Cohort and Period Effects as Explanations for Declining Dementia Trends and Cognitive Aging

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Studies have reported that the age-adjusted incidence of cognitive impairment and dementia have decreased over the past two decades. Aging is the predominant risk factor for Alzheimer's disease and related dementias and for neurocognitive decline. However, aging alone cannot explain changes in the overall age-adjusted incidence of dementia. The objective of this position paper was to describe the potential for cohort and period effects in cognitive decline and incidence of dementia. Cohort effects have long been reported in demographic literature, but starting in the early 1980s researchers began reporting large historical cohort trends in cognitive function. At the same time, period effects have emerged in the form of economic factors and stressors in early and midlife that may result in reduced cognitive dysfunction. Recognizing that aging individuals today were once children and adolescents and that research has clearly noted that childhood cognitive performance are associated with old-age cognitive performance, this review proposes the need to connect these cohort effects with differences in late-life functioning.

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Introduction

Alzheimer's disease and related dementia (ADRD) is believed to affect more than 43 million people worldwide, accounting for 2.4 million deaths per year. ADRD is the fifth leading cause of death worldwide, accountable for more than 28 million disability-adjusted life-years lost globally (Nichols et al. 2019). In preclinical phases, ADRD is characterized by slow but progressive cognitive declines including those in verbal memory, processing speed, visuospatial ability, fluency, and executive functioning (Richards and Deary 2014; Karr et al. 2018). The end result within an individual is many years of cognitive decline progressing through mild and then more severe forms of cognitive impairment (Bruscoli and Lovestone 2004). ADRD becomes clinically relevant when cognitive dysfunction causes limitations in everyday functioning (McKhann et al. 2011). The ultimate goal of the current paper is to provide a conceptual orientation and to review relevant research linking cognitive processes from childhood to debilitating health trends in older adulthood. Following a conceptual orientation now standard in demography, sociology, psychology, economics, and other behavioral sciences, we use age, period, and cohort effects to orient past, present, and future research on this link. Ultimately, we propose that linking childhood cognition with adult dementia via the Flynn effect can make contributions to both research and policy arenas.

Background

Understanding trends in ADRD incidence, prevalence, indicators, and/or risk factors is critical to improving our understanding of the burden of the disease. To that end, an increasing number of studies have suggested that the incidence of cognitive impairment and dementia have been decreasing over the past two decades in the United Kingdom, parts of Europe, across Eastern Asia (but not Japan), the Netherlands, Canada, and the United States. The overall health of the population has been improving consistently over the centuries as measured by enormous increases in lifespan (Zijdeman and de Silva 2014), which appear not to be slowing (Aburto et al. 2020). While there is increasing agreement that there are a range of preventable factors such as health behaviors and risk exposures (Livingston et al. 2020), this finding related to cognitive impairment and dementia caught researchers interested in ADRD by surprise (Larson, Yaffe, and Langa 2013). However, while this cohort shift is replicable across studies and within studies when using different methodologies (Hudomiet, Hurd, and Rohwedder 2018), it is not universally identifiable (van den Kommer et al. 2018; Dufouil et al. 2018), and as such the potential for future cohorts

to experience continuation or reversal of this downward dementia trend is unknown.

Aging is the predominant risk factor for ADRD and for neurocognitive decline. However, aging cannot explain changes in overall age-adjusted incidence in ADRD. To date, the declining trend in the incidence of ADRD has been attributed to period effects, including most notably reductions in risk factors for vascular disease, though trends have been found across socially disparate groups (Crimmins et al. 2018; Weuve et al. 2018) and are not easily explained by medical comorbidities such as cardiovascular disease and diabetes (Zissimopoulos et al. 2018). Noting strong concordance between childhood cognition and cognitive performance in old age, Dickinson and Hiscock (2010) suggest that around 85 percent of the apparent cognitive aging in cognitive scores between ages 20 and 70 was actually attributable to the Flynn effect, a cohort phenomenon with no within-person etiology.

