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ISSN: 2365-9793

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ABSTRACT

Place of Birth and Cognitive Function among Older Americans: Findings from the Harmonized Cognitive Assessment Protocol

Growing evidence suggests that place of birth (PoB) and related circumstances may have long- lasting and multiplicative contributions to various later-life outcomes. This study investigates the extent to which PoB contributes to a wide range of domains of later-life cognitive function. Leveraging a nationally representative sample of older Americans from the Health and Retirement Study (HRS), cognitive function is assessed in Harmonized Cognitive Assessment Protocol (HCAP). Regression-based Shapley decompositions are employed to quantify the contribution of PoB. We show that PoB significantly contributes to all assessed cognitive domains including memory, executive function, language and fluency, visuospatial function, orientation, and general cognitive function. Geographic disparities in cognitive function are evident across PoB, with individuals born in US southern states and foreign-born individuals performing worse than those born in other states. Overall, state of birth accounts for 2.2-9.7% of the total variance in cognition after controlling for age, sex, and race/ethnicity, which declines to 2.0-7.0% after further controlling for comprehensive socioeconomic and health factors over the life course, and are robust to the control of current state of residence. Addressing these disparities requires more equalized place-based policies, resources, and early-life environments to promote health equity over the life course.

JEL Classification: I14, I10, J13, J14, H75

Keywords: geographic disparities, health equity, cognitive domains, life course, early-life circumstances

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Introduction

Place of birth (PoB hereafter) can contribute profoundly to a host of later-life outcomes over the lifespan, spanning from educational attainment and income levels to overall health and well-being (Bifulco et al., 2011; Chetty & Hendren, 2018; Ludwig et al., 2012). Particularly, it has been considered as a critical source of inequalities later in life. The socioenvironmental and contextual factors experienced during stages of early life, for example, significantly shape human capital development and can have lasting and multiplying influences throughout their lifetimes (Bifulco et al., 2011; Borenstein & Mortimer, 2016b; Chetty & Hendren, 2018; Livingston et al., 2020; Ludwig et al., 2012). Understanding the role of PoB in shaping later-life outcomes is crucial for implementing early interventions and effective policymaking.

Despite the profound impact of PoB on health outcomes over time, direct evidence linking PoB to later-life health outcomes among older adults remains limited. Studies in the US have indicated that an individual's PoB is associated with varying levels of mental health, cardiovascular health, chronic diseases, cognition, and mortality rates in adulthood (Fang et al., 2018; Leventhal & Brooks-Gunn, 2003; Rehkopf et al., 2015; Xu et al., 2020). However, most of these studies have explored broad aspects of PoB, such as rurality (Contador et al., 2015; Lundberg et al., 2009), regions with heightened disease or mortality risks (Fang et al., 2018; Gilsanz et al., 2017; Glymour et al., 2009), or countries of birth (Fang et al., 2018; Garcia et al., 2019), with only a handful examining more specific differences, like the state of birth (Brown et al., 2019; Komro et al., 2016; Xu et al., 2020). Importantly, despite the large and persistent variations in late-life cognitive function in the US, no study to date has explicitly quantified the long-term contribution of the state of birth to cognitive function among older adults. It remains unclear to what extent the state of birth may contribute to late-life variations in cognition. Elucidating this issue is critical, considering the modifiable nature of many place-based factors influencing cognition (Xu et al., 2020). Targeted policy interventions could yield enduring benefits at both the individual and societal levels given the pivotal role of cognitive functioning in daily life, decision-making, and overall well-being.

The Multifaceted Influence of PoB on Cognitive Functioning over the Life Course

Life course theory underscores the enduring impact of early-life exposures on individuals' health and well-being (Borenstein & Mortimer, 2016a, 2016b; Cao et al., 2022; Lin & Chen, 2021). Numerous socioeconomic, environmental, and developmental factors in early life are influenced by state contexts, with conditions during individuals' formative years profoundly impacting brain development and long-term cognitive trajectories (Borenstein & Mortimer, 2016b; Glymour et al., 2011; Xu et al., 2020). This emphasizes the significance of considering PoB as a formative influence on later-life cognition, especially at the state level.

State of birth plays a pivotal role in shaping the early-life circumstances that subsequently influence later-life cognition. Variations in state-level policies, resources, and environments create distinct contexts that affect individuals' cognitive development from prenatal stages through early childhood (Xu et al., 2020). States with robust social welfare programs and investment in early childhood development may provide comprehensive prenatal care, income subsidies, nutritional support, and high-quality early childhood education, establishing a solid foundation for healthy brain development and cognitive functioning (Borenstein & Mortimer, 2016b; Hendren & Sprung-Keyser, 2020; Xu et al., 2020). In contrast, states with higher poverty levels and limited economic and social resources may offer inadequate support for maternal and child health, resulting in unfavorable early-life exposures and cognitive development. Limited access to prenatal care and nutrition, coupled with exposures to environmental toxins or pollutants, can negatively impact neurological developments and cognitive functions later in life (Livingston et al., 2020). Additionally, state-level differences in exposure to environmental stressors, such as disadvantaged communities, crime, and violence, may influence fetal growth and early childhood development, constraining optimal cognitive development potential (Strully et al., 2010). Disparities in educational contexts, resources, and opportunities across states (e.g., student-teacher ratios, term length, school segregation) can further exacerbate cognitive inequalities, particularly regarding differential access to educational support services, enrichment programs, and high-quality schools (Lin et al., 2024; Peterson et al., 2021).

A range of state-level policies and programs may lead to significant variations in early-life exposures, including policies targeting children directly or indirectly through their families, such as taxes, cash transfers (e.g., Earned Income Tax Credit, Aid to Families with Dependent Children), income transfers (e.g., food stamps, housing vouchers), education (e.g., Head Start, preschool, K-12), health insurance (e.g., Medicaid), and other social insurance (e.g., disability and unemployment insurance). These policies may determine the developmental resources (e.g., nutrition) available during individuals' formative years, thereby influencing cognitive function in the long run (Hendren & Sprung-Keyser, 2020; Strully et al., 2010).

