Title: Cognitive Functioning and Socioeconomic Status across the Early Life Course

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Abstract:

To date, analysis of the social determinants of cognitive health among younger adults is scant, especially in the US context. This study set out to test the extent to which established models of life-course health development are able to explain the reciprocal relationship between socioeconomic status (SES) and cognitive functioning from childhood through young adulthood. To do this, we used data from a nationally representative sample followed prospectively from adolescence through young adulthood that included information on SES and cognitive functioning at multiple points across the early life course. Additionally, this study aimed to expand these models by directly testing the role of occupational mental and social stimulation in influencing young-adulthood cognitive functioning. We did this by using linked occupational data that specifically measured job-task mental and social stimulation. Ultimately, our findings indicate an interwoven relationship between life-course SES, occupational characteristics, and cognition functioning across adolescence and young adulthood.

Research Highlights:

- Measures of SES in both early life and young adulthood are associated with cognition as measured by working memory in young adulthood
- Occupational characteristics related to cognitive stimulation are associated with young-adult cognition net of other predictors
- Adolescent cognitive ability completely mediates the effect of early-life SES on young-adult cognition

Keywords: Cognition; Memory; SES; Life Course; Aging; Occupations

1.1: Introduction

Like most measures of health, cognitive health is shaped by socioeconomic status (SES) (Choi et al. 2018; Crimmins et al. 2018). Higher levels of SES are associated with greater exposure to "stimulating environments" throughout the life course that actively promote the structural integrity of the brain (Fratiglioni and Wang 2007; Stern 2012). Mentally stimulating environments enhance brain health by increasing levels of "cognitive reserve", which provides protection from future cognitive health insults and delays the natural decline in cognition that occurs with age (Fratiglioni and Wang 2007; Stern 2012). Small-scale, clinical studies investigating the impact of stimulating environments on brain health have found that exposure to these environments in childhood is associated with greater brain surface area (Noble et al. 2012) and lower rates of hippocampal atrophy as individuals age (Valenzuela et al. 2008). These studies have highlighted the importance of studying social determinants of cognitive health in earlier stages of the life course, as exposure to stimulating environments was found to increases cognitive reserve even before the presence of visible cognitive decline (Noble et al. 2012; Valenzuela et al. 2008).

The current study investigates how indicators of SES from childhood through early adulthood are associated with cognitive functioning in young adulthood in a longitudinal, nationally representative sample. Young adulthood is a period of the life course for which research on the determinants of cognitive functioning is scant, despite the reported association between young-adult cognition and later-life risk of Alzheimer's disease and Alzheimer's disease-related disorders (Huang et al. 2018). Using a life-course framework, this study investigates the independent associations of both early-life and young-adult measures of SES on one measure of cognitive functioning, working memory, during this important, yet under-studied period of the life course. Defined as "the active, short-term maintenance and manipulation of information, generally in the service of guiding behavior" (Hackman et al. 2014), working memory is a primary component in executive functioning and overall cognitive ability (Snyder 2013).

This study will further explore the association between occupation and young-adult cognitive functioning above and beyond conventional measures of SES in order to investigate the role of stimulating work environments that promote the growth of cognitive reserve. While occupation is a "fundamental" determinant of health because it is strongly associated with an individual's level of economic, cultural, and social capital (Link and Phelan 1995; Phelan et al. 2010), occupational factors such as workplace freedom, task repetition, analytical demand, and frequency of social interaction represent important mental stimulators directly associated with cognitive functioning (Fratiglioni and Wang 2007). By integrating extant occupational-level data linked to a respondent's reported occupation that measure workplace cognitive stimulation and social interaction, in addition to self-reported measures

of occupational requirements, this study builds on previous literature using only broad measures of occupational classification as proxy measures of cognitive complexity at work.

Finally, this study will also explore the role of early-life cognition, as measured by adolescent verbal cognitive ability, in the relationship between life-course SES and young-adult cognition. Given the dynamic interplay between SES and cognition across the life course (Richard and Sacker 2005; Staff et al. 2016), our research is innovative by utilizing prospective measures of SES and cognition from multiple life stages. By using a longitudinal sample that includes parent-reported data on early-life SES, as well as data on cognitive ability in adolescence, this study improves on previous research that has relied on retrospective early-life data and has lacked measures of cognition in early life. Our study will address three questions:

1. Are both early-life and young-adult measures of SES associated with cognitive functioning in young adulthood?
2. Do specific aspects of an individual's occupation associated with cognitive stimulation further predict cognitive functioning in young adulthood net of conventional measures of life-course SES?
3. What is the role of adolescent cognitive ability in the relationship between life-course SES and young-adult cognitive functioning?

