AMERICAN PSYCHOLOGICAL ASSOCIATION

Psychology and Aging

© 2024 The Author(s)
ISSN: 0882-7974

2024, Vol. 39, No. 5, 457–466
https://doi.org/10.1037/pag0000833

The Flynn Effect and Cognitive Decline Among Americans Aged 65 Years and Older

Yun Zhang[1, 2, 3, 4], Joseph Lee Rodgers[5], Patrick O'Keefe[6], Wei Hou[1, 2], Stacey Voll[7], Graciela Muniz-Terrera[8], Linda Wänström[9], Frank Mann[1, 2], Scott M. Hofer[6], and Sean A. P. Clouston[1, 2]

[1] Program in Public Health, Renaissance School of Medicine, Stony Brook University
[2] Department of Family, Population, and Preventive Medicine, Renaissance School of Medicine, Stony Brook University
[3] Pediatric Cardiovascular Clinical Research Core, Pediatric Heart Center, Columbia University Vagelos College of Physicians and Surgeons
[4] Morgan Stanley Children's Hospital of New York-Presbyterian, New York, New York, United States
[5] Department of Psychology and Human Development, Vanderbilt University
[6] Department of Neurology, Oregon Health and Science University
[7] Institute of Aging and Lifelong Health, University of Victoria
[8] Department of Social Medicine, Heritage College of Osteopathic Medicine, Ohio University
[9] Department of Computer and Information Science, Linköping University

To contribute to our understanding of cohort differences and the Flynn effect in the cognitive decline among older Americans, this study aims to compare rates of cognitive decline between two birth cohorts within a study of older Americans and to examine the importance of medical and demographic confounders. Analyses used data from the National Health and Aging Trends Study (2011–2019), which recruited older Americans in 2011 and again in 2015 who were then followed for 5 years. We employed mixed-effect models to examine the linear and quadratic main and interaction effects of year of birth while adjusting for covariates such as annual round, sex/gender, education, race/ethnicity, heart disease, hypertension, diabetes, test unfamiliarity, and survey design. We analyzed data from 11,167 participants: 7,325 from 2011 to 2015 and 3,842 from 2015 to 2019. The cohort recruited in 2015 was born, on average, 5.33 years later than that recruited in 2011 and had higher functioning than the one recruited in 2011 across all observed cognitive domains that persisted after adjusting for covariates. In multivariable-adjusted analyses, a 1-year increase in year of birth was associated with increased episodic memory ($\beta = 0.045$, $SE = 0.001$, $p < .001$), orientation ($\beta = 0.034$, $SE = 0.001$, $p < .001$), and executive function ($\beta = 0.036$, $SE = 0.001$, $p < .001$). Participants born 1 year later had slower rates of decline in episodic memory ($\beta = 0.004$, $SE = 0.000$, $p < .001$), orientation ($\beta = 0.003$, $SE = 0.000$, $p < .001$), and executive function ($\beta = 0.001$, $SE = 0.000$, $p = .002$). Additionally, sex/gender modified this relationship for episodic memory (-0.007, $SE = 0.002$, $p < .001$), orientation (-0.005, $SE = 0.002$, $p = .008$), and executive function (-0.008, $SE = 0.002$, $p < .001$). These results demonstrate the persistence of the Flynn effect in old age across cognitive domains and identified a deceleration in the rate of cognitive decline across cognitive domains.

Public Significance Statement
This study contributes insights into cohort differences and the Flynn effect regarding various domains of cognitive decline among older Americans. Consistent with the Flynn effect research, results indicate that later cohorts exhibit improved cognition and a slower rate of decline in episodic memory, executive function, and orientation though the study also identified widening sex/gender disparities in cognitive domains in later generations.

Keywords: Flynn effect, cohort changes, cognition, longitudinal change, quantitative methods

Supplemental materials: https://doi.org/10.1037/pag0000833.supp

Denis Gerstorf served as action editor.
Yun Zhang https://orcid.org/0000-0002-9837-1365
Sean A. P. Clouston https://orcid.org/0000-0002-6124-0329
This work was supported by the National Institute on Aging (NIA) at the National Institutes of Health (NIH/NIA R01 AG067621 awarded to Scott M. Hofer). The National Health and Aging Trends Study was sponsored by the National Institute on Aging at the National Institutes of Health (NIH/NIA U01 AG032947) through a cooperative agreement with the Johns Hopkins Bloomberg School of Public Health. The authors declared no potential conflicts of interest with respect to the research, authorship, and/or publication of this article.

Data, analytic methods, and study materials will be made available upon request made to the corresponding author, Sean A. P. Clouston. The initial ideas and data appearing in the article have been disseminated at the Gerontological Society of America Annual Scientific Meeting 2023 as an oral presentation and published on Innovation in Aging 6 (Supplement_1) as an abstract. Statistical Analysis System code used to generate results for this

continued

Population aging is a major challenge to the economy and health systems of most and least developed countries (Wolters & Ikram, 2018), and it is expected to be accompanied by increases in the incidence of dementia that will strain health care systems worldwide (Winblad et al., 2016). A significant research question is whether later born generations suffer from more rapid cognitive decline (Chatterji et al., 2015) and to what extent developmental differences between birth cohorts might produce a reduced risk of dementia in old age (Clouston et al., 2021).