Cohort effects are common but often give rise to surprising results when examined in detail. Most aging studies are focused on survivors of cohorts exposed to what are now considered poor childhood conditions, while younger participants entering into aging studies have relatively more favorable experiences. Many of the respondents in the most common aging studies were raised in environments similar to those prevalent in many developing countries during the past 40 years. Europeans currently assessed by aging studies such as the Survey of Health, Ageing, and Retirement in Europe (SHARE) were born in the 1920s–1960s on average, a time when the average infant mortality rate in Europe was changing rapidly but was on average approximately 7/1,000 live births. Estimates from 2015 suggest that this figure is much higher than for children currently being born into Europe (1.0/1,000 live births), and 40 percent higher than across the continent of Africa (5.5/1,000 live births). Indeed, this child mortality rate is comparable to only some of the poorest countries including Somalia (7.5/1,000) and is substantially higher than present-day Malawi (4.3/1,000), one of the poorest countries in the world (UNICEF et al. 2015). Even early researchers in the United States remarked that in 1919, 60–80 percent of infant mortality was due to preventable diarrheal and infectious diseases (Palmer and Blakeslee 1921). That estimate is similar to rates of death in the poorest countries today, where 70 percent of child deaths may still be due to preventable diarrheal and infectious diseases, and 45 percent of child deaths are due directly to malnutrition (UNICEF 2016). Is it possible, then, that a portion of Alzheimer's disease risk is due to generational differences in childhood conditions?

Objective

Recent meta-analyses suggested that the Flynn effect has been operating across the world for at least the past century (Pietschnig and Voracek 2015; Trahan et al. 2014). Concurrently, global reductions in ADRD risk may have been occurring as well. The objective of this review paper is to describe the potential for cohort and period effects to account for changes commonly attributed to cognitive aging. We begin by discussing evidence for cohort-related changes and implications for cognitive reserve and brain maintenance, and then discuss the potential for influence of short-term exposures in period effects. The possibility of age and aging effects are always in the foreground and will also be treated throughout, with full knowledge of the confound that precludes consideration of all three types of effects simultaneously, particularly in cross-sectional designs (Bell and Jones 2015). Finally, we frame the potential for a broad research agenda investigating the links across the lifespan between childhood cognitive performance and later adult ADRD risk. At a policy level, such a research agenda has the potential to inform both medical and behavioral interventions.

Explanations for changes over time

Prior efforts have been completed to determine whether there are cohort trends in ADRD risk or in cognitive scores (Table 1). These results are somewhat inconclusive, but generally suggest that incidence of ADRD diagnosed clinically or algorithmically relying on cognitive scores appear to be reliably diminishing over time, and that cognitive performance later in life is often higher in those who were born in earlier cohorts. There is less evidence, however, for reasons of this decline, with multiple studies reporting only a lack of access to education or health behavior measures to explain these changes.

Flynn effects

Individuals born at the same time are born into a specific context in which parenting, access to resources, the distribution and specifics of scientific knowledge, and the methods through which communication occur are constricted by technology and knowledge available at that time. These individuals go through elementary schooling "together" and enter the same employment markets. Because of these shared experiences, cohorts represent centers through which social change often occurs (Ryder 1985). Cohort trends have been examined when highlighting the consistent improvement in overall health due to successive improvements in socioeconomic conditions in early life (Caldwell 2001). Starting in the early 1980s, Flynn (Flynn 1984) began reporting an increasing secular

TABLE 1 Existing literature targeted at understanding changing trends in dementia incidence and their results

First Author	Year	*N*	Maximum years	Last birth year	Country	Result
Manton	2005		17	1934	USA	Reduced incidence of Dementia Diagnosis
Rocca	2011				USA	Changes in cognitive impairment defined by an algorithm
Scrijvers	2012	7,496	5	1940	Netherlands	Incidence of dementia decreased
Wiberg	2013	2,039	0	1936	Sweden	No Association
Matthews	2013	7,635	0	1946	UK	Prevalence of cognitive impairment with and without dementia
Dodge	2014	3,626		1931	USA	Cognitive functioning differences across cohorts
Grasset	2015	3,573	10	1935	France	Incidence decreased (diagnosis was unchanged)
Wu	2015	Review		1948	Asia	Increased prevalence over time
Peres	2016	1,501	0	1943	France	Inconsistent: increase prevalence of dementia diagnosis, and reduced prevalence of cognitive impairment
Kosteniuk	2016	403,123	8	1968	Canada	Inconsistent: decreased incidence, increased prevalence
Ohara	2017	2,034	10	1947	Japan	Increased incidence in later cohorts
Noble	2017		15	1934	USA	Incidence decreased
Langa	2017	21,057	0	1947	USA	Prevalence cognitive impairment not dementia decreased
Donegan	2017	89,666,224	10	2015	UK	Age-standardized prevalence of dementia diagnosis
Derby	2017	1,348	22	1935	USA	Incidence of dementia decreased
Leggett	2017	3,617	25	1961	USA	Reductions in cognitive errors
Dodge	2017	3,663		1943	USA	Changes in cognitive performance and in practice effects and in rates of change over time

