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Research Article

Dementia and Cognitive Decline in Older Adulthood: Are Agricultural Workers at Greater Risk?

Kanika Arora, PhD,* Lili Xu, MS, and Divya Bhagianadh, MPH

Department of Health Management and Policy, University of Iowa, USA.

*Address correspondence to: Kanika Arora, PhD, Department of Health Management and Policy, College of Public Health, University of Iowa, 145 N. Riverside Drive, Room N238, Iowa City, IA 52242-2007, USA. E-mail: kanika-arora@uiowa.edu

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Abstract

Objectives: To examine whether long-term exposure to agricultural work is associated with dementia prevalence and the rate of cognitive change in older adulthood.

Method: We employed data from the Health and Retirement Study (1998–2014). Multiple logistic regression was used to determine whether a longest-held job in the agricultural sector was associated with differences in dementia prevalence. We examined if hearing impairment, depression, and physical health indicators mediated the relationship between agricultural work and cognitive functioning. Subgroup analyses were done by age, retirement status, job tenure, and cognitive domain. We employed growth curve models to investigate implications of agricultural work on age trajectories of cognitive functioning.

Results: Longest-held job in agriculture, fishing, and forestry (AFF) was associated with 46% greater odds of having dementia. The relationship between AFF exposure and cognitive functioning was not mediated by hearing impairment, depression, or physical health indicators. Results were stronger among younger and retired older adults as well as those with extensive job tenure. AFF exposure was associated with lower scores in working memory and attention and processing speed. Growth curve models indicated that while agricultural work exposure was associated with lower initial levels of cognitive functioning, over time, the pattern reversed with individuals in non-AFF jobs, showing more accelerated cognitive decline.

Discussion: Consistent with European studies, results from the United States also demonstrate a higher prevalence of dementia among agricultural workers. The cognitive reserve framework may explain the seemingly paradoxical result on age patterning of cognitive performance across older adults with different work histories.

Keywords: Agriculture, Cognitive functioning, Dementia, Growth curve models

Background

Dementia, a decline in memory and cognition that ultimately leads to a loss in independent function, is an irreversible disorder that affects approximately 5.7 million Americans (Alzheimer's Association, 2018). While incidence rises greatly over age 65 (Corrada et al., 2010), several scholars have employed a life-course approach to show that the risk of dementia is determined by an interplay of multiple influences across the life span (including, genetic, environmental, social, and psychological factors) with implicated pathological processes beginning many years before symptom onset (Blazer et al., 2015; Jack et al., 2013). In this context, occupational exposure, especially exposure to agricultural work, provides a unique lens for studying late-life cognitive functioning.

Multiple factors salient to agriculture have been independently associated with dementia risk. First, a number of studies suggest that chronic pesticide exposure, particularly organophosphate and organochloride pesticides, generates lasting toxic effects on the central nervous system and contributes to the development of Alzheimer's disease (AD; Baldi et al., 2011; Hayden et al., 2010; Starks et al., 2012) and Parkinson's disease (also linked with cognitive decline and dementia; Moisan et al., 2015). Farmers are routinely exposed to high levels of pesticides, mainly during the preparation and application of pesticide spray solutions and during clean-up of spray equipment. They may also be indirectly exposed through pesticide spray, drift from neighboring fields, or by contact with residue on the crop or soil (Damalas & Koutroubas, 2016).

Second, the *Lancet* Commission recently recognized midlife hearing loss as an important risk factor for dementia. Cohort studies show that even mild levels of hearing loss increase the risk of dementia in individuals who are cognitively intact but hearing impaired at baseline (Livingston et al., 2017). Farmers are frequently exposed to excessive noise from grain dryers, tractors, combines, and other powered equipment. Studies demonstrate that agricultural workers are more likely to experience noise-induced hearing loss than workers in other occupational settings (Humann et al., 2012). Prior work also shows that farmers are resistant to using hearing protection (Gates & Jones, 2007).

Third, numerous meta-analyses suggest a link between psychosocial factors and dementia (Livingston et al., 2017; Plassman et al., 2010). Specifically, depression has been found to be associated with a twofold increase in the risk of developing dementia (Dotson et al., 2010; Ownby et al., 2006). At the same time, studies demonstrate that individuals in farming jobs have a higher prevalence of depression when compared to nonfarmers (Sanne et al., 2004; Scarth et al., 2000). Contributing factors for depression among farmers may relate to longer work hours, working in isolation, lower income, pesticide exposure, and lower decision latitude (Onwuameze et al., 2013; Sanne et al., 2004). Mood disorders (including depression) have also been shown to be a powerful risk factor for suicide in older adults (Conwell et al., 2002). Recent evidence indicates that farmers are at an increased risk for suicide relative to workers in all other industries, which may indicate a higher rate of depression and therefore higher risks for cognitive decline and dementia (Ringgenberg et al., 2018).

Despite this overlap, no previous study has examined cognitive decline among agricultural workers in the United States. In Europe, Dartigues and colleagues (1992) and Frisoni and colleagues (1993) analyzed community-dwelling older adults in France's Bordeaux region and Italy's northern region, respectively. In both studies, the authors found that after controlling for age, education, and other covariates, farmworkers and farm managers had a higher risk of cognitive impairment than those in other jobs. As a follow-up to Dartigues and colleagues (1992), Helmer and colleagues (2001) conducted a longitudinal analysis by following a cohort of nondemented adults (at baseline) from the Bordeaux sample. The authors found no relationship between job type and incident AD, the most common form of dementia. Alvarado and colleagues (2002) examined a cohort of Spanish older people with low levels of formal education and found that being a farmworker predicted overall and mild cognitive decline. In addition to being relatively dated and equivocal, these studies are limited by their focus on localized regional areas and uniquely selected samples. No previous study has empirically investigated potential mechanisms for this association. Finally, prior work has only examined whether working in agriculture relates to levels (not rates) of cognitive decline.

We employ data from the Health and Retirement Study (HRS) to evaluate whether long-term work exposure to agriculture is associated with differences in dementia prevalence and the rate of cognitive change in older adulthood. We also examine the role of hearing impairment, depression, and physical health indicators as potential mediators in this relationship.