Of importance to this question is the eponymous finding wherein later born generations tend to have better performance on cognitive tests than earlier born generations (Flynn, 1984, 1987, 2007). The Flynn effect is often referred to as a secular rise in cognitive performance in young adulthood (Lynn, 2013) that is likely to extend over the lifespan to affect cognition in older adults (Rocca et al., 2011; Skirbekk et al., 2013). In the United States, seminal research reporting the Flynn effect found a secular increase in achievement scores recorded among high school students over time (Runquist, 1936), a result that was immediately replicated in children in rural Tennessee, United States (Wheeler, 1942) and among children residing in Hawaii, United States, that same year (Smith, 1942).

While studies remain unclear as to the origin of cohort shifts in cognition, prior explanations include educational opportunities (Brailean et al., 2018; Clouston et al., 2020; Skoog et al., 2017), improved technologies (Pietschnig & Voracek, 2015), better nutrition, more mental stimulation (Flynn & Flynn, 2012), or improved health and a healthier lifestyle (Elwood et al., 2013). Indeed, insofar as changes are made, it may be critically important to note that, while some changes like improved technology or increased literacy may be universally adopted, changes in the social value and improved treatment of women have changed dramatically over the past century (Caplow et al., 2001), resulting in widespread increases in educational attainment among women potentially resulting in an increased lifelong Flynn effect among women.

Noting that childhood cognition is a strong predictor of lifetime cognition, researchers began noticing that cognitive performance was higher in older adults as well (Zelinski & Kennison, 2007). Not only present, but a recent meta-analysis concluded that the Flynn effect was stronger in older ages as compared to among children (Pietschnig & Voracek, 2015), though that conclusion is somewhat contentious (Trahan et al., 2014). Globally, evidence suggests that cognition among older adults has improved over time and, in some cases, that age-related cognitive declines has slowed with time in the United States (Dodge et al., 2017), Amsterdam (Brailean et al., 2018), and France (Grasset et al., 2018), though results from Sweden only support higher cognitive performance while showing faster overall rates of cognitive decline (Karlsson et al., 2015). One notable study in Berlin suggested that not only did overall cognitive performance improve but that these improvements were associated with evidence of improved overall mental health (Gerstorf et al., 2015).

Understanding the differential impact of age on varying cognitive domains can provide valuable insights into the multifaceted nature of cognitive decline and inform targeted interventions to promote healthy cognitive aging. Yet, developmental trajectories of cognitive functioning vary between people and over time (Flynn & Weiss, 2007; Sundet et al., 2004). For example, studies recording crystallized cognition, including skills that are trained in schools and therefore involve accumulated knowledge and expertise and are related to long-term memory (Horn, 1987), report huge differences among children who undergo better schooling as compared to those who were neglected. Compared to "crystallized abilities," however, "fluid abilities" are significantly affected by biological aging processes and have been the focus of most studies on the Flynn effect (Harada et al., 2013). The gains in fluid abilities including in episodic memory or executive functioning may be stronger for fluid than for crystallized abilities in later born cohorts over 15 years (Pietschnig & Voracek, 2015; Rönnlund & Nilsson, 2009). By examining each domain separately, we might gain a nuanced understanding of how cognitive function evolves over time and explore potential differential patterns and trends. For example, studies of domain-specific changes have found that cohort differences can emerge in memory and are amplified in processing speed but are lacking for other domains including inductive reasoning in Amsterdam (Brailean et al., 2018), while others have reported that changes are persistent for cognitive decline across measures of response speed, executive function, and language fluency (Dodge et al., 2014). Additionally, identifying specific patterns within each domain can provide insights into the underlying mechanisms and potential interventions that may be effective for improving cognitive function. Thus, this research also aims to explore changes in aging trajectories for three domains of cognitive function, namely episodic memory, executive function, and orientation.

Compounding on these patterns, however, is the question of the potential slowing of cohort effects. Since around 2000, evidence has begun to amass that the Flynn effect may have begun to fade or even invert in some studies of Norway, Finland, and France (Dutton & Lynn, 2015; Dutton et al., 2016). Longitudinal data from 10 European countries from the Survey of Health, Ageing, and Retirement in Europe report that secular cohort gains were significantly smaller or close to zero in countries with initially higher performance levels, which may reflect that some countries approached the limits of cognitive plasticity or that societal structures have not yet been optimized to improve cognition (Hessel et al., 2018). Similar results have also been reported in some developing countries such as Saudi Arabia, China, and Latin America countries (Colom et al., 2007; Flynn & Flynn, 2012). Whether this is relevant among American

study are available in the Supplemental Materials.

