race/ethnicity. One possible explanation for this pattern of findings—that is, cumulative exposure to extreme heat being associated with faster cognitive decline for black older adults—is that black older adults may have disproportionately experienced systemic disadvantages throughout life due to structural racism, racial segregation and discriminatory policies that may diminish cognitive reserve. Education is a key dimension of these disadvantages with important implications for racial disparities in cognitive ageing. Growing up in the early and mid-20th century, many older blacks attended segregated schools, with starkly lower school quality and inadequate funding.[10] This educational disparity has created significant barriers for black

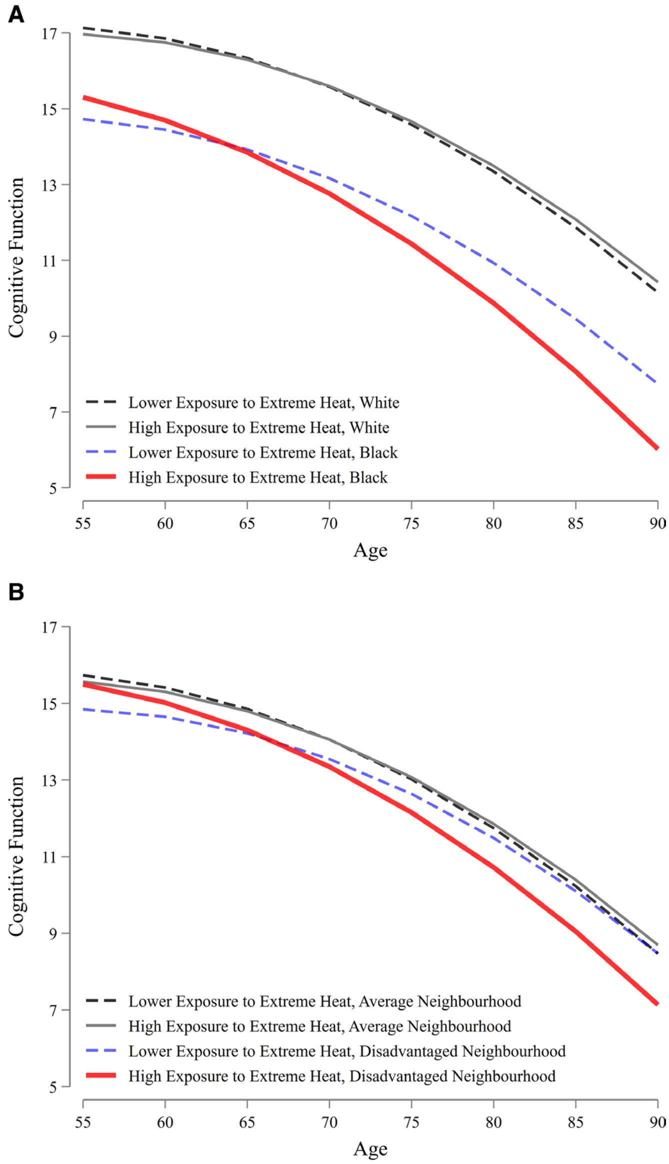

Figure 3 Predicted cognitive function trajectories by extreme heat exposure moderated by race/ethnicity and neighbourhood socioeconomic status (SES). (A) Race/ethnicity. (B) neighbourhood SES. Note: Covariates (ie, sex, living arrangement, educational attainment, household wealth, region of residence, urbanicity and years of follow-up) were held at their mean values. For the race/ethnicity interaction model, neighbourhood SES was controlled and for the neighbourhood SES interaction model, race/ethnicity was controlled. SES, socioeconomic status.

individuals in obtaining quality education, upward mobility and neighbourhood resources. The cumulative effect of these disadvantages may contribute to persistent exposure to chronic stress, which can further influence brain reserve and the neurological capacity to delay age-related cognitive decline.[28] Consequently, insults such as extreme heat exposure in later adulthood may compromise black individuals' cognitive reserve at a faster rate.[29] To explore some of these possibilities, we conducted supplementary analyses controlling for childhood SES and lifetime stress scales. While the coefficients for the interaction with race were slightly attenuated, the results remained largely consistent. It is worth noting that cognitive testing implemented in population surveys may not always capture the full range of cognitive performance, particularly among minoritised older adults. This limitation may result in reduced predictive ability and an incomplete representation of the cultural diversity among black older adults.