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TABLE 1 (continued)

First Author	Year	*N*	Maximum years	Last birth year	Country	Result
Freedman	2018	27,547	4	1950	USA	Inconsistent: Incidence stable, Prevalence dementia decreased yearly
Wolters	2020	49,202		1950	USA/European Union	Incidence of dementia decreased per decade

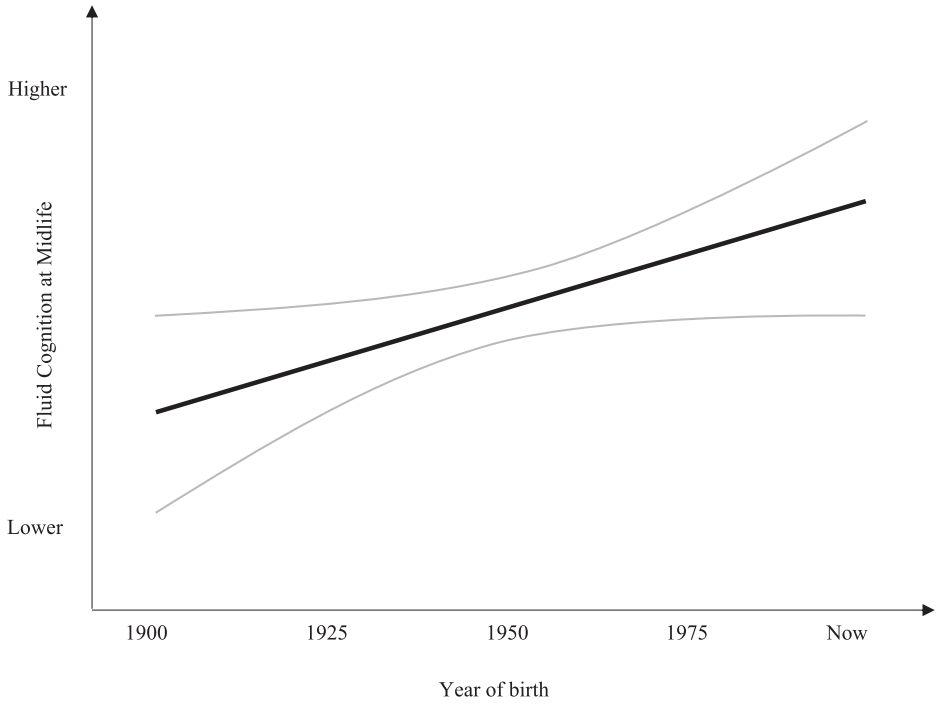
pattern during most of the twentieth century whereby individuals born into successive birth cohorts experienced increased cognitive performance (Lynn 2013).

Flynn's original explanation for this effect was neurofunctional: the modern world, he hypothesized, was drastically changing in terms of the amount of information that was being processed by the brain, and the result was increased cognitive performance. Specifically, rapid increases in *social complexity*, as defined by the complexity of verbal and/or written communications between individuals, were thought to be accountable for cohort-related changes in cognition. Indeed, enormous shifts have occurred within the rate at which access to the written word is passed through a larger range of media. One possibility is that these have resulted in drastic increases in the overall and effective literacy rates, while also improving the ability to manage technologies and learn novel concepts. These two literacy rates have increased monotonically over the past 200 years, along with rapid increases in the rate at which the average person communicates in a way that can be reliably understood. Furthermore, even after literacy was widespread throughout countries in Europe by the early 1900s (United Nations Educational Scientific and Cultural Organization 1953)), there was a marked increase in the use of the written word in everyday life throughout the twentieth century (Houston 2001).