Understanding this association is relevant for two reasons. First, farmers are particularly vulnerable to occupational injury because they routinely work to an advanced age. This is compounded by the hazardous nature of agricultural work in general and by the fact that older farmers work long hours on average and are also more likely to use older equipment (Myers et al., 2009; Rautiainen et al., 2010; Reed et al., 2012). Cognitive impairment associated with dementia may exacerbate this heightened risk for occupational injuries among older farmers (Myers et al., 2009).

Second, as compared to other seniors, a dementia diagnosis among farmers may be more likely to be missed or delayed. Previous research has indicated that rural residents are often reluctant to seek services due to a strong tradition of self-reliance, desire for privacy, fear of institutionalization, and suspicion of health care systems (Spleen et al., 2014). A diagnosis may also be missed or delayed due to lack of awareness or access to appropriate primary care, specialist, and supportive services in rural areas (Szymczynska et al., 2011). Even though dementia is an irreversible disease, pharmacologic interventions in early stages may slow the pace of cognitive decline (Andrade & Radhakrishnan, 2009). A missed or delayed dementia diagnosis may lead a cognitively impaired older adult to unknowingly continue to engage in potentially hazardous activities on and off the farm, posing a serious risk to themselves and others.

Method

Data and Sample

We use nine waves (1998–2014) of HRS data, a nationally representative, biennial, longitudinal survey of adults older than 50 years in the United States (Juster & Suzman, 1995). The HRS includes information on employment, wealth, chronic conditions, and indicators of physical and mental health. We begin in 1998 because several questions related to health and occupation are worded differently in previous waves, rendering comparisons difficult. We extract study variables from the RAND HRS Longitudinal File 2016 (Bugliari et al., 2018).

Because cognitive impairment becomes increasingly prevalent with advancing age, we limit our sample to HRS participants age 65 years or older. We exclude proxy respondents because previous evidence indicates substantial overreporting of disease histories and health and functional limitations in proxy reports (Li et al., 2015; Wolinsky et al., 2014). In sensitivity analyses, we test whether the inclusion of these respondents changes our findings. We eliminate individuals with missing values for longest-held job. A majority of these individuals report not participating in the labor force in the last 20 years or not knowing whether they ever worked. Finally, to reduce measurement error and to allow for consistent coding of agricultural exposure throughout the sample, we also eliminate HRS AHEAD cohort participants whose responses on occupation and industry were categorized using a different classification scheme than that used for other respondents.

Dependent Variables

The HRS objectively assesses cognitive function in self-respondents with a range of tests adapted from the Telephone Interview for Cognitive Status. These tests include a 10-word immediate and delayed recall test of verbal memory (0–20 points), a serial-sevens subtraction test of working memory (0–5 points), and a backwards count from 20 test to assess attention and processing speed (0–2 points). Composite scores using all the items create a measure of cognitive functioning, which can range from 0 to 27.

Cutpoints for normal, cognitive impairment–no dementia (CIND), and dementia categories are validated against the prevalence of CIND and dementia in the Aging, Demographics and Memory Study, an HRS substudy of AD and dementia that uses 3- to 4-hr neuropsychological and clinical assessment as well as expert clinical adjudication to obtain a gold-standard diagnosis of CIND or dementia (Langa et al., 2005). Respondents who scored from 0 to 6 on the 27-point scale are classified as having dementia, 7–11 as having CIND, and 12–27 as normal (Crimmins et al., 2011). While the analytic data for both analyses are the same, we utilize them differently for assessing dementia prevalence and the trajectory of cognitive functioning. For dementia prevalence, we pool data across waves, and, for each person-wave observation, generate a binary variable coded as "1" if the cognitive functioning score was below 7 points, and "0" otherwise. After assessing dementia prevalence, we use these pooled data to conduct a mediation analysis. Here, the total cognitive functioning score is used as the outcome variable. For examining the trajectory of cognitive performance, we employ the panel structure of the data and use repeat measures of each respondent's total score on the cognitive functioning scale as the outcome variable.

Primary Independent Variable

The primary explanatory variable is based on respondents' report of their longest-held job. The HRS classifies each respondent's longest-held job into a set of occupation and industry codes based on the U.S. Census Bureau's Occupation and Industry Classification System. The occupational classification reflects the type of work that a person does, while the industry classification reflects the business activity of their employer. To measure long-term exposure to agricultural work, we construct a binary variable, agriculture, fishing, and forestry (*AFF*) *worker*, coded as "1" if the respondent's longest-held job is classified as "farmer/forestry/fishing" in the occupational classification system and as "agriculture/forestry/fishing/hunting" in the industrial classification system, and "0" otherwise. In the Supplementary data, we provide additional information on the census year and industry/occupation codes used to construct this variable.

Because our primary independent variable captures characteristics of an older adult's longest-held job, its value generally remains time-invariant within sample respondents. However, 24 individuals were observed to switch *AFF worker* status across different waves. This switching does not affect the pooled analysis as person-wave observations are treated as independent. The trajectory analysis, however, uses the panel structure of the data. For this analysis, we consider a respondent to have long-term exposure to agricultural work if *AFF worker* is "1" in any of the nine waves in which they appear. In other words, when examining the trajectory of cognitive performance, these 24 switchers are considered as *AFF workers*.

Mediators

We examine if hearing loss, depression, and physical health indicators mediate the effect of agricultural work on cognitive functioning. The HRS asks all participants to rate their hearing (while wearing a hearing aid, if relevant) on a 5-point scale (excellent, very good, good, fair, poor). Depressive symptomatology is based on a summed score of responses to an eight-item version of the Center for Epidemiologic Studies Depression Scale (CES-D; Radloff, 1977). The CES-D is a self-reported inventory of depressive symptoms ("was depressed," "everything was an effort," "sleep was restless," "was happy," "felt lonely," "enjoyed life," "felt sad," and "could not get going") that occurred in the week prior to the respondents' interview date. Responses are summed and range from 0 to 8. Higher scores indicate more depressive symptoms. We capture physical health using the following: (a) two variables representing summary scores for difficulty with activities of daily living (ADL) and instrumental activities of daily living (IADL; scores range from 0 to 5, where 0 represents "no difficulty" and 5 represents "difficulty with all five ADLs/IADLs"), and (b) multiple binary variables capturing self-reported diagnoses of cancer, lung disease, stroke, heart disease, and diabetes.