Existing theories shed light on multiple pathways through which state of birth and related early-life circumstances may influence later-life cognition (Borenstein & Mortimer, 2016a; Kuh et al., 2003). The *critical period theory* posits that early-life exposures, particularly during the most sensitive periods of brain development (e.g., age 0-3), have the most profound impact on later-life cognition (Lynch & Smith, 2005). For instance, individuals born in different states may experience differential exposure to quality care, nutrition and environmental toxins during prenatal and postnatal states, resulting in significant variations in brain development and cognitive trajectories in later life (Cao et al., 2022; Lynch & Smith, 2005; Xu et al., 2020). The *cumulative risk theory* suggests that individuals exposed to multiple adversities and risk factors in early life are likely to experience more adverse cognitive function in later life. These risk factors may include malnutrition, poverty, violence, and inadequate access to health care. The cumulative effects of these risk factors may exacerbate the decline in cognitive function over time (Borenstein & Mortimer, 2016a; Cao et al., 2022; Horvat et al., 2014; Kuh et al., 2003; Lyu & Burr, 2016). Lastly, the *chains of risk theory* point out that the early-life disadvantages associated with PoB indirectly affect later-life cognitive function through their influence on other pivotal factors over the life course. A substantial body of literature has demonstrated that early-life adversities may lead to disadvantaged socioeconomic status (SES) (e.g., education, labor participation, wealth, insurance), health (e.g., functional limitations and chronic diseases) and health behaviors (e.g., smoking) over the lifespan, resulting in poorer cognitive function in older ages (Borenstein & Mortimer, 2016a; Cao et al., 2022; Horvat et al., 2014; Kuh et al., 2003; Lyu & Burr, 2016). These life course factors are also recognized as leading modifiable risk factors for cognitive impairment and dementia (Livingston et al., 2020). Overall, these theories suggest that state of birth can both directly affect cognitive function by influencing early brain development, especially during formative stages, and indirectly affect later-life cognition through its impact on various risk factors over the life course. This motivates us to explore the underlying pathways by incorporating various crucial life course factors over the lifespan that may explain the effects of PoB on cognitive function. We expect that state of birth has both a direct effect and an indirect effect (through factors such as SES and health) on later-life cognition.

Potential Heterogeneity in PoB Contributions to Different Domains of Cognitive Function

In elucidating the effect of PoB on later-life cognition, a comprehensive examination of cognitive domains is essential to capture the multifaceted nature of cognitive functioning. Memory, language and fluency, visuospatial function, orientation, and executive function represent key domains that encompass a range of cognitive processes, from basic sensory and perceptual abilities (e.g., visuospatial function) to higher-order problem-solving and decision-making processes (e.g., executive function) (Harvey, 2019).

These domains constitute a broad spectrum of cognitive processes essential to daily living, functioning, and well-being, relying on various brain regions. While they are interconnected, there is heterogeneity across domains due to their diverse nature of cognitive processing (Arce Rentería et al., 2019; Harvey, 2019; Jones, Manly, et al., 2023; Langa et al., 2019; Wellman & Gelman, 1992). Empirical evidence suggests that socioeconomic disparities in early life (e.g., education), potentially driven by state of birth, may have significant but heterogenous effect on cognitive trajectories across multiple domains, such as memory, language and visuospatial function (Arce Rentería et al., 2019; Livingston et al., 2020). Deficits in various cognitive domains may manifest differently at both individual and population levels (Livingston et al., 2020; Wellman & Gelman, 1992). As state of birth may affect later-life cognitive functions through diverse pathways, it is essential to examine various cognitive domains under the same framework to understand the similarities and differences in the effects of state of birth on cognition.

Moreover, examining comprehensive cognitive domains may identify key aspects of cognition with the most notable geographic variations (Glymour et al., 2011; Zacher et al., 2023). This information is crucial for developing targeted interventions and policy initiatives to promote cognition and reduce the burden of cognitive disorders in rapidly aging populations. However, to date, no study has provided such evidence on a nationally representative sample.

Given the importance of the research questions and the existing research gaps, this study aims to examine the long-term contribution of state of birth to a variety of domains of cognitive function among Americans aged 65 and older. We linked comprehensive cognitive assessments from the Health and Retirement Study (HRS) Harmonized Cognitive Assessment Protocol (HCAP) with historical geographic data on state of birth from the HRS. We hypothesized that 1) statistically significant geographic variations exist in cognitive function across states of birth; 2) states of birth may statistically significantly contribute to variations in later-life cognitive function, potentially through their influence on various SES and health factors over the life course; 3) states of birth may have a statistically significant contribution to various domains of cognitive function, with some heterogeneity across these cognitive domains.

Methods

Data and Study Participants

The data for this study were obtained from the Health and Retirement Study (HRS), a nationally representative study of American adults aged 50 and older. The HRS has been conducted biannually since 1992, with approximately 19,000 participants interviewed in each wave. In 2016, the HRS developed and conducted the Harmonized Cognitive Assessment Protocol (HCAP) to obtain a comprehensive assessment of cognitive function and dementia risk among older adults (Jones, Manly, et al., 2023; Langa et al., 2019; Manly et al., 2022). 4425 participants were randomly selected from the age-eligible sample who participated in the 2016 HRS core survey and were 65 years or older within two months of completing the core interview. Among this group, 3496 older adults aged 65 and older completed the HCAP assessment, and a comprehensive set of cognitive measures were collected from the respondents and their knowledgeable informants (Jones, Manly, et al., 2023; Langa et al., 2019; Manly et al., 2022).

Figure 1 illustrates the sample selection process. After excluding 12 participants without PoB data from the HRS restricted cross-wave geographic data file, 3,484 older adults were included. Subsequently, 151 participants without complete measures of demographics, SES and health factors were further excluded. Finally, a total of 3,333 participants aged 65 and older with complete data on PoB, demographics, SES, and health factors over the life course were included in the analysis.

Cognitive Function

Cognitive function in this study were multifaceted. Harmonized general and domain-specific cognitive function scores were derived from the HRS HCAP, encompassing six continuous cognitive measures (Gross et al., 2023; Jones, Langa, et al., 2023; Jones, Manly, et al., 2023; Langa et al., 2019; Manly et al., 2022). These scores, included as our primary outcomes, were estimated through confirmatory factor analyses in a previous study using carefully selected cognitive measures collected in the HCAPs (Gross et al., 2023). Included in this framework were validated assessments of memory, executive function, language and fluency, orientation, and visuospatial function, with the latter assessed via CERAD constructional praxis test, as well as general cognitive function (Gross et al., 2023; Jones, Langa, et al., 2023). Each of these factor scores was standardized to a mean of 0 and a standard deviation of 1 (Gross et al., 2023).