Following Flynn's (1984) original paper, hundreds of scholars have devoted attention to explaining the apparent increases in intelligence across countries all over the world. Besides Flynn's original interpretation, a number of social and economic explanations have emerged including increasing nutritional quality (Lynn 1990), improved education (First et al. 1998), positive developments in health care (Steen, 2009), improvements in test-taking performance (Brand, Freshwater, and Dockrell 1989), and hybrid vigor (Mingroni 2007) have also been proposed as explanations for the Flynn effect, though none of the explanations have been universally accepted. Particularly popular have been the Dickens and Flynn (2001) social multiplier theory (a gene–environment interaction explanation) and the life history explanation (Woodley 2012). Rodgers (1998, 2015) provided methodological reviews of past Flynn-effect research, and Trahan et al. (2014) and Pietschnig and Voracek (2015) contributed meta-analyses. In the latter piece, the authors suggested that the Flynn effect is greater for adults than for children, although explanation and interpretation of this finding are lacking.

Only a few studies have linked the Flynn effect to aging. As noted above, Dickinson and Hiscock's (2010) study suggested that 85 percent of the apparent within-person decline in cognitive testing scores in a cross-sectional study was in fact due to the Flynn effect. Skirbekk et al. (2013)) identified Flynn effects among older adults (age 50+) in the United Kingdom, while Karlsson et al. (2015) identified these effects among older adults

FIGURE 1 Theoretical differences in fluid cognitive performance commonly labeled the Flynn effect by year of birth



(70+) in Sweden. In a larger study, Hessel et al. (2018) found Flynn effects of approximately the same size across different older age groups in a study of 10 European countries. Only one study (Snowdon, Greiner, and Markesbery (2000) linked Flynn-effect patterns to Alzheimer's explicitly, finding that suboptimal early life performance patterns may predispose individuals to some of the clinical symptoms of Alzheimer's, particularly lesions in the neocortex. There is sufficient support for the existence of a Flynn effect such that domains of fluid cognition should improve among younger-born cohorts (e.g., Figure 1) and this effect should carry through to older ages, though little attention has been given to this possibility in the past writing and research.

Early life exposures

Individuals of later-born cohorts are born and raised in a very different context from earlier-born cohorts in a way that may alter lifetime cognitive functioning. Schaie (1994) lists a number of factors that contribute, including changes in childrearing practices, improved health care, changes in the educational system, and shifts in the public policy innovations. Historically, cognitive aging research has focused on cross-sectional old-young differences to understand cognitive aging and, in some cases, to provide

controls for studies of Alzheimer's and other related neurological diseases. For example, relying on cross-sectional data, some researchers have argued that the size of the aging effect is stable across studies (Salthouse 2017) and explain deviations between longitudinal and cross-sectional studies by attributing them to learning effects in the latter (Salthouse 2015). However, such results do not allow us to consider differences between cohorts that may be attributable to multiple causes. Instead, age-related differences were conceptualized as age-related degradation in capability, so that each decade of aging after age 20 was associated with the loss of approximately 0.50 SD in a wide array of domains of cognitive functioning. However, the consistency and size of that decline estimate are concerning. For example, by the ages of 65 and 90, the average person should have lost approximately half and all their cognitive capacity, respectively. Yet, many 90-year-olds preserve their cognitive function, potentially challenging that interpretation. A more complete explanation may be that these comparisons in cross-sectional samples partially conflate cognitive aging with cohort-related changes in cognitive function (Hofer, Berg, and Era 2003; Dickinson and Hiscock 2010).

Childhood has long been highlighted as a period critical to understand when examining late-life health and functioning (Hayward and Gorman 2004; Kuh et al. 2005; Nandi et al. 2012), in part because childhood cognition is considered to be a primary determinant of late-life cognition (Deary 2012). Indeed, restricted caloric intake both in utero (de Rooij et al. 2010) and during childhood (van den Berg, Pinger, and Schoch 2016) may be associated with lowered cognitive performance later in life. For example, studies have suggested that nutritional intake in childhood is linked with reductions in lifetime cognition and in height (Case and Paxson 2008; Guven and Lee 2015).

Historical efforts have consistently linked improvements in quality of life throughout the lifespan, but especially in childhood, with considerable shifts in biological measures including increased height (Fogel 2012), reductions in resting body temperature (Protsiv et al. 2020), and even improvements in life expectancy (Caldwell 2001). For example, childhood nutrition has been linked to increases in height and improvements in physical function (Fogel 1986a, 1986b), overall health (Fogel 1994, 2004), and lifespan (Fogel 2012). Bridging early life with aging research has resulted in an identified association between height and late-life cognition in the United States (Case and Paxson 2008), Europe (Guven and Lee 2015), China (Zhang, Gu, and Hayward 2008), as well as Latin America and the Caribbean (Maurer 2010). Similar increases in height have been linked, globally, to improved cognitive performance in childhood and later in life (Case and Paxson 2008; Guinosso, Johnson, and Riley 2016; Guven and Lee 2015) and in our preliminary analyses.