1.2: SES and Cognitive Functioning Across the Life Course

It is well established that SES across the life course is positively associated with health in adulthood, and that the ability for higher SES to ensure better health in individuals across life is a function of how SES can be translated into greater access to health promoting resources (Link and Phelan 1995; Phelan et al. 2010). Increased socioeconomic capital can also buffer the negative health effects of exposure to social stressors, which can delay the onset of disease in individuals with high SES relative to those of low SES (Perlin 1981; Thoits 2010). However, there is debate regarding the way in which life-course SES translates into later-life health outcomes, and three life-course models have been used to theorize this relationship. The first is the *Sensitive Periods Model* (Ben-Shlomo and Kuh 2002) which posits a direct causal relationship between early-life circumstances and adult health, and that subsequent intervening exposures or events do not mediate or modify this relationship. This model argues that early-life SES influences young-adult cognitive functioning, regardless of SES in early adulthood. The second is the *Pathways Model* (Hayward and Gorman 2004; Pudrovska and Anikputa 2014) which posits that early-life circumstances lead to later-life health outcomes through their influence on adult social conditions. In this mediating-effects model, early-life SES determines young-adult SES, and young-adult SES would fully predict young-adult cognition, with no direct effect from early-life exposures. Finally, the *Accumulation of Risks Model* (O'Rand 2009; Willson et al 2007) posits that early-life circumstances

have both lasting, direct consequences for adult health *and* shape the adult socioeconomic conditions that also contribute to later-life health. In this additive-effects model, both early-life and young-adult SES are associated with young-adult cognitive functioning.

While the evidence in support of each life course model varies by health outcome, the research to date on SES and cognition has generally supported the *Accumulations of Risks Model*, finding that SES in both early life and adulthood have independent and additive effects on cognition at older ages (Horvat et al. 2014; Landy et al. 2017; Luo and Waite 2005; Lyu 2015; Lyu and Burr 2016, Marden et al. 2017; Richards and Sacker 2005). However, some researchers have provided evidence for the pathways model, finding that the effect of early-life SES on measures of cognition are completely mediated by adult SES (Signh-Manoux et al. 2005; Zeki Al Hazzouri et al. 2011a). Research that has assessed SES trajectories across the life course, i.e., how individuals transition between both high and low levels of education from adolescence into old age, has also led to conflicting results. Haan et al. (2011) found that having achieved high SES in adulthood, regardless of early-life SES, was associated with better cognition in old age, while those with low levels of achieved education from high-SES backgrounds had levels of cognition on par with those who had consistently low SES across the life course. However, Zeki Al Hazzouri and colleagues (2011b) found that the risk of dementia or cognitive impairment in old age was only lower for those that were consistently in high SES across the life course.

But the extant studies are limited. Many have utilized small, local samples, often from European settings with no direct reference or applicability to the United States (Horvat et al. 2014; Landy et al. 2017; Signh-Manoux et al. 2005). Of the studies that did utilize large samples from the United States, all have focused on elderly populations (Haan et al. 2011; Luo and Waite 2005; Lyu and Burr 2015; Lyu et al. 2014; Marden et al. 2017; Zeki Al Hazzouri et al. 2011a; Zeki Al Hazzouri et al. 2011b), hence offering no insights into the SES—cognitive health relationships of young adults. Considering that decline in cognition may begin as early as the late 20 or early 30s (Hartshorne and Germine 2015), it is essential to study the association between life-course SES and cognitive functioning in a younger-adult sample of the U.S. population.