Place of Birth

State-level PoB data were extracted from the HRS restricted cross-wave geographic information data file. During their baseline interview, respondents were asked about their PoB, with those born in the U.S. providing further details regarding their specific state of birth. The sample encompassed respondents born across all 50 U.S. states, as well as individuals born in 2 U.S. territories (Washington, D.C., and Puerto Rico), those born in the U.S. without state information, and foreign-born individuals, who were distinctly categorized in the study.

Due to constraints regarding the disclosure of summary statistics at the state level, census division level birth location data were also extracted from the HRS public data file. This facilitated the reporting of summary statistics and enabled the mapping of regional variations in cognitive function. Nonetheless, the primary geographic unit for analyzing the contribution of PoB remained the state of birth. Consequently, all principal statistical analyses, encompassing testing and modeling, were executed at the state level, a framework underpinned all our key findings. Therefore, our results should be interpreted at the state level rather than census division level.

All analyses adhered to the HRS disclosure guidelines, and any results generated using HRS state-level restricted data were reviewed and approved by the HRS.

Statistical Analyses

We used Kruskal-Wallis test to assess distributional differences in cognitive function across multiple sampled groups, specifically states of birth in our analysis. The nonparametric test is advantageous as it does not rely on assumptions of normal distribution and is insensitive to the underlying distribution of the outcome. This makes it suitable for analyzing cognitive performance across diverse birth locations at the state level, where normality may not hold. Unlike parametric tests such as the one-way ANOVA, which require normality, the Kruskal-Wallis test offers greater reliability when analyzing non-normally distributed variables. Significance from this test indicates statistically significant differences in cognitive performance distributions across individuals' state of birth, providing valuable insights into regional cognitive variations (Ostertagová et al., 2014).

Shapley value decomposition was used to evaluate the contribution of state of birth to the variance in cognitive function. This regression-based method enables the explicit quantification and comparison of the explained variance of different groups of regressors. By using Shapley value decomposition, we can estimate both the absolute contributions of state of birth and its relative contributions compared to other groups of life course variables included in the model (Cao et al., 2022; Liu et al., 2019; Shorrocks, 2013; Yan et al., 2020).

In our regression models, we treated state of birth as the independent variable. Recognizing that states of birth can indirectly influence cognition in later life through their impact on various risk factors across the lifespan, we incorporated two key groups of life course factors identified in the literature (i.e., SES and health factors) to explore the potential mechanisms and pathways. (Alzheimer's Association, 2023; Alzheimer's Disease International, 2018; Livingston et al., 2020). Additionally, we included demographic covariates encompassing age, sex, and race/ethnicity to account for their potential influence on cognitive function and other factors. The interrelationships among these variables were elucidated in Supplementary Figure S1, providing a visual representation of the pathways through which state of birth, SES, and health factors may collectively impact cognitive functioning in later life.

The decomposition analyses were conducted stepwise, adding the two groups of life course factors subsequently to examine potential pathways through which state of birth may affect late-life cognitive function. In Model A (the most parsimonious setting), we only adjusted for demographic covariates, including age, sex and race/ethnicity. In Model B, we additionally adjusted for life course SES, including education (measured in years), wealth level (categorized into quartiles), working status, Medicare enrollment, Medicaid enrollment, military health plan enrollment, private health insurance coverage, and employer-based insurance coverage. Lastly in Model C (the most comprehensive setting), we further adjusted for health factors over the life course, including various chronic diseases and conditions (hypertension, diabetes, cancer, lung diseases, heart diseases, stroke, psychiatric disorders, arthritis), functional limitations for basic or instrumental activities of daily living (ADL/IADL), and smoking behaviors (Alzheimer's Association, 2023; Alzheimer's Disease International, 2018; Livingston et al., 2020).

Linear models were used for the continuous outcomes (e.g., memory score). Joint significance tests were conducted to assess the contribution of state of birth on each domain of cognitive function, and then the decomposition analyses were performed to quantify the contribution of state of birth to cognitive function and the contribution of each group of life course factors. The analyses were weighted using HRS HCAP sampling weights to account for sample selection and non-response and improve the representativeness of the results (Cao et al., 2022; Liu et al., 2019; Shorrocks, 2013; Yan et al., 2020).

Sensitivity analyses were conducted to explore the potential influence of contemporaneous geographic exposures on the state of birth's contribution. Specifically, we reran all regression models, controlling for individuals' current state of residence in 2016, i.e., the year of the HCAP survey. We then examined the changes in the contribution and estimates related to state of birth.

All statistical analyses were performed using Stata 17.0, and significance was determined at the 5% level.

Results

Sample Characteristics

Table 1 presents the characteristics of the sample. Among the 3,333 participants, the mean age was 75.9 years (SD=7.5), and 1,995 (59.9%) were female. The majority of participants were non-Hispanic White (71.8%). The mean years of education was 12.7 years (SD=3.1), and 3,172 (95.2%) were covered by Medicare. The most prevalent chronic diseases and conditions were hypertension (70.5%) and arthritis (71.8%), followed by heart diseases (34.2%) and diabetes (29.6%). Additionally, 55.2% of participants had ever smoked cigarettes, while 7.6% were current smokers.

Regarding PoB, 387 (11.6%) of participants were born outside the US (i.e., foreign born); and migration was common, with 52.5% residing in a state different from their birth state. Supplementary Table S1 presents the characteristics of the sample by PoB. Participants born in the South (i.e., states in East South Central, West South Central and South Atlantic divisions) were more likely to be non-Hispanic Black, female, and have lower SES and poorer health conditions in later life.

Geographic Variation in Cognitive Function by PoB

Figure 2 illustrates the geographic variations in cognitive function by PoB after adjusting for age and sex. Each map shows the average levels of cognitive function across PoB, with deeper color indicating worse cognitive performance (detailed distributions and summary statistics across PoB were presented in Supplementary Figure S2 and Table S2). The P-values of Kruskal-Wallis tests are provided at the bottom of each graph, indicating the significance of distributional differences in cognitive function across state of birth. Notable geographic variations in cognitive function were observed by state of birth, with consistent patterns across various cognitive domains. Specifically, participants born in southern states and foreign-born individuals, tended to exhibit poorer cognitive function compared to those born in other census divisions. Among the southern states, individuals born in states within West South Central had the lowest cognitive function scores across most cognitive domains. Variations were also observed among participants born in non-southern states, with those born in the West (i.e., states in Mountain and Pacific divisions) exhibiting relatively poorer cognitive performance compared to others. The Kruskal-Wallis tests indicated that the distributional differences in cognitive function across state of birth were statistically significant for all five cognitive domains and general cognitive function (P<0.001). The test statistics for differences in cognition by state of birth were reported in Supplementary Table S3.