Research on food insufficiency, even when instrumentalized by height, is often mired in selection biases because malnutrition more heavily

afflicts individuals living in poorer places or born into poorer families. Researchers have often relied on quasi-experimental designs using short-term exposures to famine to note the impact of restricted food intake evident during times of food shortages (de Rooij et al. 2010) and stunting (Berkman et al. 2002; Crookston et al. 2011). Although it is easy to imagine that we are now immune to food insufficiency or famine—indeed Deaton (2007) states that "the restriction of height by malnutrition and disease may no longer be important in rich countries" (pp. 13232)—this is not true of the effects that these exposures have on cognitive aging, which may continue to reflect these early life exposures as long as individuals who survived these times continue to participate in social life.

Educational changes and improved cognitive reserve

Increased educational attainment has also improved lifetime cognition (Clouston et al. 2012) with concomitant health implications due to improved health behaviors (Clouston et al. 2015) and reduced risk of mortality (Link and Phelan 2010) including from causes of death such as suicide (Clouston et al. 2014). Yet, although this research has identified substantial differences in cognitive performance, large imaging studies have not found sizable changes in the brain's overall structure (Kremen et al. 2019), potentially indicating that improvements in fluid cognition due to factors in late adolescence and early adulthood are due to functional rather than structural differences.

The theory of cognitive reserve may, however, provide us with some topics to consider (Stern et al. 2020). Cognitive reserve and brain reserve emerge from processes affecting how individuals perform cognitively while they age (Stern et al. 2020). Brain reserve includes overarching differences in the neurobiological substructure and its component maintenance operations that help the brain to better cope with adverse lifestyle and environmental exposures and avoid effects of neurodegenerative disease. Cognitive reserve, in contrast, captures changes in the manner in which the brain functions operationally. Although the exact mechanisms in the brain and cognitive reserve are hotly debated, the theory of cognitive reserve suggests that some individuals are able to resist the ill effects of neuropathology, tolerating considerable neuropathological burden before cognitive symptoms emerge. Indeed, individuals higher in the cognitive reserve are less likely to develop cognitive impairment and typically experience a later onset of cognitive decline. The processes underlying cognitive and brain reserve are not well understood, but researchers have proposed that factors contributing to reserve include higher educational attainment, improved childhood cognition, and engagement in cognitively demanding tasks or occupations (Valenzuela and Sachdev 2006; Wang et al. 2017).

Exposure to social stressors at midlife

Chronic stress is increasingly being considered a risk factor for cognitive aging and for Alzheimer's disease (Veitch, Friedl, and Weiner 2013). Chronic stress can interrupt normal functioning and is associated with physical and cognitive declines (Stawski, Sliwinski, and Smyth 2006) as well as with increased response variability (Munoz et al. 2018). Chronic stress may predict lowered cognitive function and increased risk of dementia (Veitch, Friedl, and Weiner 2013). Some studies have additionally noted that stressors may broadly affect cognitive function by reducing executive functioning (Ohman et al. 2007), worsening attention (Vasterling et al. 2002), reducing working memory (Flaks et al. 2014; Stawski, Sliwinski, and Smyth 2006), and slower reaction time (Kertzman et al. 2014) as well as incidence of mild cognitive impairment (Clouston et al. 2019).

Exposures to high social inequality and high unemployment risk were reduced for individuals born in later birth cohorts, yet inequality has increased recently in some countries (Piketty 2014; Piketty and Saez 2006). High levels of income inequality and exposure to high unemployment risk have been consistently linked with health (Pickett and Wilkinson 2015; Wilkinson and Pickett 2006). Structural forms of social inequality have long been known to create material changes in educational quality and investment due, in part, to lowered return on investments in human capital (Bourdieu 1979). Structural inequality concentrates and legitimates disadvantage, thereby increasing the severity and chronicity of stress in a larger proportion of the population (Jones, Squires, and Ronzio 2016). Additionally, exposure to economic stressors can cause thoughts that intrude on an individual as they are awake and bother them as they sleep (Hirst et al. 2009).