Covariates

Empirical models account for several sociodemographic and geographic variables. Age is captured as a continuous variable. Gender, race, ethnicity, education, marital status, nonhousing wealth, rural/urban location, census region, and region of birth are ascertained as categorical variables. We also control for childhood socioeconomic status by including years of parental education (separately for mother and father) and self-rated childhood socioeconomic status (response options include "pretty well off," "about average," and "poor"; note, about 1% reported "it varied"—these were recoded to "about average"). All empirical models include controls for HRS wave indicators.

Analytical Strategy

To assess the association between agricultural work exposure and dementia prevalence, we estimate a multiple logistic regression model with a dichotomous dependent variable indicating dementia presence (the reference group included those with normal cognition or CIND). The primary independent variable is *AFF worker*. The model controls for all covariates described in the previous section.

Next, we examine if hearing impairment, depression, and physical health indicators mediate the relationship between *AFF worker* and cognitive functioning. In order to enable comparison of coefficients across models, we estimate a series of linear regressions. First, we estimate an ordinary least squares (OLS) regression with cognitive functioning score as the dependent variable and *AFF worker* and all other covariates as independent variables. We do not include mediators in this model. In this "reduced model," the coefficient on *AFF worker* provides the "total effect" of long-term agricultural work on cognitive functioning. In subsequent OLS models, we separately enter variables associated with each mediator in the reduced model. In these "full models," any change in *AFF worker* coefficient postadjustment for mediators is expected to reveal whether these variables serve as a mechanism through which exposure to agricultural work influences cognitive functioning.

We test for heterogeneity in dementia prevalence results by conducting subgroup analyses based on respondent's age and retirement status. We also investigate whether our results vary by tenure at the longest-held job. Specifically, based on definitions provided by the U.S. Department of Agriculture, we generate two groups: "beginning" workers (those with longest-held job tenure of 10 years or less) and "established" workers (those with longest-held job tenure of over 10 years; Ahearn & Newton, 2009). If there exists a dose response, we expect the results to be stronger among the latter group. In additional analyses, we employ OLS regressions to examine associations between agricultural work and distinct cognitive domains (represented by scores on the three subtests of the cognitive functioning scale). Because we pool observations across waves for all above analyses, standard errors are clustered at the individual-level to account for the panel structure of the HRS data.

Next, we employ growth curve models using repeat observations on respondents to examine the impact of agricultural work on respondents' age trajectories of cognitive performance. This analytical approach considers the clustering of observations by estimating a single model that describes data at two levels—within respondent and between respondent (Singer & Willett, 2003). For this analysis, the exact age was centered at 65, the lowest observed age, to facilitate interpretation (i.e., at 65 years, *Centered Age* = 0). We additionally include the cube of centered age to account for nonlinearity.

The level 1 model specifies individual trajectories of change and contained both an intercept (i.e., an average level of cognitive performance at age 65) and a slope (i.e., an average rate of change in cognitive performance with increasing age). The level 2 model accounts for variability in trajectories of change between individuals and includes random effects for the intercept and slope that indicate whether respondents vary in their levels of cognitive performance at age 65 and/or the rate of change in their cognitive performance with increasing age, respectively.

We begin with a linear change trajectory model of cognitive performance of individual i at time t (Y_{it}), as a function of age (Age_{it}) and cubed age ($Age3_{it}$). We then add our primary independent variable, $AFFWorker_i$. We also include the interaction term between age and $AFFWorker_i$ to investigate whether the effect of being exposed to an agricultural job on the respondent's cognitive function varies by age. The level 1 equation is as follows:

$$Y_{it} = \pi_{0i} + \pi_{1i} \quad Age_{it} + \pi_{2i} \quad Age3_{it} + \pi_{3i} \\ AFFWorker_i + \pi_{4i} \quad AFFWorker_i * \quad Age_{it} + \varepsilon_{it}$$

In the level 2 model, the coefficient πs in the level 1 model are modeled as dependent variables. In addition, the level 2 models examine whether variations in the intercept are predicted by a set of covariates ($X_{1i \ldots} X_{ki}$). Because the focus

Table 1. Summary Statistics (Means [*SD*] and Sample Proportions) for AFF and Non-AFF Workers

	AFF worker	Non-AFF worker	Diff.[c]
Cognitive function			
Overall score (*SD*)	12.80 (4.76)	14.66 (4.47)	***
Dementia (%)	11.0	4.7	***
CIND (%)	25.7	18.3	***
Normal (%)	63.3	77.0	***
Sociodemographic			
Age in years (*SD*)	74.36 (6.75)	73.11 (6.11)	***
65–74 (%)	56.7	63.7	***
75–84 (%)	34.0	31.1	**
≥85 (%)	9.4	5.2	***
Female (%)	25.2	54.8	***
Race (%)			
White	84.3	82.9	n.s.
Black	8.3	13.8	***
Others	7.4	3.3	***
Hispanic (%)	19.2	7.0	***
Marital status (%)			
Married/partnered	70.6	63.0	***
Divorced/separated	7.4	10.5	***
Widowed	18.6	23.7	***
Never married	3.5	2.9	n.s.
Education level (%)			
<12 years	45.7	23.3	***
12 years	38.7	35.1	*
13–15 years	9.4	20.0	***
≥16 years	6.2	21.6	***
Nonhousing wealth (in millions)[a]			
Quartile 1 (−1.56 to 0.01)	31.2	24.9	***
Quartile 2 (0.01–0.08)	15.0	25.3	***
Quartile 3 (0.08–0.35)	17.5	25.2	***
Quartile 4 (0.35–51.0)	36.4	24.7	***
Years of tenure at longest reported job	27.87 (16.99)	20.78 (11.86)	***
Retirement status (%)			
Completely retired	53.5	68.8	***
Partially/not retired	46.5	31.2	***
Childhood conditions			
Region of birth (%)			
New England	1.1	4.9	***
Mid-Atlantic	4.2	14.9	***
East North Central	19.3	17.6	n.s.
West North Central	24.4	11.3	***
South Atlantic	11.7	15.1	***
East South Central	6.3	8.5	**
West South Central	12.4	9.8	***
Mountain	3.1	3.5	n.s.
Pacific	2.8	5.3	***
US/NA division	0.2	0.2	n.s.
Not in United States	14.5	9.0	***
Years of education: father (*SD*)	1.59 (3.76)	1.95 (4.18)	***
Years of education: mother (*SD*)	1.71 (3.86)	2.06 (4.32)	***
Self-reported childhood SES (%)			
Pretty well off	3.5	5.5	***
About average	58.3	62.0	**
Poor	38.2	32.5	***