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Yun Zhang conceived the work, performed the statistical analyses, and led the development of the article. Joseph Lee Rodgers, Patrick O'Keefe, Stacey Voll, Graciela Muniz-Terrera, Linda Wänström, and Frank Mann critically reviewed and edited the article. Wei Hou participated in the design of the methodology. Scott M. Hofer and Sean A. P. Clouston critically helped shape the research. All authors approved the analysis and the final version of the article.

Correspondence concerning this article should be addressed to Sean A. P. Clouston, Program in Public Health, Renaissance School of Medicine, Stony Brook University, 101 Nichols Road, Health Sciences Center, #3-071, Stony Brook, NY 11794-8338, United States. Email: sean.clouston@stonybrookmedicine.edu

older adults has not been adequately addressed, and as such this is one topic to which additional research could contribute.

Our goal is to expand on previous investigations of cohort differences in cognitive aging. The most popular method for advancing our understanding of the Flynn effects on cognitive aging is to examine cohort differences by comparing incidences and transitions of cognitive impairment and dementia. However, the classification criteria for cognitive status impacts the estimates of cases of cognitive impairment and dementia and, thus, impacts the comparison of secular cognition over time. Meanwhile, a few studies compared the micro changes in cognitive decline among nationally representative cohorts (Freedman et al., 2018). Thus, in our study we use a nationally representative sample of American older adults to examine continuous declines in cognitive function across different age cohorts to investigate the role of cohort-related differences in cognitive decline.

Method

Transparency and Openness

This research used data from the National Health and Aging Trends Study (NHATS) conducted by the Johns Hopkins University Bloomberg School of Public Health, with data collection by Westat, and support from the National Institute on Aging. The de-identified data and materials on which the study conclusions are based are publicly available online at https://www.nhats.org and available after an approval process as described by Freedman and Kasper (2019). The Statistical Analysis System code necessary to reproduce these analyses is available in the Supplemental Statistical Analysis System Code. The study design, hypotheses, and analytic plan were not preregistered.

Sample

We used data from the NHATS (2011–2019). The NHATS is a nationally representative sample of adults aged 65 years and older residing in community settings in the United States. It used a three-stage sampling design from the national Medicare enrollment file and targeted sample sizes by age group and race. The NHATS commenced recruitment in 2011 and reinterviewed participants annually with successive rounds enumerating the number of times that a person was interviewed as well as the number of years since 2010. The NHATS refreshed the sample in 2015 (Figure 1), to account for attrition and mortality biases that can affect prevalence and incidence estimates from longitudinal studies (Nunan et al., 2018). From all the NHATS respondents (n = 8,245), we excluded respondents who were represented by a proxy to complete interview questions and those lacking cognitive scores. We include a total of 7,325 participants who were followed from 2011 until 2015 and labeled them “Cohort 1” and examined results from the additional 3,842 participants who were followed from 2015 until 2019 that were labeled “Cohort 2.”

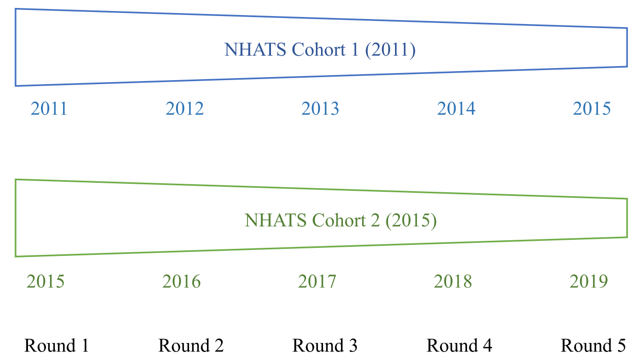
Measures

Cognitive Assessment

NHATS respondents took tests in three domains: *Episodic memory* is a critical measure of cognition and is sensitive to cognitive aging and Alzheimer’s disease (Elwood et al., 2013). A list of 10 nouns was read to each respondent as they appeared on a computer screen. Then, the respondent was asked to recall as many words as possible, given up to 2 min, in any order. A delayed word recall was administered after two other cognitive tests, in which the respondent was asked what words he/she could recall from the list read earlier. Scoring was 1 point for each word remembered immediately and delayed. The sum of immediate and delayed verbal recall tests of each respondent is his/her episodic memory score (/20 points). *Orientation* consists of date naming and naming the U.S. President and Vice President. For date naming, respondents were asked “to tell today’s date without looking at a calendar or watch,” including the month, day, year, and day of the week. For the orientation test based on naming the President and Vice President, respondents were asked the names of the current President and Vice President. Each accurate answer to the questions granted respondents a point covering date, month, year, day of the week, as well as the first and last names of the President and Vice President (/8 points). *Executive function* was measured based on the Clock Drawing Test, in which each respondent was asked to draw a clock on a piece of article in 2 min. The scoring for this test is based on Schretlen’ s approach (/5 points; Schretlen et al., 2010), utilizing a scale ranging from 0 to 5: 0 = *unidentifiable representation of a clock*, 1 = *highly distorted depiction*, 2 = *moderately distorted rendering*, 3 = *slightly distorted portrayal*, 4 = *reasonably accurate depiction*, and 5 = *entirely accurate rendition*. All cognitive scores have been standardized to facilitate comparisons and interpretations across different individuals and time points.