Contextual stress may amplify the impact of new stressful events on mental health (Mukherjee et al. 2017) and might change sleep habits resulting in shorter duration and more fractured sleep environments (Rowshan Ravan et al. 2010). While the mechanisms linking chronic stress to cognitive decline remain unclear, a common pathway includes neuroinflammatory responses (Yehuda 2002) that may accelerate the pathological cascade (Calsolaro and Edison 2016). Social inequality may therefore increase risk and chronicity of social stress and strain and increasing these negative consequences (van Deurzen, van Ingen, and van Oorschot 2015).

Shifts in preventive health behaviors including accessing medical intervention

Mid-to-late life health behaviors that have been increasing among younger and older individuals may result in improved cognition. Although we think health behaviors are very different overall at younger versus older ages,

with different policy implications, we highlight them together because they may improve cognition and decrease cognitive decline for very similar reasons: *health behaviors* have been associated with decreased incidence of stroke (Wilhelmsen et al. 1987), improved health after stroke (Maier et al. 2015), and lower tauopathy burden in Alzheimer's disease (White et al. 2013). To date, researchers have focused on medical interventions including statins, with little result.

Health lifestyle theory has, however, recognized that although particular behaviors may have their own risk profiles, good and poorer health behaviors often cluster within individuals, thereby making the spread in behavioral risk factors even greater and confounding any unique effect (Christensen and Carpiano 2014; Cockerham 2005, 2007). Changes to a healthy lifestyle to include increased physical activity, smoking cessation, and moderate alcohol intake may (1) correspond to and (2) reduce risk of cerebrovascular disease by relieving via modulation of stress hormones such as epinephrine (Jacotte-Simancas et al. 2013), a biomarker of chronic stress that has been linked to cognitive dysfunction (Delahanty et al. 2005; Kosten et al. 1987; McEwen 2000; Seeman et al. 2001), thereby diminishing the most cognitively-active effects of chronic stress while also improving cerebrovascular outcomes more generally. Access to medical intervention behaviors may, therefore, be critical because they target risk of disease by relaxing blood walls, reducing angiotensins, α- and β-adrenergic blockers, increasing electro-conductance of heart muscles, and regulating cholesterol (Henson et al. 2013) thereby improving neural vesicle formation and transportation (Pfrieger 2003).

Genetic variability

Cohort effects on cognitive decline and ADRD may integrate some components of genetic change as well. Notably, the allele with the greatest known impact on ADRD, APOE-ε4, is evolutionarily older than variants that are protective in later life (APOE-ε2 and APOE-ε3) (Ashford 2002; Finch and Sapolsky 1999; Hanlon and Rubinsztein 1995). APOE-ε4 is also less prevalent in modern human populations, especially as compared to APOE-ε3 (Glass and Arnold 2012; Hill, Bhattacharjee, and Neumann 2007). If natural selection were to act to winnow variation observed in the APOE genotype, the phylogenesis of the APOE gene may cause slow changes in ADRD risk when protective variants become increasingly common over time via at least two pathways: *selective neutrality* and *antagonistic pleiotropy*. Under *selective neutrality*, risk alleles are likely to be neutral to selection because the onset of ADRD occurs after reproductive maturity. However, in the absence of evolutionary pressures, genetic drift might lead to the extinction of neutral alleles in the population (Glass and Arnold 2012; Keller and Miller 2006). *Antagonistic pleiotropy*, in contrast,

occurs when a gene affects two phenotypes, one that increases and another that decreases reproductive fitness. Indeed, APOE-ε4 could persist in modern human populations by simultaneously decreasing risk of deleterious phenotypes in early life, such as liver damage in patients with hepatitis C (Wozniak et al. 2002), adverse cardiovascular response to mental stress (Ravaja et al. 1997), and a chance of miscarriage (Zetterberg et al. 2002), while also *increasing* risk of ADRD in late-life as early-life genetic pressures prevail. Whether protective variants are selectively neutral, favored by kin selection or pleiotropy, efforts to consider cohort changes may consider the possibility that the APOE-ε4 allele is becoming increasingly rare.

Critical and sensitive periods in adolescence

The proposed theories above seek to understand the role of long-term social forces on late-life cognitive decline. However, when examining life exposures, the timing is often as interesting as the type of exposure (Kuh et al. 2005; Nandi et al. 2012). For example, nutritional deficits likely influence lifetime cognition most during childhood, when neuronal connections are developing or during neuronal trimming in adolescence (Frodl and O'Keane 2013; Hanson, Smith, and Zimmer 2015). Childhood improvements in cognition may carry through to improved lifetime cognitive reserve. For example, lifespan research has suggested that much of old-age cognitive performance can be predicted from childhood (Deary et al. 2000), raising the potential for early life factors to operate as a potentially sensitive period when explaining old-age differences in cognitive performance (Brailean et al. 2018; Dodge et al. 2014, 2017;).