Contribution of State of Birth to Later-life Cognitive Function

Figure 3 presents the influence of state of birth and the estimates of Shapley decomposition analyses, which quantify the contribution of state of birth to the total variance of each domain of cognitive function (also see Supplementary Table S4 for the estimates). Panel A shows the contributions of state of birth from Model A to Model C. In Model A, which only adjusted for demographic covariates including age, sex and race/ethnicity, state of birth accounted for a statistically significant amount of the total variance in memory (3.6%; significance of joint test: P <0.001), executive function (9.7%; P <0.001), language and fluency (5.7%; P <0.001), visuospatial function (6.2%; P <0.001), orientation (2.2%; P <0.001), and general cognitive function (7.6%; P<0.001). As additional life course SES and health factors were controlled from Model B to C, the contribution of state of birth gradually declined, but even in the most comprehensive setting (Model C), it still explained a statistically significant proportion of variance in memory (2.7%; 95% CI, 1.8-3.6%; *P*=0.001 for joint test), executive function (7.0%; 95% CI, 5.8-8.3%; *P*<0.001), language and fluency (4.6%; 95% CI, 3.2-6.1%; *P*<0.001), visuospatial function (5.2%; 95% CI, 3.8-6.5%; *P*<0.001), orientation (2.0%; 95% CI, 1.0-2.9%; *P*<0.001), and general cognitive function (5.5%; 95% CI, 4.3-6.6%; *P*<0.001).

Figure 4 illustrates the absolute contribution of state of birth compared to other life course factors in explaining variations in cognition, as estimated in Model C (see Supplementary Table S5 for detailed estimates). Although the contribution of state of birth was relatively lower compared to SES and health in the fully adjusted model, it exhibited a comparable effect size to life course factors in cognitive domains reflecting basic sensory and perceptual abilities, such as visuospatial function, orientation, and language and fluency. Overall, state of birth accounted for 14% to 28% of the total variance explained by state of birth and life course SES and health factors combined (see relative contribution in Supplementary Table S5). These findings underscore the potential clinical significance of PoB in contributing to late-life cognitive function.

Lastly, sensitivity analyses were performed to examine the robustness of the findings to the control of current state of residence. As shown in Supplementary Figure S3 and Figure S4, the estimates were fairly consistent with our main results (see Supplementary Tables S6-S7 for detailed estimates). Particularly, we found limited changes in state of birth contribution after controlling for individuals' current state of residence in old age.

Discussion

PoB can have critical and enduring contributions to individuals' health and well-being throughout their lives. In this study, we provided first evidence on the long-term contribution of state of birth to a range of later-life cognitive function. We found that state of birth statistically significantly explained cognition, accounting for 2.2-9.7% of the total variance after adjusting for demographic covariates. We showed that less than half of these effects were potentially mediated through various life course SES and health factors, with the remaining ones being the direct contribution of PoB, highlighting the importance of early-life exposures on cognitive development during formative stages.

Our findings revealed marked geographic variations in cognitive function across states of birth. Individuals born in southern states exhibited poorer cognitive function compared to those born in other states. Furthermore, these geographic variations extended beyond the South versus non-South divide. Specifically, individuals born in state within the West South Central division exhibited the lowest cognitive performance across most cognitive domains compared to other southern states. Additionally, those born in states within the West region (i.e., states in Mountain and Pacific divisions) exhibited poorer cognitive function compared to individuals from other non-southern states. These findings align with previous research linking region of birth to cognition (Zacher et al., 2023), such as the higher risk for dementia in the Stroke Belt states (Gilsanz et al., 2017; Glymour et al., 2011; Topping et al., 2021). In our study, a comprehensive set of cognitive domains and outcomes were examined in the same context and consistent patterns of geographic disparities were found, which further demonstrates the strength and robustness of the finding. Moreover, individuals born in foreign countries showed poorer cognitive performance than those born in the US, which is consistent with previous evidence (Kovaleva et al., 2021).

We showed that state of birth contributed significantly to later-life disparities in cognition. Prior literature suggests that PoB may influence various aspects of individuals' health and well-being over their life course, including education, income (Bifulco et al., 2011; Chetty & Hendren, 2018; Ludwig et al., 2012), and various diseases and conditions (Fang et al., 1996, 2018; Gilsanz et al., 2017; Glymour et al., 2009; Lundberg et al., 2009; Patton et al., 2011; Rehkopf et al., 2015; Shiue, 2014; Xu et al., 2020). In our study, accounting for these factors attenuated about 10-30% of the contribution of state of birth to various cognitive domains, emphasizing the importance of addressing these underlying pathways through improved policies affecting education and socioeconomic factors. However, even after accounting for these factors, state of birth still contributed significantly to later-life cognition. For instance, early-life circumstances shaped by state policies and social environments may contribute directly to brain development and cognitive reserve, leading to long-lasting disparities in later life. Policymakers should consider targeted interventions such as child subsidies and insurance to reduce potential long-term inequities (Brown et al., 2019; Komro et al., 2016; Lin & Chen, 2021; Strully et al., 2010; Zhang et al., 2008, 2016).

Importantly, we demonstrated that the contribution of state of birth to cognitive function remained consistent even after accounting for current state of residence in old age. While the geographic patterns may potentially capture the combined influence of both contemporaneous and earlier place-based exposures and experiences, our sensitivity analyses suggest that the documented state of birth contribution primarily reflect the long-lasting impact of early-life place-based exposures and experiences, rather than current geographic variations. These findings are consistent with previous evidence on the relationship between region of birth, region of residence and dementia (Zacher et al., 2023).

Furthermore, while state of birth significantly contributed to cognitive function, there was some heterogeneity across different cognitive domains. State of birth had a relatively larger impact on domains involving higher-order problem-solving and decision-making processes, such as executive function. The complex and multifaceted nature of these top-down cognitive processes makes them more susceptible to place-based exposures and experiences. The larger contribution observed in these domains may reflect the combined influence of PoB on components of more basic cognitive abilities and skills. These findings underscore the importance of collecting comprehensive measures of cognitive function. Focusing solely on global cognitive function or specific classification criteria may obscure important differences across cognitive domains and underestimate the contribution of certain risk factors on cognitive function (Jones, Manly, et al., 2023; Langa et al., 2019; Manly et al., 2022).