Figure 1

National Health and Aging Trends Study Cohorts



Note. National Health and Aging Trends Study (NHATS) Cohorts were representative of older Medicare beneficiaries. The first cohort in the NHATS was recruited in 2011 and reinterviewed annually, while the 2nd cohort was complemented in 2015. See the online article for the color version of this figure.

Demographic, Health, and Temporal Variables

Demographics are provided according to which year the participant is included. Advanced age and sex/gender are the two most widely recognized risk factors for cognitive decline. Race/ethnicity is also found to be related to the risks of cognitive decline and progression to dementia (Mehta & Yeo, 2017). Education plays a beneficial role in both cognitive assessment and decline processes (Clouston et al., 2020). Cognitive instruments used repeatedly may be sensitive to test unfamiliarity, also known as a learning/practice effect. People tend to perform better upon repeated cognitive tests between the first and subsequent assessments, due to increased familiarity with the tests and decreased anxiety (Vivot et al., 2016). Test familiarity effect can lead to improved performance over time due to practice or improved familiarity with the test and testing circumstances, rather than improved cognition. By including control for test unfamiliarity, this study aims to separate the cognitive decline from potential bias introduced by a lack of familiarity with the assessment. This allows for a more accurate assessment of the actual cognitive changes occurring over time, providing a clearer understanding of the factors contributing to cognitive decline in our sample.

In summary, we controlled for annual observation round, year of birth, sex/gender (male/female), educational attainment (less than high school diploma, high school diploma, college degree and beyond), race/ethnicity (non-Hispanic White, non-Hispanic Black, Hispanic, other minorities), familiarity (1 for each individual's first round in the cohort when they were unfamiliar with cognitive assessments within the NHATS studies, and 0 for participants' subsequent rounds), heart disease, hypertension, and diabetes of each individual into our models.

The NHATS research team conducted the interviews and obtained written informed consent from the participants. This research was determined by the ethics review board at Stony Brook University to be exempt from human subject review (Stony Brook, #498619, "Integrative Analysis of Longitudinal Studies on Aging").

Statistical Analyses

Linear mixed models (Laird & Ware, 1982) are a flexible approach to modeling unbalanced longitudinal data with considerable variation in the content, number, and timing of observations for the individual trajectories. It considers all available information over the follow-up and deals with the intra-subject correlation observations (Gueorguieva & Krystal, 2004; Raji et al., 2005).

We used year of birth as a continuous variable predictor and test for linear and quadratic main and interaction effects in linear mixed models to describe and compare cognitive decline among different years of birth while we centered the year of birth variable in 1936 to improve interpretability of intercepts, and facilitate the assessment of its effects on the cognitions. We ran separated models unadjusted and adjusted for year of birth, round (year; 1–5), sex/gender (male = 1, female = 2), education (<high school = 1, high school graduate = 2, and college and beyond graduate = 3), race (non-Hispanic White = 1, non-Hispanic Black = 2, other non-Hispanic race = 3, and Hispanic = 4), unfamiliarity (first test = 1, other tests = 0), heart disease (yes = 1, no = 0), hypertension (yes = 1, no = 0), and diabetes (yes = 1, no = 0) to describe and compared trends of standardized scores of episodic memory, orientation, and executive function. We tested step-by-step to include significant interactions between covariates and the cohort effect, including the interaction between year of birth and sex/gender. All models adjusted for survey design (weight, stratum, and cluster) to ensure result generalizability to separately represent the older Medicare beneficiary Americans living in community settings in 2011 and 2015. We conducted analyses using Statistical Analysis System 9.4. All statistical tests used two-sided $\alpha = .05$ to identify statistically significant coefficients and 95% confidence intervals were used.

Results

Demographics

We present the demographic characteristics and comparison tests of the two NHATS cohorts at baseline in Table 1. The NHATS cohorts were majority female, high school graduates, and non-Hispanic Whites. Compared to participants recruited in 2011, a higher percentage of participants recruited in 2015 had high school diplomas or were college graduates.

Table 1
Baseline Sample Characteristics of the National Health and Aging Trends Study

Characteristic	Cohort 1 (2011–2015)[a]	Cohort 2 (2015–2019)[a]	p^b	p^c
Sex/gender				
Female	4,252 (58.05)	2,174 (56.59)	.137	.094
Education				
<High school	1,945 (26.83)	768 (20.73)	<.001*	<.001*
High school graduate	3,752 (51.76)	2,047 (55.26)		
College and beyond graduate	1,552 (21.41)	889 (24.00)		
Race				
White, non-Hispanic	5,030 (69.36)	2,517 (68.03)	.023*	.039*
Black, non-Hispanic	1,585 (21.86)	793 (21.43)		
Other non-Hispanic	205 (2.83)	135 (3.65)		
Hispanic	432 (5.96)	255 (6.89)		
Heart disease				
Yes	1,332 (18.22)	618 (16.14)	.006*	.004*
Hypertension				
Yes	4,897 (66.94)	2,549 (66.47)	.611	.359
Diabetes				
Yes	1,859 (25.39)	1,032 (26.90)	.083	.127
Year of birth	1,933.53 (7.78)	1938.86 (7.83)	<.001*	<.001*
Total	7,325	3,842		

[a] Cohort 1 was recruited in 2011, while Cohort 2 was recruited in 2015 (See Figure 1). [b] p values calculated for an unweighted survey design. [c] Adjusted p values accounting for the intricacies of complex survey design (including strata, clusters, and weights).
* $p < .05$.