Table 1. Continued

	AFF worker	Non-AFF worker	Diff.[c]
Geographic location			
Census region (%)			
Northeast	3.6	16.1	***
Midwest	40.2	25.3	***
South	40.3	40.1	n.s.
West	15.7	18.4	**
Other	0.2	0.2	n.s.
Urban, suburban, and rural (%)[b]			
Urban	14.0	46.7	***
Suburban	25.8	24.0	n.s.
Rural	60.2	29.3	***
Mediators			
Hearing rate (%)			
Excellent	11.2	20.4	***
Very good	19.8	28.6	***
Good	42.5	34.4	***
Fair	20.8	13.5	***
Poor	5.7	3.2	***
CES-D score (*SD*)	1.38 (1.80)	1.35 (1.83)	n.s.
Physical health			
No. of ADL needs (*SD*)	0.34 (0.91)	0.29 (0.80)	**
No. of IADL needs (*SD*)	0.28 (0.83)	0.22 (0.69)	***
Other diagnosed chronic diseases (%)			
Cancer	12.0	18.4	***
Lung disease	10.8	11.9	n.s.
Stroke	8.1	8.2	n.s.
Heart disease	28.4	30.2	n.s.
Diabetes	23.3	22.6	n.s.
Sample size	1,788	64,581	
Unique observations	400	14,262	

Notes: ADL = activities of daily living; AFF = agriculture, fishing, and forestry; CES-D = Center for Epidemiologic Studies Depression Scale; CIND = cognitive impairment–no dementia; IADL = instrumental activities of daily living; SES = socioeconomic status. US/NA division indicates in the US, but without the Census Division information. [a]Nonhousing wealth was inflation adjusted to 2014 dollars. [b]Urban, suburban, and rural were defined based on 1993 and 2003 Beale Rural–Urban Continuum Code for the first two waves (1998–2002) and the remaining five waves (2004–2012), respectively. "Urban" refers to counties with a population of 1 million individuals or more. "Suburban" refers to counties with a population of 250,000 to 1 million individuals. "Rural" refers to counties having fewer than 250,000 residents. [c]"Diff." represents statistical significance associated with the difference between two means/proportions.
$^{*}p < .05$. $^{**}p < .01$. $^{***}p < .001$.

of our analysis is the impact of agricultural exposure, the slope of age does not depend on level 2 covariates. The level 2 equation is written as follows:

$$\pi_{0i} = \beta_{00} + \beta_{01} X_{1i} + \beta_{02} X_{2i} \ldots \beta_{0k} X_{ki} + \sigma_{0i}$$

$$\pi_{1i} = \beta_{10} + \sigma_{1i}$$

where β_{00} and β_{10} are the average intercept and the average linear slope of the age trajectory respectively, σ_{0i} is the random error term of the average intercept, and σ_{1i} is the random error term of the average linear slope.

To account for panel attrition in growth curve models, we use maximum likelihood estimation that enables us to incorporate all respondents observed at least once. Because attrition due to death or other reasons is associated with lower cognition scores (analysis available on request), we follow Warner and Brown (2011) and include a control for *appearances* that captures the number of waves a subject was observed (average = 6.09, range = 1–9). Additionally, we include a dummy variable to account for a respondent's exit from the analytical sample. This variable, *death/transition*, is coded as "1" if the respondent died or transitioned out of the sample during the 2000–2014 waves and set to "0" otherwise. In sensitivity analyses, we estimate a joint model that predicts both death and cognitive function to formally investigate whether selective mortality influences our results.

Results

Table 1 provides summary statistics for respondents in AFF worker and non-AFF worker groups. Approximately 3%

Table 2. Predictors of Dementia Presence and the Role of Hearing Impairment, Depression, and Physical Health as Mediators

		Mediation analyses			
		Cognitive functioning score			
	Dementia presence	Reduced model	+ Hearing impairment	+ CES-D score	+ Physical health
	Odds ratios (CI)	OLS coefficients (*SE*)			
AFF worker	1.461**	−0.401*	−0.393*	−0.393*	−0.396*
	(1.130, 1.889)	(0.163)	(0.165)	(0.162)	(0.155)
Hearing rate: excellent as reference					
Very good			−0.004		
			(0.078)		
Good			−0.275***		
			(0.077)		
Fair			−0.638***		
			(0.098)		
Poor			−1.093***		
			(0.160)		
CES-D score				−0.249***	
				(0.013)	
IADL					−0.916***
					(0.041)
ADL					−0.090**
					(0.033)
Cancer					0.095
					(0.064)
Lung disease					0.173*
					(0.073)
Stroke					−0.745***
					(0.093)
Heart disease					0.037
					(0.053)
Diabetes					−0.290***
					(0.059)
Age	1.113***	−0.210***	−0.205***	−0.208***	−0.190***
	(1.104, 1.123)	(0.004)	(0.004)	(0.004)	(0.004)
Female	0.798***	1.063***	0.942***	1.117***	1.060***
	(0.698, 0.912)	(0.057)	(0.058)	(0.056)	(0.056)
Race: White as reference and ethnicity					
Black	2.145***	−1.971***	−1.993***	−2.019***	−1.932***
	(1.823, 2.524)	(0.101)	(0.100)	(0.099)	(0.099)
Other race	1.498**	−0.983***	−0.987***	−0.981***	−0.970***
	(1.106, 2.029)	(0.174)	(0.174)	(0.170)	(0.167)
Hispanic	0.969	−0.613***	−0.606***	−0.607***	−0.602***
	(0.744, 1.263)	(0.138)	(0.138)	(0.136)	(0.134)
Region of birth: New England as reference					
Mid-Atlantic	0.909	0.417**	0.424**	0.422**	0.408**
	(0.636, 1.298)	(0.131)	(0.130)	(0.130)	(0.129)
East North Central	1.130	0.184	0.199	0.175	0.206
	(0.773, 1.654)	(0.147)	(0.146)	(0.146)	(0.144)
West North Central	1.131	0.126	0.143	0.087	0.150
	(0.758, 1.687)	(0.155)	(0.154)	(0.154)	(0.152)
South Atlantic	1.599*	−0.344*	−0.338*	−0.322*	−0.253
	(1.111, 2.301)	(0.149)	(0.148)	(0.148)	(0.147)
East South Central	1.499*	−0.323*	−0.264	−0.310	−0.265
	(1.022, 2.197)	(0.162)	(0.160)	(0.160)	(0.159)