Our study has some limitations. First, due to sample size constraints, we were unable to conduct subsample analyses or further investigate the impact of early childhood migration compared to prolonged residence in a specific location, despite the notable lifetime migration rate (>50%) shown in our summary table. Future studies using residential history data with measured durations could provide more insights into these mechanisms. Second, a more comprehensive examination of the mechanisms through which PoB affects later-life cognition is needed. Future research should incorporate specific place-based policies, environments and resources at the state level to shed light on their influences. Lastly, recall bias may potentially affect the accuracy of the PoB measure. However, since PoB data were collected during the initial survey when respondents were at younger ages, this concern is somewhat mitigated.

Despite the limitations, our study makes unique contributions to the literature. The most recent study by Zacher et al., (2023) documented the geographic patterns of dementia in the US by census division of birth. They showed that being born in the South was associated with higher prevalence of dementia, after accounting for region of residence, region of birth, and sociodemographic covariates including age, sex, race/ethnicity and education. Our study offers several strengths that distinguish it from previous research. First, we extend the analysis beyond the traditional examination of PoB at the census division level to the state level, capturing both state-level variations within and across regions of birth. Second, we provide novel evidence on a comprehensive set of cognitive domains using the most up-to-date nationally representative population survey data and cognitive assessment – HRS/HCAP. This approach enables us to document and understand the consistency and heterogeneity of state of birth contributions to various domains of cognitive function. Third, employing regression-based decomposition methods, we explicitly quantify the contributions of PoB to later-life variations in cognitive function. Unlike previous studies, such as Zacher et al., (2023), which examines disease prevalence by PoB without providing evidence on the exact size or magnitude of PoB variations, our study offers the first quantitative estimates of the state of birth's contribution. We compare this with the contributions of other life course factors within the same model to show relative magnitude of the effect size. Lastly, we include a wide array of life course factors in our analysis to explore the potential pathways through which state of birth contributes to cognitive function in old age, an aspect not previously examined. While these life course factors attenuate some of the state of birth's contribution, our findings show that the contribution of state of birth remains quantitatively meaningful and statistically significant even after accounting these factors and current state of residence. This new finding further underscores the importance of PoB in explaining later-life cognitive function.

In conclusion, our findings demonstrate the long-lasting and enduring contributions of state of birth on later-life cognition. Addressing state-level policies, resources, and early-life environments is crucial to improving health equity over the life course. Policymakers should prioritize efforts to equalize opportunities and resources across different states to promote better cognitive function for all individuals.

Funding

This work was funded by the National Institute on Aging (NIA) of the National Institutes of Health [R01AG077529; P30AG021342]; and James Tobin Research Fund at Yale Economics Department. The views expressed are those of the authors and not necessarily those of the funders. The funders had no role in the design and conduct of the study; collection, management, analysis, and interpretation of the data; preparation, review, or approval of the manuscript; or decision to submit the manuscript for publication. The IZA Discussion Paper Series serves as a preprint server to deposit latest research for feedback.

Conflict of Interest

We have no conflict of interest to declare.

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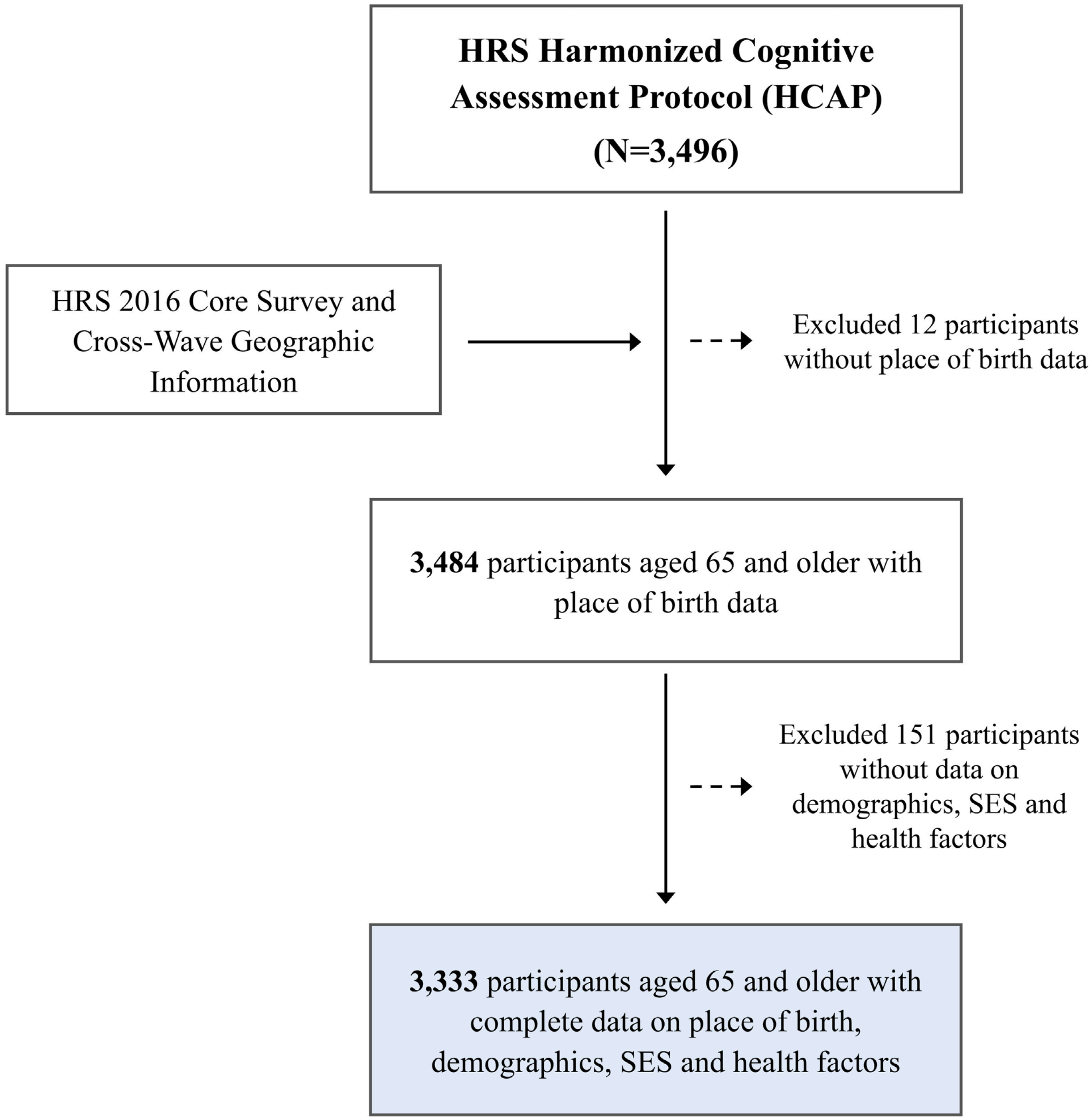
Table 1. Characteristics of study participants (*N*=3,333)