During the baseline assessment, participants recruited in 2015 exhibited notably higher average scores across all cognitive tests (global cognition, episodic memory, orientation, and executive function) when compared with those recruited in 2011. This difference was observed in both unadjusted and adjusted analyses, accounting for covariates such as cohort, sex/gender, baseline age, education, race/ethnicity, heart disease, hypertension, and diabetes.

Comparison of Cognitive Decline Between Cohorts

To explore the effects of covariates on cognitive decline, we used mixed-effect models adjusted for centered year of birth, round (year), sex/gender, education, race/ethnicity, heart disease, hypertension, diabetes, test unfamiliarity, as well as survey designs (Table 2).

In Table 3, we report the effects of year of birth, round, the interaction between year of birth and round. The only significant interaction was the one between the year of birth and sex/gender in orientation, which was included in the final models. For each 1-year increase in the year of birth, there was a significant increase observed in the standardized scores of episodic memory, orientation, and executive function, with estimated coefficients of 0.045 (SE = 0.001, p < .001), 0.034 (SE = 0.001, p < .001), and 0.036 (SE = 0.001, p < .001), respectively. These findings suggest that advancing in birth year is associated with higher scores in all three cognitive domains.

The interaction between the year of birth and round reveals that the association between cognition and time significantly varies based on the participant's birth year. Notably, as cognitive scores decline over time, participants born in later years exhibited a significantly slower rate of decline in the standardized scores of episodic memory, orientation, and executive function. Specifically, the estimated coefficients were 0.004 (SE = 0.000, p < .001), 0.003 (SE = 0.000, p < .001), and 0.001 (SE = 0.000, p < .001), respectively. These findings indicate that individuals born in later years are expected to experience a more gradual decline in cognitive function compared to those born in earlier years.

Effect of Demographics and Chronic Health Conditions on Cognitive Decline

Older individuals who graduated from high school demonstrated significantly higher standardized scores in episodic memory (0.381, SE = 0.019, p < .001), orientation (0.435, SE = 0.019, p < .001), and executive function (0.306, SE = 0.018, p < .001) when compared to those who did not graduate from high school. Furthermore, individuals with a college degree displayed a more pronounced decline in episodic memory (0.721, SE = 0.022, p < .001), orientation (0.686, SE = 0.022, p < .001), and executive function (0.497, SE = 0.021, p < .001) when compared to high school graduates.

Consistently, the presence of diabetes was associated with lower standardized scores in episodic memory (−0.137, SE = 0.016, p < .001), orientation (−0.090, SE = 0.016, p < .001), and executive function (−0.093, SE = 0.015, p < .001). In comparison to females at baseline, males exhibited a significantly lower score in episodic memory (−0.231, SE = 0.014, p < .001) but better orientation (0.034, SE = 0.014, p = .018). Specifically, we found a significant interaction such that sex/gender disparities are increasing across all the standardized scores in episodic memory (−0.007, SE = 0.002, p < .001), orientation (−0.005, SE = 0.002, p = .008), and executive function (−0.008, SE = 0.002, p < .001). As expected, we found a significant effect of testing unfamiliarity across episodic memory (−0.095, SE = 0.010, p < .001), orientation (−0.080, SE = 0.009, p < .001), and executive function (−0.057, SE = 0.012, p < .001).

Figure 2 illustrates the estimated cognitive scores encompassing episodic memory, orientation, and executive function, acquired using mixed-effect models that were adjusted for various factors including Year of Birth, Round (year of observation), Year of Birth × Round, Year of Birth × Year of Birth, Male Sex/Gender, Year of Birth × Sex/Gender, Education, Race/Ethnicity, Heart Disease, Hypertension, Diabetes, Testing Unfamiliarity, and Survey Designs. Our analysis was centered on birth year cohorts in 1926, 1936, and 1946, observing their cognitive trajectories across five distinct rounds. The results reveal a noteworthy pattern: subsequent generations exhibit notably higher initial cognitive scores and relatively gentler declines across episodic memory, orientation, and executive function. Moreover, since gender differences, females consistently exhibit superior episodic memory and executive function scores, both at the baseline and in the trajectory of decline, with this advantage widening over time. Although males initially hold an advantage in orientation compared to females, this advantage erodes over generations, and there is a possibility of females catching up or surpassing males in subsequent generations.