Table 2. Continued

	Dementia presence	Mediation analyses: Cognitive functioning score — Reduced model	+ Hearing impairment	+ CES-D score	+ Physical health
	Odds ratios (CI)	OLS coefficients (*SE*)			
West South Central	1.576*	−0.359*	−0.315*	−0.331*	−0.289
	(1.081, 2.297)	(0.157)	(0.156)	(0.156)	(0.154)
Mountain	1.793*	−0.241	−0.226	−0.252	−0.193
	(1.116, 2.881)	(0.202)	(0.201)	(0.201)	(0.198)
Pacific	1.793**	−0.189	−0.173	−0.190	−0.163
	(1.161, 2.770)	(0.183)	(0.182)	(0.182)	(0.180)
US/NA division	1.074	0.168	0.185	0.217	0.167
	(0.187, 6.162)	(0.632)	(0.648)	(0.613)	(0.600)
Not in United States	1.355	−0.071	−0.076	−0.045	−0.071
	(0.906, 2.026)	(0.165)	(0.164)	(0.163)	(0.161)
Fathers' education	0.953	0.023	0.027	0.024	0.025
	(0.907, 1.000)	(0.020)	(0.020)	(0.020)	(0.019)
Mothers' education	1.033	−0.022	−0.028	−0.024	−0.026
	(0.989, 1.080)	(0.019)	(0.019)	(0.019)	(0.019)
Self-reported family SES: pretty well off as reference					
About average	0.882	0.050	0.058	0.035	0.005
	(0.645, 1.207)	(0.118)	(0.118)	(0.116)	(0.115)
Poor	0.840	0.169	0.198	0.202	0.143
	(0.610, 1.158)	(0.125)	(0.125)	(0.123)	(0.121)
Marital status: married/ together as reference					
Divorced/separated	0.902	0.137	0.147	0.235**	0.135
	(0.749, 1.086)	(0.089)	(0.089)	(0.089)	(0.088)
Widowed	0.983	0.034	0.044	0.140*	0.031
	(0.850, 1.138)	(0.068)	(0.067)	(0.067)	(0.066)
Never married	1.196	−0.095	−0.097	−0.036	−0.153
	(0.878, 1.628)	(0.156)	(0.154)	(0.156)	(0.153)
Years of education: <12 years as reference					
12 years	0.341***	1.991***	1.955***	1.909***	1.875***
	(0.296, 0.392)	(0.081)	(0.080)	(0.080)	(0.079)
13–15 years	0.278***	2.647***	2.591***	2.536***	2.537***
	(0.228, 0.339)	(0.092)	(0.092)	(0.091)	(0.089)
≥16 years	0.171***	3.599***	3.517***	3.461***	3.486***
	(0.136, 0.214)	(0.093)	(0.093)	(0.092)	(0.090)
Nonhousing wealth: Quartile 1 as reference					
Quartile 2	0.492***	1.053***	1.035***	0.926***	0.809***
	(0.435, 0.557)	(0.066)	(0.066)	(0.065)	(0.064)
Quartile 3	0.392***	1.431***	1.401***	1.260***	1.127***
	(0.333, 0.461)	(0.075)	(0.075)	(0.074)	(0.074)
Quartile 4	0.235***	1.868***	1.829***	1.682***	1.535***
	(0.189, 0.292)	1.053***	1.035***	0.926***	0.809***
Residence census reg.: Northeast as reference					
Midwest	1.026	−0.038	−0.043	−0.043	−0.057
	(0.796, 1.322)	(0.115)	(0.114)	(0.113)	(0.111)
South	1.055	0.052	0.050	0.053	0.027
	(0.842, 1.320)	(0.096)	(0.095)	(0.094)	(0.094)
West	0.893	0.140	0.138	0.145	0.138
	(0.689, 1.157)	(0.116)	(0.116)	(0.115)	(0.113)

Table 2. Continued

	Dementia presence	Mediation analyses: Cognitive functioning score			
		Reduced model	+ Hearing impairment	+ CES-D score	+ Physical health
	Odds ratios (CI)	OLS coefficients (*SE*)			
Rural/urban: urban as reference					
Suburban	1.022	−0.013	0.007	−0.018	0.000
	(0.881, 1.186)	(0.065)	(0.065)	(0.065)	(0.064)
Rural	1.183*	−0.313***	−0.273***	−0.326***	−0.293***
	(1.022, 1.370)	(0.066)	(0.066)	(0.065)	(0.065)
Wave dummies	✓	✓	✓	✓	✓
N	61,734	61,734	61,698	61,476	61,441

Notes: ADL = activities of daily living; AFF = agriculture, fishing, and forestry; CES-D = Center for Epidemiologic Studies Depression Scale; IADL = instrumental activities of daily living; OLS = ordinary least squares; SES = socioeconomic status. US/NA division indicates in the US, but without the Census Division information. Robust *SE*s clustered at the individual level in all models.
$^*p < .05$. $^{**}p < .01$.

of the overall sample was categorized as an AFF worker. Individuals in the AFF group had a lower mean cognitive functioning score compared to individuals exposed to other jobs. Based on this score, a substantially greater proportion of AFF workers were assessed to have dementia (11% vs 5%). Respondents in the AFF group were relatively older (with a larger proportion in the 85 years and older category), more likely to be Hispanic, married or partnered, and less likely to be female. There was wider disparity in nonhousing wealth (in constant 2014 dollars) among AFF workers, with a greater proportion in both the lowest and highest wealth quartiles. AFF respondents (as well as their parents) had fewer years of education and were more likely to report "poor" childhood socioeconomic status relative to those in other jobs.