1.3: Cognitive Functioning and Occupation

The occupation in which an individual works is a measure of SES that has long been considered an important predictor of health. Using the concept of "occupational prestige" to measure the socioeconomic status associated with a given occupation, a positive association between health and occupation is known to exist, even when accounting for education and income (Fujishiro et al. 2010). When using occupational prestige to measure the association between work and health, the assumption is that an occupation of an individual determines health indirectly. Namely, one's occupation is strongly tied

to the amount of economic, cultural, or social capital one accumulates to invest in health-promoting resources that reduce the risk of disease (Fujishiro et al. 2010; Phelan et al. 2010). Higher occupational prestige may also result in more positive social interactions due to shared social beliefs and norms that value individuals of higher occupational standing (Fujishiro et al. 2010). However, the function that occupation plays in determining *cognitive* health in adulthood is unique and transcends its role as a measure of access to health promoting resources. Occupations act as environments that either promote or inhibit cognitive stimulation and as a result, the levels of task complexity and control inherent to an occupation have consequences for lifetime cognitive functioning. High-complexity jobs require that employees work through complex, mentally stimulating tasks and engage in communication with co-workers and others while on the job. In contrast, low-complexity jobs often involve repetitive tasks that require little mental effort or social interaction (Fay and Kamps 2006). Jobs with high control enable autonomy when carrying out the tasks of the job, while low-control jobs give workers little opportunity to decide the best way to complete job-related tasks (Zacher and Frese 2011).

Previous research on occupational contexts and cognition has found that occupations defined by repetitive, low-skilled tasks with low levels of control are associated with lower cognitive functioning and memory capacity (Gajewski et al. 2010), while those employed in jobs with greater mental demands and more complex social interactions show higher cognitive abilities across several tests of cognitive efficiency (Andel et al. 2005; Karp et al. 2009; Marquie et al. 2010; Potter et al. 2007; Siedler et al. 2004). High complexity jobs are also associated with a lower risk of dementia diagnosis in later life (Kröger et al. 2008). In addition to the epidemiological evidence that mentally stimulating, high-control jobs are associated with better cognitive functioning and delayed cognitive decline, there is also evidence from clinical studies that these jobs are associated with both greater hippocampal volume and a slower decline in this hippocampal volume over time (Valenzuela et al. 2008), as well as higher levels of cognitive functioning controlling for hippocampal volume (Boots et al. 2015). By including measures of occupational cognitive stimulation, this study will build on this work by exploring the unique contribution of these occupational factors within the life course development of young-adult cognitive functioning.

1.4: Adolescent Cognitive Ability, Life-Course SES, and Later-Life Cognitive Functioning

Finally, pathways between measures of life-course SES and young-adult cognition are likely to be highly influenced by cognitive ability in childhood and adolescence. The extant research suggests that early-life SES and early-life cognitive ability influences young-adult cognitive functioning in two ways. First, both early-life SES and early-life cognitive ability can select individuals into higher levels of SES. This in turn can lead to increased adult cognitive functioning through increased access to health promoting resources and greater exposure to stimulating environments, both within and outside of the

workplace (Fratiglioni and Wang 2007; Link and Phelan 1995; Phelan et al. 2010; Stern 2012). The understanding that parental SES is a strong determinant of one's own SES is well established within the sociological literature (Alexander et al. 1975; Blau and Duncan 1967; Haller and Portes 1973; Yang et al. 2018) and research on the relationship between parental SES and early-life cognitive ability has found that both factors independently predict occupational attainment in early adulthood (Cheng and Furnham 2012).

Second, early-life SES is positively correlated with both tests of cognitive performance (Kane et al. 2007; McVay and Kane 2009) and several measures of brain health (Noble et al. 2015) during the early life. Research has found that high-SES households offer a more advanced linguistic environment for children, with parents speaking and reading to their children with greater frequency and complexity (Noble et al. 2012). This exposure to a stimulating environment early in the life course increases cognitive reserve before adulthood (Stern 2002; 2012). In addition, these homes are less stressful environments in which to grow up (Noble et al. 2012) and exposure to stress is a leading cause of negative life course health outcomes across all measures of health and wellbeing (Pearlin et al. 1981; Thoits 2010). Whether through increased exposure to stimulating environments or decreased exposure to early-life stress, early-life high SES is associated with higher levels of early-life cognition, which translates into higher cognitive functioning in adulthood and less visible cognitive impairment at later ages (Richard and Sacker 2005; Richards et al. 2004).