Returning to the Flynn effect, Pietschnig and Voracek (2015) provide an outstanding question about the timing of the Flynn effect across the lifetime as early life exposures are translated into later life outcomes. Specifically, Pietschnig and Voracek (2015) suggested that "stronger gains were shown for adults than children" in the Flynn effect, especially for fluid and spatial IQ (p. 289). What is not resolved is whether these gains among adults are cumulative—caused by the continuing influence of some few processes, accumulating over time—or whether there are some processes that by their nature affect adults more than children. Lynn (1990) suggested that improvement in in utero and young childhood nutrition was critical in driving the Flynn effect; yet such influences would have no continuing effect into adulthood. Likewise, educational improvements have a mostly restricted age influence (with a few exceptions, such as adults returning to college). The processes that drive "stronger gains" in adults—including older adults—have not been carefully studied, and this arena is wide open for new empirical and theoretical developments.

Macroeconomic stressors play an outsized role in "emerging adulthood" (Arnett 2000), as emerging adults become increasingly aware of the impact of a lack of material resources. During emerging adulthood, individuals are highly competitive and constantly being compared with cohort norms resulting in high levels of interpersonal stress (Sheets and Craighead 2014). Emerging into a recession changes occupational trajectories and lifetime expectations about their own job stability (Genda, Kondo, and Ohta 2010). Concurrently, emerging adults are only beginning to experience realities of employment markets but have not yet built up resilience to such stressors, resulting in increased internalization of such experiences (Brake 2014; Conger et al. 1994) and subsequent higher rates of suicide (Miller et al. 2005). The largest impacts of early life health behaviors and health information tend to be through their role in improving healthier lifestyles across the lifespan (Cockerham 2005), when such behaviors are most important to reducing the risk of ADRD pathology (Friedland et al. 2001; Rovio et al. 2005; Sabia et al. 2009). Because the benefits of improved health behaviors can be immediate (Williamson et al. 2009), having a healthy lifestyle will be observable and important later in life.

Although much of this literature has focused on the first couple of years of life, research on cognitive development has increasingly highlighted the important role of adolescence as a critical neurodevelopmental period during which key indicators of neurological functioning, such as personality and components of fluid cognition including executive functioning are being developed (Knafo et al. 2013; Monahan et al. 2009). Indeed, researchers have noted a substantial depression in children's social traits in the early teenage years and have attributed much of this change to neurological changes in gray matter as the brain begins to trim the vast array of neural connections formed in early childhood in order to improve cognitive efficiency in hippocampal and prefrontal cortex (Murty, Calabro, and Luna 2016). Side effects of this trimming can include signs of depression, fatigue, lowered cognitive efficiency, and changes in the ability of individuals to organize their thinking thereby resulting in a number of researchers highlighting this period as a sensitive period for the development of effective social and cognitive processing (Blakemore and Mills 2014). What is potentially fascinating about this period is how closely it resembles the changes seen during the prodromal period of Alzheimer's disease, such as changes to personality (Mortby, Cherbuin, and Anstey 2015), increases in depression (Robitaille et al. 2018), and changes in fluid cognition.

Discussion

The risk of ADRD appears to be reducing over time. In this theoretical study, we propose for the first time that this reduction is likely to be due to cohort-related factors including improvements in childhood conditions.

One implication of this perspective is that, with relatively small changes in mediators of cognitive functioning over the past 50 years, changes in lifetime functioning may have modified both baseline scores and might also reasonably have changed the vulnerability to neurological pathologies later in life and hastened the rate of cognitive decline. Indeed, estimates from Scandinavia and the United Kingdom suggest that, even while the Flynn effect is slowing in children (Dutton, van der Linden, and Lynn 2016; Teasdale and Owen 2008), the average cognitive performance of older individuals will continue to increase for two more decades as the children currently benefitting from the Flynn effect age (Skirbekk et al. 2013). Additionally, the factors through which these risks may have been modified are generally more diverse than previously believed. Indeed, while most of the literature has been focused on improvements in cardiovascular risk factors and the proliferation of early life education, large benefits may have also emerged from the increased complexity of information being taught as well as from large improvements to the stability of nutrition in children. These changes may have multiple far-reaching implications for estimates of the rate of cognitive aging across different studies as well as the risk of dementia. This is the first study to review connections between cohort effects in cognition in childhood with late-life cognitive functioning and risk of ADRD in old age.