Our results suggest that exposure to extreme heat can accelerate cognitive decline for those who live in socioeconomically disadvantaged neighbourhoods, an instance of compound disadvantage.[30] This is consistent with previous research that environmental exposures have an especially large effect on cognitive function for those who live in disadvantaged neighbourhoods. It is possible that disadvantaged neighbourhoods have limited access to quality healthcare facilities, including specialised services for cognitive health, which may lead to delayed diagnosis and treatment of cognitive disorders, exacerbating cognitive decline for those who are exposed to extreme heat. Another explanation is that chronic stress arising from high levels of crime, violence and physical disorder in disadvantaged neighbourhoods may trigger physiological responses that can accelerate cognitive ageing.[31 32] Residents of disadvantaged neighbourhoods may withdraw themselves from public space and experience social isolation, which have been found to be a significant predictor for increased cognitive decline and higher risk of cognitive impairment. Future research exploring the role of neighbourhood physical and social environment could expand our understanding of the relationship between neighbourhood disadvantage and exposure to extreme heat on cognitive decline. Regardless, previous studies on this topic are primarily limited to air pollution and lead poisoning,[33 34] we contribute to the existing literature by identifying extreme heat as an important contributing factor for cognitive ageing especially among the socially vulnerable groups.

The strengths of our study include the use of a nationally representative sample of older US adults over 12-year records merged with historical temperature data. Our measure of average extreme heat exposure during an extended period goes well beyond prior studies that have been heavily limited to short-term exposures (eg, several hours or a few days). We also model cognitive trajectories rather than momentary cognitive assessments. Furthermore, with a large sample, we were able to determine whether extreme heat exposure is universally associated with cognitive outcomes or whether there are more vulnerable groups at elevated risk.

Despite these strengths, we acknowledge several limitations. First, our extreme heat measure was based on outdoor temperatures and can lead to some degree of exposure misclassification because people also spend more time indoors with varying conditions. However, prior research shows relatively strong correlations between indoor and outdoor temperatures in warmer temperatures.[35] Second, the HRS does not collect information on respondents' access to and use of air conditioning. While we included wealth, which is associated with these characteristics, we could not directly control for the role of air conditioning. Another potential limitation is attrition. To minimise this, our estimates were adjusted by the years of follow-up. In addition, our sensitivity analyses with the sample who completed all cognitive assessments were similar to the main findings, indicating minimal evidence of bias due to attrition. Finally, we used the TICSm rather than clinical assessments. TICSm is a cognitive performance that can be impacted by the external environment like other measures of functioning (ie, walking speed). Despite the validity and reliability of the TICSm,[24 25] it is less sensitive to subtle cognitive deficits and the cognitive performance of racially diverse groups. This might have resulted in null findings for the association of extreme heat with cognitive trajectories in our study.

CONCLUSION

Our study demonstrates that extreme heat may disproportionally affect later-life cognitive decline among older Blacks and residents of poor neighbourhoods, reinforcing the social vulnerability perspective in the context of climate change.[36] Our findings support the call for robust public policy that identifies groups and communities susceptible to extreme heat to develop targeted support and mitigate disparities.[37] Local Health Action Plans, which are localised policy tools guiding responses to extreme heat, should prioritise increased outreach and communications with at-risk individuals to ensure that their perspectives are incorporated into the strategies deployed.[38] Concerted efforts are required at every level to empower vulnerable communities, map their specific needs, bolster green infrastructure and advance our knowledge of key factors leading to disproportionate harm.

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Contributors EC and HL conceptualised the study and designed the methodology. EC conducted data management and formal analysis. HL provided statistical supervision and conducted the main literature search. VWC supervised each part of the project, including study design, model specification and statistical analysis, and framed results. All authors contributed to the interpretation of data. EC drafted the manuscript, and HL and VWC contributed to the critical revision of the manuscript for important intellectual content. All authors reviewed and approved the final version of the manuscript for submission for publication. EC and HL are the guarantors.

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Competing interests None declared.

Patient consent for publication Not applicable.

Ethics approval This study involves human participants and this study was approved by the Institutional Review Board at New York University (IRB-FY2022-6659). Participants gave informed consent to participate in the study before taking part.

Provenance and peer review Not commissioned; externally peer reviewed.

Data availability statement Data are available in a public, open access repository. Data used in this study include publicly available and restricted data sets from the Health and Retirement Study (HRS), which is sponsored by the National Institute on Aging (NIA U01AG009740) and conducted by the University of Michigan website. The analytical datasets for this study incorporate multiple restricted data sources from the HRS. Due to privacy and confidentiality requirements, these datasets are not publicly available.

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