Ultimately, SES may be associated with adult cognitive functioning through both its influence on early-life cognitive reserve as well as its role in determining later-life SES and adult cognitive functioning. What remains to be investigated is the degree to which early-life measures of SES and cognitive ability influence young-adult cognitive functioning. Only a few studies have investigated the role of life-course SES on adult cognitive functioning while accounting for baseline cognition in early life (Richard and Sacker 2005; Staff et al. 2016), all using non-US samples. Research on life-course SES and cognitive functioning that lacks multiple measures of cognition across the life course inhibits our ability to understand how early-life SES can shape early-life cognition, and how both these factors play a role in the development of adult cognitive functioning.

Cognitive ability in the early life course can also have direct implications for the association between occupation and young-adult cognitive functioning. Using a life course framework, Dekhtyar and colleagues (2015) utilized a Swedish survey to investigate the relationship between early-life cognition, adult SES, adult job complexity, and adult cognition. In this study, researchers found that early-life cognitive ability (measured by the academic grades received in elementary school) and adult job-task complexity were both negatively associated with later risk of dementia diagnosis. The lowest levels of dementia risk were seen among those individuals who had been able to achieve both high elementary

school grades in childhood and employment in a highly complex, mentally stimulating occupation in adulthood. However, those with complex jobs and low elementary school grades had the same levels of risk as those with low grades and non-complex jobs, highlighting the importance of early-life cognitive ability in determining cognition in adulthood. These researchers also found that the protective effect of adult education on dementia risk was fully explained by occupational complexity. Interestingly, this was the exact opposite finding of Staff and colleagues (2016), who conducted a similar study. These researchers, using a British cohort, found that education in adulthood, along with childhood cognitive ability, was enough to fully explain any positive effect of occupation on adult cognition.

Clearly, there remains debate regarding the independent role of both attained education and occupational complexity in influencing adult cognition, and limitations exist in these previous life-course studies. While the study by Dekhtyar and colleagues utilized direct measures of occupational cognitive stimulation and mental complexity, it did not include a measure for childhood SES. Considering that early-life SES can influence both early-life cognitive ability and adulthood SES, omission of this variable is problematic. The study by Staff et al. *did* include a measure of childhood SES, but did not utilize direct measures of occupational cognitive stimulation. Rather they relied on broad occupational classifications to inform the mental rigor of an occupation. Moreover, both studies used samples that only included elderly respondents.

1.5: Hypotheses

By utilizing a prospective longitudinal sample of young-adult respondents with life course information on SES and cognition at multiple stages, along with data that integrate self-reported occupational measures and direct measures of the analytic intensity and social interaction inherent to an occupation, this study aims to advance our knowledge about the pathways between SES, occupation, and cognition across the life course. Our set of hypotheses is as follows:

Hypothesis 1: Both early-life SES and young-adult SES, as measured by education, economic capital, and occupational prestige, will be positively associated with young-adult working memory, consistent with the Accumulation of Risks Model.

Hypothesis 2a: Measures of occupational cognitive stimulation will be associated with young-adult working memory independent of traditional measures of SES.
Hypothesis 2b: These measures of occupational cognitive stimulation will, at least partially, mediate the relationship between both early-life and young-adult SES with young-adult working memory.

Hypothesis 3a: Adolescent verbal cognitive ability will partially confound the association between young-adult SES and young-adult working memory.
Hypothesis 3b: Adolescent verbal cognitive ability will partially confound the association between occupational cognitive stimulation and young-adult working memory.
Hypothesis 3c: Adolescent verbal cognitive ability will partially mediate the association between early-life SES and young-adult working memory.