Table 2

Crude and Multivariable-Adjusted Differences in Cognitive Functioning Across Three Domains in the National Health and Aging Trends Study, Stratified by Recruitment Cohort

Cognitive outcome	Unstandardized *M* (*SD*)		Standardized *M* (*SD*)		Unadjusted for covariates		Adjusted for covariates	
	Cohort 1 (2011–2015)[a]	Cohort 2 (2015–2019)[a]	Cohort 1 (2011–2015)[a]	Cohort 2 (2015–2019)[a]	Unweighted p[b]	Weighted p[c]	Unweighted p[d]	Weighted p[e]
Episodic memory	7.41 (3.67)	7.85 (3.68)	−0.13 (0.97)	−0.02 (0.98)	**<.001**	**<.001**	**.046**	**<.001**
Orientation	5.77 (1.96)	6.23 (1.92)	−0.16 (1.00)	0.07 (0.98)	**<.001**	**<.001**	**<.001**	**<.001**
Executive function	3.24 (1.29)	3.55 (1.24)	−0.23 (1.02)	0.02 (0.99)	**<.001**	**<.001**	**<.001**	**<.001**

Note. Bold typface was used to highlight p values that were considered to be statistically significant.
[a] Cohort 1 was recruited in 2011, while Cohort 2 was recruited in 2015 (See Figure 1). [b] p values calculated without applying any survey design or adjustments for covariates. [c] p values computed by considering survey design (including strata, clusters, and weights) but without applying any additional adjustments for covariates. [d] p values calculated without applying any survey design to the survey design, but adjusted for covariates (cohort, sex/gender, baseline age, education, race/ethnicity, heart disease, hypertension, diabetes). [e] p values computed by considering survey design (including strata, clusters, and weights) and adjusted for covariates (cohort, sex/gender, baseline age, education, race/ethnicity, heart disease, hypertension, diabetes).

Table 3

Results From Longitudinal Mixed-Effects Models Showing Associations Between Year of Birth and Cognitive Functioning and Decline, National Health and Aging Trends Study

Risk factor	Episodic memory			Orientation			Executive function		
	Est.	*SE*	*p*	Est.	*SE*	*p*	Est.	*SE*	*p*
Intercept	0.001	0.026	.984	−0.165	0.025	**<.001**	−0.161	0.026	**<.001**
Year of birth	0.045	0.001	**<.001**	0.034	0.001	**<.001**	0.036	0.001	**<.001**
Round (year of observation)	−0.039	0.003	**<.001**	−0.037	0.003	**<.001**	0.001	0.004	.888
Year of Birth × Round	0.004	0.000	**<.001**	0.003	0.000	**<.001**	0.001	0.000	**.002**
Year of Birth	−0.001	0.000	**<.001**	−0.001	0.000	**<.001**	−0.001	0.000	**<.001**
Male sex/gender	−0.231	0.014	**<.001**	0.034	0.014	**.018**	−0.003	0.014	.803
Year of Birth × Sex/Gender	−0.007	0.002	**<.001**	−0.005	0.002	**.008**	−0.008	0.002	**<.001**
High school diploma versus <high school	0.381	0.019	**<.001**	0.435	0.019	**<.001**	0.306	0.018	**<.001**
College graduate versus <high school	0.721	0.022	**<.001**	0.686	0.022	**<.001**	0.497	0.021	**<.001**
Heart disease	0.007	0.019	.724	−0.060	0.018	**.001**	−0.013	0.018	.454
Hypertension	0.009	0.014	.533	0.058	0.014	**<.001**	0.038	0.014	**.005**
Diabetes	−0.137	0.016	**<.001**	−0.090	0.016	**<.001**	−0.093	0.015	**<.001**
Black, non-Hispanic versus White, non-Hispanic	−0.355	0.026	**<.001**	−0.173	0.025	**<.001**	−0.377	0.025	**<.001**
Other race/ethnicity versus White, non-Hispanic	−0.418	0.036	**<.001**	−0.217	0.036	**<.001**	−0.231	0.035	**<.001**
Hispanic versus White, non-Hispanic	−0.334	0.029	**<.001**	−0.389	0.029	**<.001**	−0.348	0.028	**<.001**
Testing unfamiliarity	−0.095	0.010	**<.001**	−0.080	0.009	**<.001**	−0.057	0.012	**<.001**

Note. Bold typeface was used to highlight p values that are statistically significant. Mixed-effect models were employed, adjusting for covariates such as centered year of birth (1928), annual observation round, sex/gender, education, race/ethnicity, heart disease, hypertension, diabetes, and testing unfamiliarity. The models also accounted for significant interactions. All outcomes were standardized ($M = 0$, $SD = 1$) to facilitate between-domain comparisons. Est. = Estimate; *SE* = standard error.

Discussion

The main aims of our research were to investigate trends in cognitive decline and determinants for the differences using a nationally representative sample. Our findings show that significant gains occurred in all the tested cognitive domains, across episodic memory, executive function, and orientation, when comparing participants born in an earlier year to those born in a later year. Specifically, later generations had slower rates of decline for episodic memory, executive function, and orientation. Consistently, poorer educational attainments, diabetes, and minority race/ethnicity, are associated with worse cognition. Significantly, our findings highlight the escalating sex/gender disparities observed in the domains of episodic memory, executive function, and orientation.