Characteristics	Descriptive statistics
Demographics	
Age, mean (SD)	75.9 (7.5)
Female, n (%)	1,995 (59.9%)
Race/Ethnicity	
Non-Hispanic White, n (%)	2,392 (71.8%)
Non-Hispanic Black, n (%)	518 (15.5%)
Hispanic, n (%)	350 (10.4%)
Other, n (%)	73 (2.2%)
Socioeconomic Status	
Education in years, mean (SD)	12.7 (3.1)
Wealth level	
Lowest, n (%)	599 (18.0%)
Lower-middle, n (%)	767 (23.0%)
Upper-middle, n (%)	909 (27.3%)
Highest, n (%)	1,058 (31.7%)
Working for pay, n (%)	598 (17.9%)
Medicare enrollment, n (%)	3,172 (95.2%)
Medicaid enrollment, n (%)	339 (10.2%)
Military health plan enrollment, n (%)	258 (7.7%)
Private health insurance coverage, n (%)	1,314 (39.4%)
Employer-based health insurance coverage, n (%)	717 (21.5%)
Health	
Hypertension, n (%)	2,349 (70.5%)
Diabetes, n (%)	988 (29.6%)
Cancer, n (%)	664 (19.9%)
Lung diseases, n (%)	453 (13.6%)
Heart diseases, n (%)	1,140 (34.2%)
Stroke, n (%)	418 (12.5%)
Psychiatric disorders, n (%)	651 (19.5%)
Arthritis, n (%)	2,393 (71.8%)
ADL limitations, n (%)	763 (22.9%)
IADL limitations, n (%)	695 (20.9%)
Currently smoking, n (%)	253 (7.6%)
Ever smoking, n (%)	1,840 (55.2%)
Cognition	
Memory, median (IQR)	0.1 (1.3)
Executive function, median (IQR)	0.1 (1.4)
Language and fluency, median (IQR)	0.0 (1.3)
Visuospatial function, median (IQR)	-0.1 (1.3)
Orientation, median (IQR)	0.0 (1.3)
General cognitive function, median (IQR)	0.1 (1.4)
Place of Birth	
New England (6 states)	126 (3.8%)
Middle Atlantic (3 states)	455 (13.7%)
East North Central (5 states)	595 (17.9%)
West North Central (7 states)	346 (10.4%)
South Atlantic (9 states)	499 (15.0%)
East South Central (4 states)	301 (9.0%)
West South Central (4 states)	326 (9.8%)
Mountain (8 states)	100 (3.0%)
Pacific (5 states)	195 (5.9%)
Foreign born	387 (11.6%)
Relocation Relative to State of Birth	
Same state of residence in 2016 as state of birth	1,583 (47.5%)
Different state of residence in 2016 from state of birth	1,750 (52.5%)

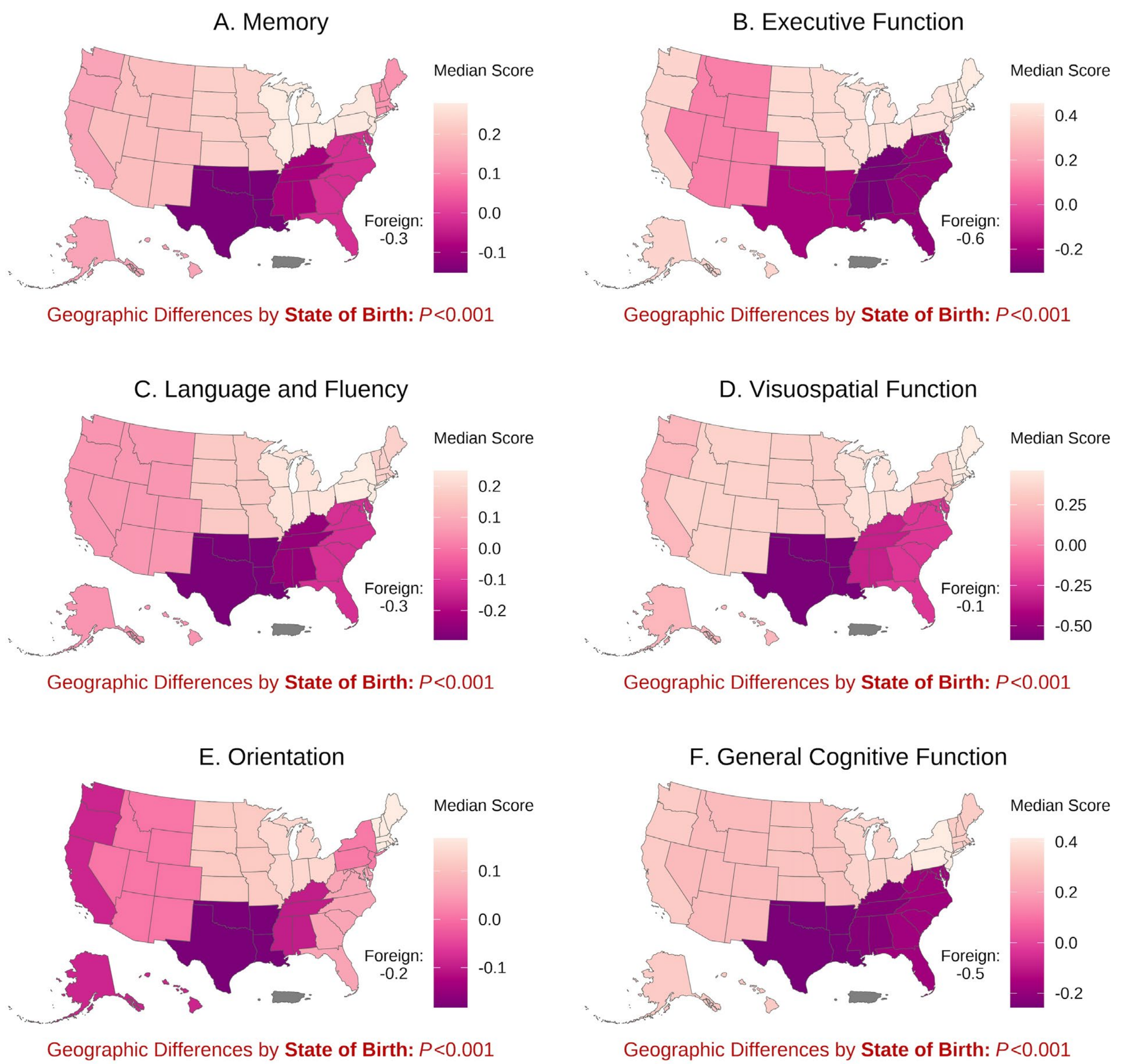
Notes: ADL = Activities of Daily Living; IADL = Instrumental Activities of Daily Living; IQR = Interquartile Range. The primary geographic unit for analyzing the contribution of place of birth was at the state level. However, due to restrictions on disclosing summary statistics at the state level, census-division-level birth location data were extracted from the HRS public data file to report the summary statistics at the U.S. census division level as shown in this table. The cognitive scores of each domain, were standardized to a mean of 0 and a standard deviation of 1 during the initial construction of domain-specific estimates. The sample size for each cognitive domains might be slightly lower than the total sample size (N=3,333), though the missingness was minimal.