Measures that are associated with cohort effects in childhood are likely to be associated with cohort differences in adult cognitive performance. To date, studies of cognitive development have linked cohort effects to fluid reasoning, often measured using Raven's matrices. While many of the above theories generically imply increased cognitive functioning, it remains unclear whether specific subdomains of cognitive performance are more sensitive to period or cohort effects.

To date, results have identified cohort trends in ADRD incidence and prevalence of both research diagnoses and cognitive test scores, but an absence of changes to clinical diagnoses, in a number of studies in the United Kingdom (Matthews et al. 2013), Europe (Schrijvers et al. 2012), and the United States (Derby et al. 2017; Freedman et al. 2018; Langa et al. 2017; Leggett et al. 2019; Manton, Gu, and Ukraintseva 2005; Rocca et al. 2011). However, our theory also suggests that there should be similar trends in lower income countries where cognitive functioning is only beginning to be measured reliably in cohort studies (Gildner et al. 2014; Kohler et al. 2020). More work using longitudinal data needs to clarify the replicability of this work and to clarify whether trends are due to changes in the rate of cognitive decline or in the average performance at baseline of individuals in cohort studies. Our study suggests that more research is warranted to determine which countries are not seeing increases and, also, to determine mechanisms that help to explain these results.

One methodological implication of this perspective may be that individuals who were less exposed to cognitively limiting cohort or period-based

factors as noted above may have increased lifetime cognitive performance and, thus, have reduced risk of misdiagnosis in later life. Misdiagnosis occurs when the tests used to identify a threshold for dementia diagnosis are difficult for some individuals with the disease relative to others. Prior work has revealed substantial variability in the level of misclassification between studies in different samples and across cohorts (Robitaille et al. 2018); however, to date the reasons for differences in misclassification have been unexamined. Nevertheless, positive cohort-related changes that may improve cognitive reserve might be expected to result in reductions in the risk of misdiagnosis, especially when using data that have external norms, since the average individual may have cognitive performance that is much higher than individuals in previous birth cohorts.

The implications of changes in cognition across the life course may be wide ranging. For example, one possibility is that improved healthcare has allowed individuals who are increasingly frail to survive longer into old age. If so, then we might imagine that current estimates of reductions in incidence of ADRD are underestimates since physical frailty is a common risk factor for ADRD (Borges et al. 2019). However, an alternative conclusion may be that because neurodegenerative disease-causing cognitive decline also causes physical functional decline (Clouston et al. 2013), that we might expect reductions in ADRD risk to be accompanied by overall reductions in frailty as well. Notably, recent work has noted that changes in cognition are often accompanied by such as slowed walking speed, reduced muscle strength, and reduced capacity to maintain balance (Zammit et al. 2021; Duggan et al. 2019). These disabilities are important because they can independently cause long-term frailty and an increased risk of mortality (Guralnik et al. 2000). Insofar as individuals are experiencing reduced risk of ADRD, we may then also suggest that they may be healthier and more capable later in their lives. As such, this study suggests that further work is warranted to determine whether the overall risk of frailty is similarly reduced in younger born cohorts.

Conclusions

Aging individuals were once children, and the exposures of their childhood may have long-term implications (Hayward and Gorman 2004). Especially, lifespan patterns such as the Flynn effect can help us orient our thinking about the transition from childhood into adulthood and eventually into older adulthood. Most older individuals reside in developing countries even now (Skirbekk, Loichinger, and Weber 2012), and the population of older persons will only increase as the world's population ages (Ferri et al. 2006), and thus researchers are beginning to prioritize studying aging globally (World Health Organization 2012). Aside from high infant mortality rates, famines are still relatively common globally, raising the potential for

cohort and period effects when economic systems melt down and preferentially disadvantage vulnerable individuals. To consider ADRD in relation to the Flynn effect forces the perspective that ADRD potentially has causal origins much earlier in life, and that population processes at the cohort and period level must be carefully accounted for in studying aging. Insofar as these factors have longstanding effects, health researchers should be aware of differences in childhood contexts as a possible explanation for trends in late-life cognition.

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