After deleting cases with incomplete covariate information (approximately 7%), the analytical sample included 61,735 observations (12,991 unique respondents). Column 1 in Table 2 presents odds ratios from a logistic regression model with dementia presence as the outcome variable. When all covariates are included in the model, we find that older adults with long-term exposure to agricultural work had 46% higher odds of having dementia relative to those in other jobs. Supplementary Table A1 shows a similar pattern of results when proxy respondents are included in the sample, though the magnitude of the *AFF worker* coefficient is smaller.

The next four columns provide results from the mediation analyses. Column 2 reports estimates from the reduced OLS model. Controlling for all covariates, older adults with long-term exposure to agricultural work score 0.4 points lower (on average) on the cognitive functioning scale as compared to those in other jobs. Columns 3–5 assess whether hearing impairment, depression, and physical health serve as mediators in the relationship between agricultural work and cognitive functioning. Our findings indicate that the inclusion of these variables does not substantially change the *AFF worker* coefficient. Because different mediators have different missing values, as a sensitivity check, we re-estimate the reduced and full models on comparable samples. A formal test showed that the indirect effect (computed as the difference between *AFF worker* coefficients in reduced and full models) was statistically insignificant for all three sets of mediators. These results are provided in Supplementary Table A2.

Subgroup analyses are presented in Table 3. Panels 1 and 2 show a statistically significant association between agricultural work and dementia presence among the "young-old" (i.e., those younger than age 75), the completely retired, and those with over 10 years of occupational exposure. Among older seniors, those reporting partial or no retirement, and those with 10 or fewer years of job tenure, we found no detectable association between agricultural work and dementia presence.

Further, we examined whether agricultural work was differentially related to distinct cognitive domains associated with verbal memory, working memory, and attention and processing speed (panel 3). Raw scores for each cognitive domain were transformed into proportions to enable comparisons across domains. Separate regressions were used to predict adjusted cognitive scores in each domain. *AFF worker* was negatively associated with scores for working memory as well as attention and processing speed. There was no detectable association between agricultural work and the verbal memory score.

Table 4 presents results from growth curve models that examine whether exposure to agricultural work is associated with the rate of change in cognitive functioning. Model 1 estimates the direct effect of agricultural work on the respondent's trajectory of cognitive functioning. In Model 2, we add the interaction term between age and the AFF worker variable to examine whether the effect of agricultural exposure on cognitive functioning varies by age.

Table 3. Subgroup Analyses: Age, Retirement Status, Job Tenure, and Cognitive Domain

Panel 1: age group				
	Age 65–74		Age 75–84	Age ≥ 85
AFF worker, odds ratio (95% CI)	1.580* (1.115, 2.239)		1.405 (0.980, 2.013)	1.163 (0.661, 2.047)
N	38,778		19,577	3,379
Panel 2: retirement status and job tenure				
	Completely retired	Partially/ not retired	Tenure ≤10 years	Tenure >10 years
AFF worker, odds ratio (95% CI)	1.530** (1.152, 2.033)	1.541 (0.966, 2.458)	1.294 (0.750, 2.232)	1.503** (1.121, 2.016)
N	42,147	19,587	12,683	49,051
Panel 3: scores in three cognitive domains: verbal memory, working memory, and attention and processing speed				
		Verbal memory	Working memory	Attention and processing speed
AFF worker (*SE*)		−0.011 (0.014)	−0.025* (0. 010)	−0.015*(0.006)
N		61,735	61,735	61,735

Notes: AFF = agriculture, fishing, and forestry. All regressions in panels 1–3 control for covariates included in Table 2. Robust *SE*s were clustered at individual level. Panel 3 presents ordinary least squares coefficients. To generate the dependent variables in panel 3, raw scores for each cognitive domain were transformed into proportions to account for differences in the range of possible scores on each task when making comparisons across domains.
$^*p < .05$. $^{**}p < .01$. $^{***}p < .001$.

Finally, Model 3 includes all other covariates in the estimation and thus presents the results for age trajectories of cognitive functioning net of other variables. All three models include controls accounting for panel attrition.

The results from the reduced models are presented in columns 1 and 2. Model 1 (and Figure 1A) indicates that agricultural work is associated with lower cognitive functioning among older respondents. This effect is significant, with *AFF workers* scoring approximately 2 points less than other older adults on the cognitive functioning scale. Compared to the average cognitive functioning score for non-AFF workers at age 65 (15.74), this reflects a relative difference of about 11%.

In Model 2, the statistically significant interaction term between *AFF worker* and age suggests that the rate of cognitive decline over time differs by job type. However, the coefficient on the interaction term is positive, indicating that the rate of decline is, on average, slower for older adults exposed to agricultural jobs relative to those in other jobs. The predictions from this model are plotted in Figure 1B, which shows that with increasing age, the difference in cognitive functioning trajectories between AFF and non-AFF individuals is diminished, with AFF workers scoring slightly better than non-AFF workers at older ages.

The results from the full model are presented in column 3 of Table 4. In this specification, the association between *AFF worker* and cognitive functioning, though still statistically significant, is smaller in magnitude. This is expected as additional variables capture some of the effect that would otherwise be attributed to agricultural work exposure. At the same time, the interaction term remains statistically significant with the coefficient practically unchanged. On the basis of Model 3, Figure 1C demonstrates that while the initial level of cognitive functioning is lower among agricultural workers, exposure to non-AFF jobs is associated with more rapid decline in cognitive functioning after approximately age 85. A joint model in which we simultaneously model death and cognitive functioning does not indicate that our results are biased by selective mortality (Supplementary Table A3).

Additional Sensitivity Analyses

For all pooled analyses, we estimated alternative models with clustering of standard errors at household-level to account for presence of spouses. We estimated a model with all three sets of mediators included as covariates. We restricted the growth curve models to respondents who did not switch across agricultural and nonagricultural jobs over time. In all cases, the pattern of results remained unchanged (available on request).