Figure 1. Flow chart of sample selection process.



Notes: HRS = Health and Retirement Study, SES = socioeconomic status.
Alt Text: Flow chart detailing the step-by-step process of sample selection for the study.

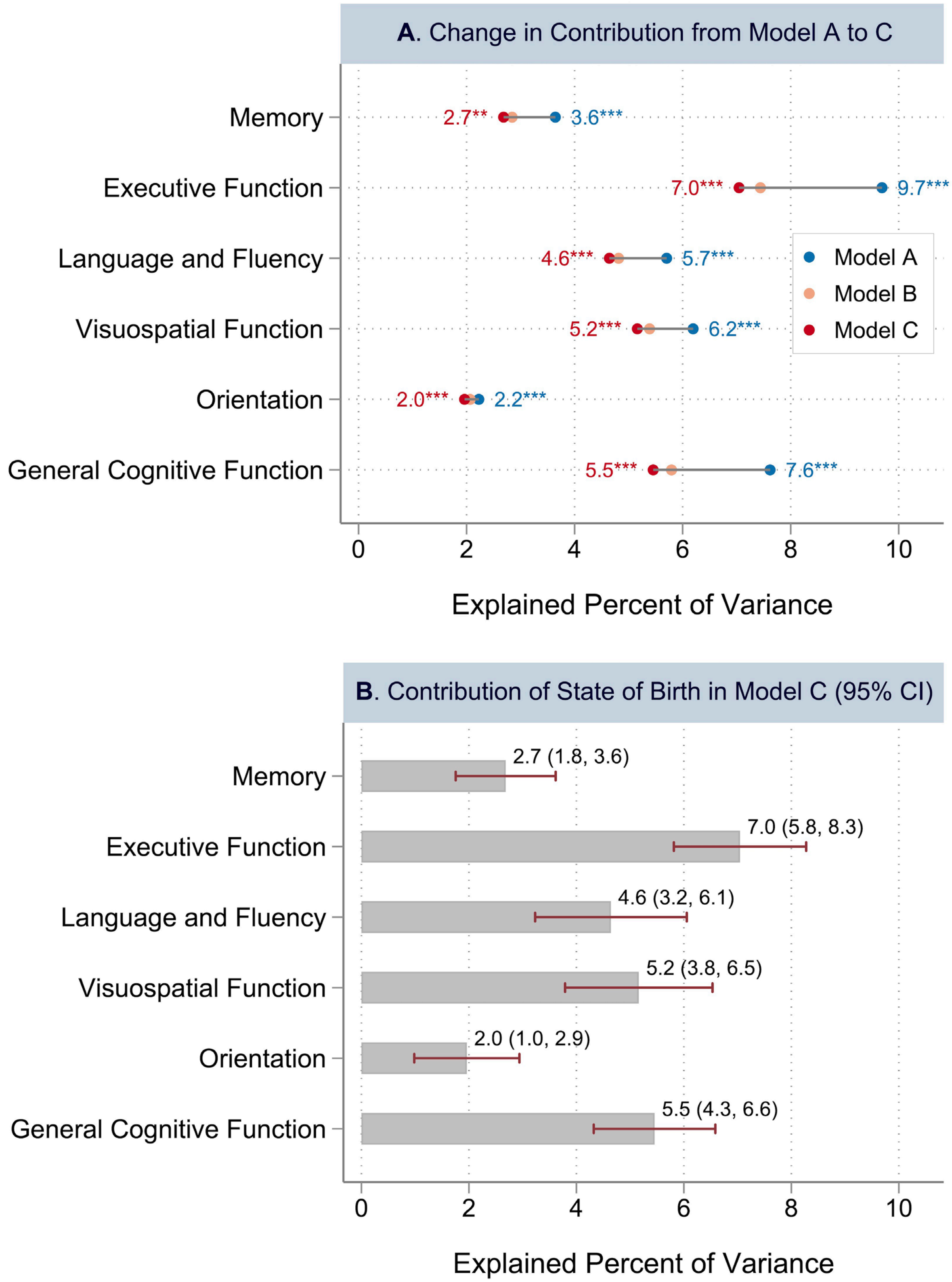
Figure 2. Geographic variation in cognitive function by place of birth.



Notes: State-level geographic differences in cognition across place of birth were tested based on HRS restricted data using Kruskal-Wallis tests; and P-values are shown in the caption of each panels, indicating statistically significant differences across state of birth. Medians of cognitive function scores were estimated and plotted at the census division level based on HRS public data after adjusting for age and sex (state-level statistics were not allowed to be disclosed); and deeper colors denote poorer average cognitive performance. Detailed summary statistics of cognitive function by place of birth (e.g., mean, median, standard deviation, interquartile range, and range) are shown in Supplementary Figure S2 and Table S2.