Cohort Trends

As described above, we described continuous changes in the rate of cognitive decline among older Americans aged 65 years and older from 2011 to 2015 and 2015 to 2019. Using the year of birth as a continuous variable predictor and test for linear and quadratic main and interaction effects, we focus on differences in intraindividual change over time, accounting for interindividual differences in cognition. In our comparison results, the difference in intercept and cognitive decline was consistent across cognitive domains. The most supportive evidence we found comes from analyses of episodic memory, a part of "fluid cognition" and most sensitive to biological aging processes. The later generation has a significantly higher intercept and a slower rate of decline for episodic memory. These results support the view that birth cohorts differ in terms of lifetime cognitive performance, but also support the view that earlier cohorts also have a slower decline of episodic memory (Skirbekk et al., 2013) and that the participants' episodic memory is better over time. Furthermore, our comprehensive analysis illuminated a notable reverse quadratic impact of birth year, underscoring that the observed enhancements possess a finite trajectory and gradually decelerate as time progresses. Furthermore, we found a consistent pattern in orientation and executive function for the later cohort. These results are in line with previous studies showing that later cohorts demonstrate higher levels of cognition and decreased prevalence of dementia, which continues in the 2000s for older people in the United States (Crimmins et al., 2016; Freedman et al., 2018; Hudomiet et al., 2018; Langa et al., 2017; Rocca et al., 2011; Weden et al., 2018).

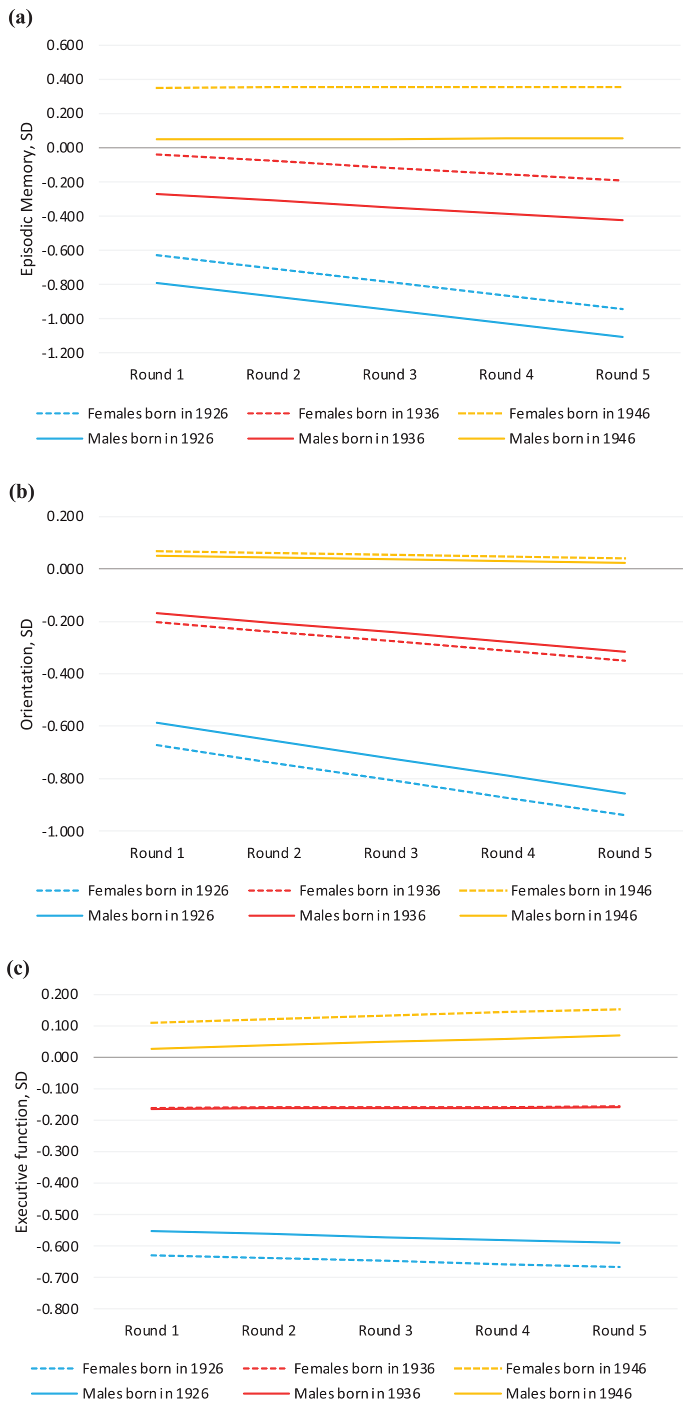
The intricate relationship between the cohort effect, the period effect, and the Flynn effect warrants clarification. The cohort effect addresses "the impact of historical effects on a group of individuals who share similar environmental circumstances at equivalent points in their maturation sequence" (Schaie, 2005). In contrast, the period effect involves a specific alteration that transpires at a certain juncture, uniformly impacting all age groups and cohorts. Crucially, a hallmark of the period effect is its consistency across age groups, remaining unaffected by birth year or cohort distinctions. The Flynn effect, which describes the rise in average intelligence test scores over generations, is intertwined with these concepts. Given that our study encompassed participants born from 1906 to 1950 and employed both birth cohort as a categorical predictor and year of birth as a continuous predictor, we could effectively discern the cohort effect during a period when no period effects were expected, contributing to our understanding of cognitive trends in the context of the Flynn effect.