Discussion

Beyond support for cognitively protective effects of mentally challenging work, there exists little evidence on the extent to which exposure to specific lifetime occupations

Table 4. Adjusted Growth Curve Models Estimating the Effect of AFF Exposure on Cognitive Functioning Score Over Time

	Model 1	Model 2	Model 3
Fixed effects			
Intercept	15.74 (0.17)***	15.75 (0.17)***	13.11 (0.23)***
Linear slope (centered age)	−0.18 (0.005)***	−0.18 (0.005)***	−0.13 (0.01)***
AFF worker	−1.71 (0.19)***	−2.17 (0.24)***	−0.92 (0.21)***
Centered age cube	−0.0002 (0.00)***	−0.0002 (0.00)***	−0.0002 (0.00)***
AFF worker × Centered age		0.06 (0.02)***	0.06 (0.02)**
Female			0.97 (0.06)***
Race: White as reference			
Black			−2.19 (0.09)***
Others			−1.01 (0.15)***
Hispanic			−0.79 (0.12)***
Marital status: married/together as reference			
Divorced/separated			0.07 (0.07)
Widowed			0.07 (0.05)
Never married			−0.23 (0.14)
Years of education: <12 years as reference			
12 years			2.11 (0.07)***
13–15 years			2.87 (0.08)***
≥16 years			3.88 (0.09)***
Nonhousing wealth: Quartile 1 as reference			
Quartile 2			0.46 (0.04)***
Quartile 3			0.72 (0.05)***
Quartile 4			1.03 (0.06)***
Years of education: father			0.02 (0.02)
Years of education: mother			−0.01 (0.02)
Family SES: pretty well off as reference			
About average SES			0.01 (0.12)
Poor SES			0.06 (0.12)
Region of birth: New England as reference			
Mid-Atlantic			0.47 (0.14)***
East North Central			0.16 (0.15)
West North Central			0.09 (0.16)
South Atlantic			−0.38 (0.15)*
East South Central			−0.31 (0.16)
West South Central			−0.35 (0.16)*
Mountain			−0.17 (0.20)
Pacific			−0.14 (0.18)
US/NA division			−0.01 (0.72)
Not in the United States			−0.19 (0.16)
Residence census reg.: Northeast as reference			
Midwest			−0.03 (0.11)
South			0.08 (0.09)
West			0.18 (0.11)
Other			1.40 (3.68)
Rural/urban status: urban as reference			
Suburban			−0.04 (0.05)
Rural			−0.25 (0.06)***
No. of appearances	0.11 (0.02)***	0.11 (0.02)***	0.12 (0.02)***
Died	−1.09 (0.10)***	−1.09 (0.10)***	−0.86 (0.08)***
Wave dummies	No	No	Yes
Random effects			
Intercept variance	11.85 (0.23)	11.85 (0.23)	7.13 (0.17)
Slope (age 65) variance	0.03 (0.001)	0.03 (0.001)	0.03 (0.001)
Residual variance	6.88 (0.05)	6.88 (0.05)	6.92 (0.05)

Table 4. Continued

	Model 1	Model 2	Model 3
Goodness-of-fit measures			
Log likelihood	−161,935.2	−161,929.7	−159,221.2
Degrees of freedom	10	11	52
AIC	323,890.3	323,881.3	318,546.4
BIC	323,980.6	323,980.7	319,016
N	61,735	61,735	61,735

Notes: AFF = agriculture, fishing, and forestry; AIC = Akaike information criterion; BIC = Bayesian information criterion; SES = socioeconomic status. US/NA division indicates in the US, but without the Census Division information. *SE*s in parentheses. We used cubic instead of quadratic age because our models did not converge with the inclusion of the latter as a covariate.

$^{*}p < .05$. $^{**}p < .01$. $^{***}p < .001$.

relate to cognitive difficulties in older adulthood (Berr & Letellier, 2019). This study examined the prevalence of dementia among older adults reporting employment in the agricultural sector as their longest-held job. It is the first study to do so using nationally representative data from the United States, as well as the first to investigate longitudinal patterns of cognitive functioning among older adults exposed to agricultural and nonagricultural jobs.

Our study, consistent with prior studies from Europe (Alvarado et al., 2002; Dartigues et al., 1992; Frisoni et al., 1993), supports the hypothesis that the prevalence of dementia is higher among older adults with a long work history in agriculture relative to those in other types of work. Specifically, a report of longest-held job in agriculture was associated with 46% greater odds of having dementia relative to those whose longest-held job was not in agriculture. This finding was statistically significant only among younger seniors, those who reported being fully retired, and "established" workers (i.e., those with over 10 years of tenure at their longest-held job). It is possible that empirical models for other subgroups (particularly the "oldest old" and "beginning" workers) lack power due to small group sizes. Further, the results among retired older adults should be interpreted cautiously. While continued mental and social stimulation associated with working may positively impact cognitive functioning, this relationship may be endogenous because maintaining a certain level of cognition is likely a necessary condition for ongoing employment.

In this analysis, we do not find evidence that hearing impairment, depression, or physical health indicators mediate the relationship between agricultural work and cognitive functioning. Future research should examine the mediating effect of pesticide exposure. This is relevant as our additional results demonstrate a negative association between being an AFF worker and measures of working memory and attention and processing speed. A study examining cognitive performance among Gulf War veterans with varying levels of pesticide exposure demonstrated that veterans with high levels of pesticide exposure had significantly slower information processing and reaction times than veterans with low exposures to similar neurotoxicants (Sullivan et al., 2018). Similarly, Starks and colleagues (2012) studied the relationship between unusually high pesticide exposure events (HPEEs) and nine neurobehavioral tests. Adverse associations were observed between ever having an HPEE and two of the nine neurobehavioral tests, one of which focused on processing and motor speed.

We find that exposure to agricultural work is associated with lower cognitive functioning at earlier stages of aging (age 65), with older adults exposed to agricultural work scoring about 11% lower on the cognitive functioning scale relative to older adults in other jobs. To put this difference into context, previous studies using the same scale have shown a difference of similar magnitude in cognitive scores among older adults in the 65–74 age group and those in the 75–84 age group (Langa et al., 2009).