Alt Text: U.S. maps illustrating geographic variation in cognitive function domains by place of birth, with annotation indicating statistically significant differences across state of birth.

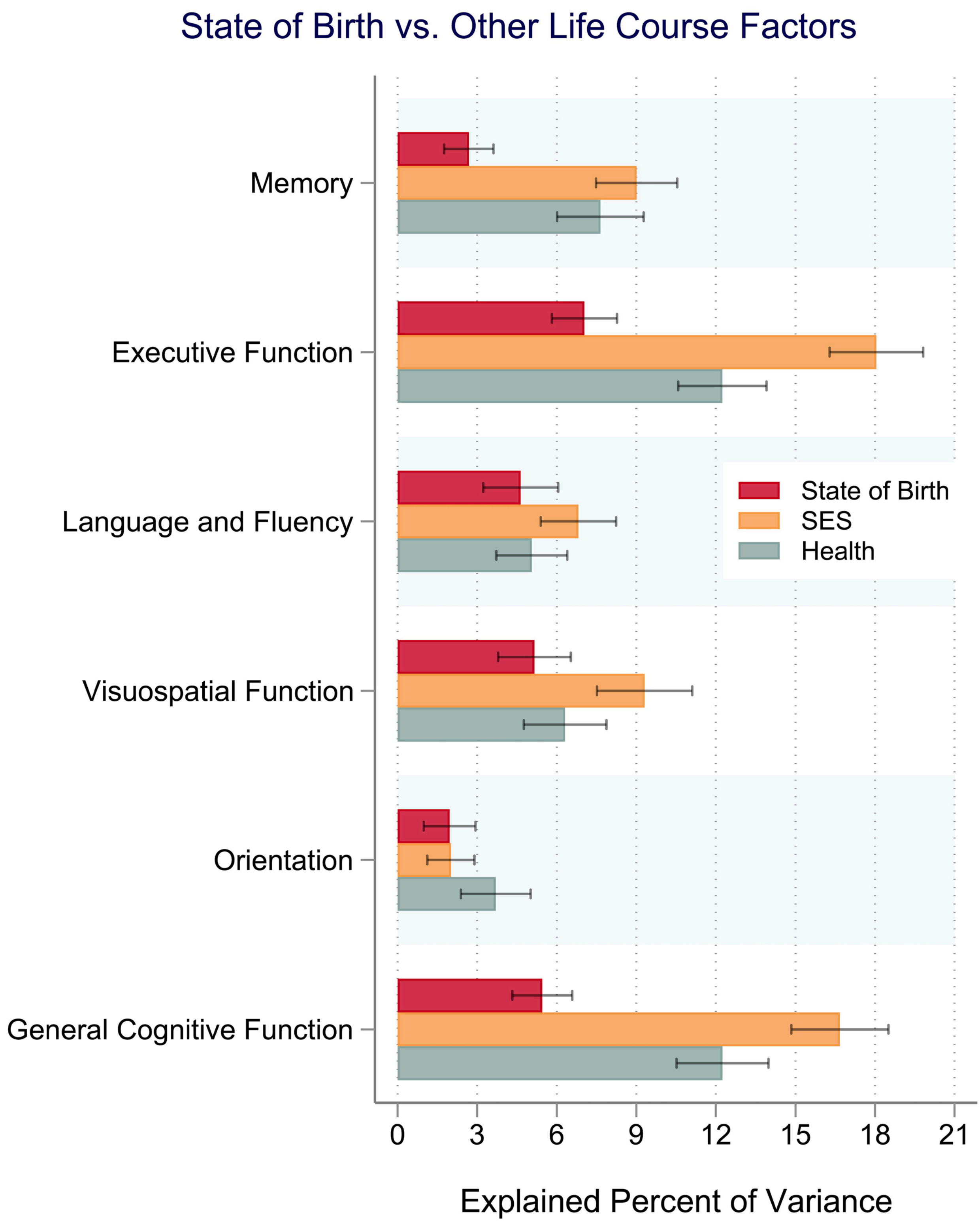
Figure 3. Contribution of state of birth to late-life cognitive function with different model specifications.



Notes: Model A was the most parsimonious model that only adjusted for demographic covariates, including age, sex, and race/ethnicity; Model B additionally adjusted for socioeconomic status including education (years), wealth level, working status, Medicare enrollment, Medicaid enrollment, military health plan enrollment, private health insurance coverage, and employer-based insurance coverage; and lastly, Model C further adjusted for health factors including hypertension, diabetes, cancer, lung diseases, heart diseases, stroke, psychiatric disorders, arthritis, ADL limitations, IADL limitations and smoking behaviors. Panel A displays the change in state of birth's contribution from Model A (blue color) to Model C (red color). Panel B presents the estimated contribution of state of birth in the most comprehensive setting (i.e., Model C) along with 95% bootstrapped confidence intervals. Each row represents the estimates for its corresponding cognitive function as shown on Y axis. The sample size for the analyses were 3,198 for memory, executive function, language and fluency, and general cognitive function, 3,161 for visuospatial function, and 3,191 for orientation. The analyses were weighted using HRS HCAP sampling weights to account for sample selection and non-response and improve the representativeness of the results.

Alt Text: Graphs showing the contribution of state of birth to cognitive domains in Model A-C, with Model C including the most comprehensive controls and displaying estimated confidence intervals.

Figure 4. Contribution of state of birth to cognitive function as compared to other life course factors.



Notes: The figure presents the decomposition results for state of birth, socioeconomic status (SES), and health factors estimated using Model C with the additional adjustment of demographic covariates including age, sex, and race/ethnicity. The horizontal bars denote the absolute contribution of each group of factors to the variation in each domain of cognitive function, i.e., explained percent of cognitive variance. 95% bootstrapped confidence intervals are displayed as horizontal lines. The sample size for the analyses were 3,198 for memory, executive function, language and fluency, and general cognitive function, 3,161 for visuospatial function, and 3,191 for orientation. The regression analyses were weighted using HRS HCAP sampling weights to account for sample selection and non-response and improve the representativeness of the results.
Alt Text: Bar graph comparing the contribution of state of birth and other life course factors to cognitive domains in the most comprehensive Model C setting.