Other Results

Consistent with the previous evidence, we found that poorer educational level, minority race/ethnicity, heart disease, hypertension, and diabetes were associated with lower cognition, while a higher

Figure 2

Expected Trends in Cognitive Decline Across Birth Year Cohorts and Sex/Gender in the National Health and Aging Trends Study



Note. (a) Episodic memory changes in birth cohorts stratified by sex/gender. (b) Orientation changes in birth cohorts stratified by sex/gender. (c) Executive function changes in birth cohorts stratified by sex/gender. Cognitive scores were estimated using mixed-effect models, adjusting for variables such as Year of birth, Round (year), Year of Birth × Round, and Year of Birth × Year of Birth. The centered year of birth (1936) were incorporated to show mean rates of cognitive change by cohort.

level of education and test unfamiliarity was associated with cognition (Yaffe et al., 2009). There were racial and ethnic differences in cognition in late life (Garcia et al., 2018; Sheffield & Peek, 2011; Weuve et al., 2018) that we also identified here.

In contrast with non-Hispanic Whites, individuals of other races and ethnicities exhibit lower scores in episodic memory, orientation, and executive memory at baseline. We also observed lowered cognition in the first round consistent with testing unfamiliarity, wherein participants scored lower in episodic memory, orientation, and executive memory when undertaking the test for the first time. In addition to the recognized sex/gender differences in cognition during late life, our study revealed a widening gap in cognitive functions between males and females, with males exhibiting poorer cognitive function. We examined the potential for interaction effects between the year of birth and participants' sex/gender. Specifically, when compared to females, males exhibited lower performance in episodic memory, and this gap was observed to increase over time. Furthermore, while males initially displayed advantages in orientation and executive function, our findings suggest that these advantages gradually diminish, indicating a convergence between the sex/gender in these cognitive domains. The widening sex/gender disparity across various cognitive domains within later generations is likely influenced by a combination of sociocultural, biological, and environmental factors. Changes in gender roles, improved educational opportunities for women, and increased participation of women in cognitively stimulating activities could contribute to enhanced cognitive performance among females. Additionally, improvements in health care and lifestyle factors might disproportionately benefit women's cognitive aging. On the other hand, societal shifts might have differentially impacted cognitive engagement between genders, potentially leading to the widening disparity observed over time. Future research could delve deeper into the interplay of sociocultural, biological, and environmental factors, which may yield insights into potential intervention strategies to mitigate or manage the observed disparities.

Limitations and Strengths

Our study is novel in the description of continuous cognitive decline trends across various cognitive domains of older Americans and its use of large longitudinal, nationally representative cohorts of older Americans. Despite several strengths of this study, several limitations should be acknowledged. First, survivor bias could emerge if participants who dropped out and those who stayed may differ in terms of their cognitive function. Second, the participants in our cohort were 65 years and older, and the average age was over 70 years old, so results may not generalize to people born after 1950 or who are younger than 65 years. Third, while we did identify a cohort effect, the timespan of the study is very small and our difference between cohorts was only 5.3 years. Since the theory behind the Flynn effect implies that cognitive functioning changes regularly over time, the ability to see that effect is determined largely by three factors: sample size, the time between initial observations, and the sensitivity of the outcome to these effects. Here, we used highly sensitive measures of cognition and a relatively large sample size, and we believe that this helped to facilitate the identification of cohort changes despite the tight observational window. Fourth, here, we do not specifically interrogate causation. Prior work has clarified that higher educational attainment is related to improved cognition even when accounting for earlier cognitive performance measures (Clouston et al., 2012). Nevertheless, educational attainment here was an incomplete explanation for cohort effects, thereby suggesting that educational attainment alone is insufficient to explain the complete cohort effect in the U.S. context. Finally, prior studies examining changes in cognitive domain have reported improved cognition but have also shown a similar tendency toward improved mental health that was not interrogated here (Gerstorf et al., 2015). As such, results may imply the potential for changes to brain structure or functioning that could have broader implications and should be studied further in follow-up studies.

Conclusion

This research provides mixed support for cohort differences in cognitive decline among Americans aged 65 years and older. Although the rate of cognitive decline varies across domains of cognition, our results support the Flynn effect in cognitive domains that the general levels of episodic memory, orientation, and executive function of a later American cohort improve over generations. It was noteworthy that our results indicate an expanding disparity in episodic memory, orientation, and executive function between males and females over time. Monitoring the significant risk factors and disparities is important for the social security and health system implications of population aging in the United States.

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Received August 11, 2022
Revision received May 6, 2024
Accepted May 13, 2024 ■