However, this pattern appears to reverse at later stages of adulthood with more accelerated cognitive decline observed among those in non-AFF jobs. The cognitive reserve hypothesis (Stern, 2009) provides one potential explanation for this seemingly paradoxical result. Cognitive reserve reflects the capacity of the brain to protect against age- or illness-related brain pathology and is typically associated with education and engagement in intellectually challenging or complex occupations. Studies have shown that individuals classified as having "low lifetime occupational attainment" (defined as longest-held jobs in either AFF, skilled trade, craft, sales, processing, or the unskilled sector) have lower reserve against the effect of AD pathology relative to those classified to have "high lifetime occupational attainment" (defined as longest-held jobs in either professional, technical, and managerial occupations; Ghaffar et al., 2012). This is consistent with our results on dementia prevalence. However, the cognitive reserve hypothesis also predicts that because persons with high reserve can tolerate more brain pathology and neural insults before exhibiting clinical symptoms of cognitive disease, the onset of disease may be postponed, but *rates* of cognitive decline will be faster among those with high compared to low reserve

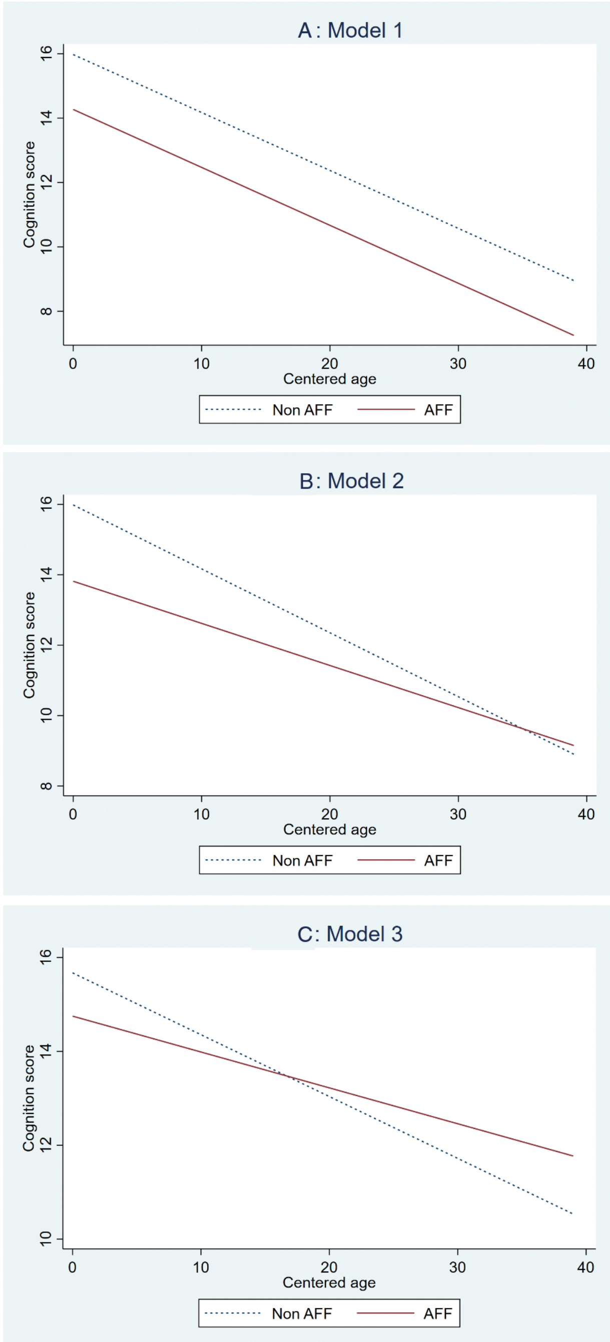

Figure 1. Age trajectories of cognitive function: the role of AFF exposure and other factors. AFF = agriculture, fishing, and forestry. (**A**) Growth curve model without covariates or interaction term between AFF worker and age (Model 1). (**B**) Growth curve model with interaction term between AFF worker and age but without covariates (Model 2). (**C**) Growth curve model with all covariates and interaction term between AFF worker and age (Model 3).

due to greater accumulation of brain pathology. This was empirically tested by Hyun and colleagues (2019), who examined rates of cognitive decline among those working in mentally challenging occupations versus those in less complex occupations. Similar to our results, the authors also found that while greater occupational complexity was associated with higher cognitive scores at retirement, it was simultaneously associated with faster declines in cognitive scores over time.

This study has several limitations. First, we are unable to account for all factors that might confound the relationship between engaging in agricultural work and dementia presence. Based on a life-course perspective, dementia is likely to have several social and physiological antecedents in early and mid-life. Thus, it is possible that our results may simply reflect selection into agricultural work. Second, occupational and industrial codes associated with a respondent's longest-held job merge agriculture with fisheries and forestry subsectors. However, according to the U.S. Bureau of Labor Statistics (BLS), agricultural workers comprised about 90% of all employees in farming, fishing, and forestry occupations in 2019 (BLS, 2020). If study results are mainly attributable to agricultural workers, then the inclusion of workers from related subsectors provides an underestimate of the true relationship. Third, we are unable to differentiate between hired agricultural workers and farm owner/operators. The results of this study are likely to be heterogeneous across these groups. Finally, the statistical models employed in this study do not account for survey stratification and clustering which may underestimate standard errors. Unadjusted comparisons may be particularly affected by these design effects. These limitations notwithstanding, this study contributes to our understanding of cognitive decline among older adults with strong occupational and industrial ties to agriculture. The results from this study can be used to develop future work characterizing the distinct nature of health and safety concerns on the farm for agricultural workers with dementia, and to develop effective interventions for these older adults.

Supplementary Material

Supplementary data are available at *The Journals of Gerontology, Series B: Psychological Sciences and Social Sciences* online.

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Conflict of Interest

None declared.

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Author Contributions

K. Arora conceptualized and planned the study, supervised the data analysis, and wrote the paper. L. Xu and D. Bhagianadh conducted the data analysis and assisted with writing the paper.

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