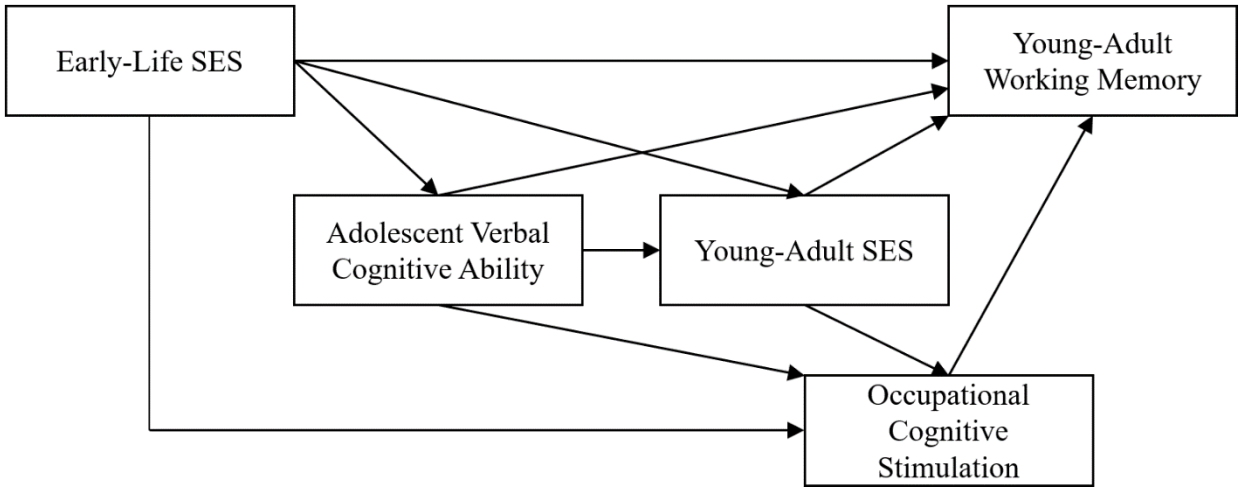

Figure 1: Theoretical model

2.1: Data

The current study uses data from Waves I and IV of the National Longitudinal Study of Adolescent to Adult Health (Add Health) (Harris et al. 2019). Add Health is a nationally representative sample of Americans who were in middle school or high school during the 1994-1995 school year, and have since been followed with four additional interviews (Waves II-V). Data for Wave I were collected when respondents were between the ages of 12 and 19 through in-school and in-home interviews. For most of the respondents, parent interviews were also collected in order to gain information on the parents' health and health behaviors, as well as the household situation of the child during their adolescent years. Respondents were re-interviewed at Wave IV in 2008 when they were between the ages of 24 and 32. The survey focused on the topics of health, health behaviors, well-being, socioeconomic security and social behaviors/friendship networks. This wave also included information on the self-reported current or most recent occupation for the respondents. These occupations were then coded using the Standard Occupational Classification System (SOC) of the U.S. Census.

In order to supplement the Add Health dataset with additional information on the mental complexity and social interaction of respondents' occupations, we integrated data from the Occupational

Information Network (O*NET). O*NET is a data collection effort run by the U.S. Department of Labor and the National Center for O*NET Development (National Center for O*NET Development 2018) in which businesses around the United States were sampled and workers within these businesses were randomly selected. Those sampled were administered surveys inquiring about the importance of myriad tasks, abilities, and skills necessary in order to fulfill the requirements of their occupation. By using crosswalks available from the Bureau of Labor Statistics (Bureau of Labor Statistics 2019) and O*NET (O*NET Resource Center 2019) it was possible to link data from O*NET to the reported occupations of the Add Health respondents, as both O*NET and Add Health used SOC codes to classify occupations. In some instances, O*NET variables were not available at the finest grain of occupational classification for all respondents in Add Health. Those respondents without linkable SOC codes were assigned the value of the modal occupation (among those Add Health respondents *with* linkable SOC codes) within the next highest order of occupational classification, as individual SOC codes are nested within more general occupational categories.

Overall, 15,701 respondents were re-interviewed at Wave IV (80 percent response rate), however we made some restrictions to the analytic sample. First, those without proper sampling weights to account for Add Health's complex sampling design were excluded (n=901). Second, respondents who were missing proper occupational codes at Wave IV were omitted (n=361). Third, because O*NET does not collect occupational data for occupations within the military, all those who were coded as having current occupations within the military were excluded (n=37). Finally, all respondents who were missing information on the dependent variable of working memory or any independent variable were omitted (n=2,283). The final analytic sample size was 12,129 respondents.

2.2: Variables

2.2.1: Young-adult working memory

To assess working memory, we used three memory-ability tasks from Add Health Wave IV; immediate word recall, delayed word recall, and digits backwards recall. In the word recall tasks, respondents were first read a list of 15 words and then asked to relay back as many as they could remember in 90 seconds. The number of words recalled formed the *immediate word recall* score. After a span of about five minutes, during which the respondent was asked additional questions for the Wave IV interview, they were again asked to recall as many of the same 15 words as they could. The number of words correct formed the *delayed word recall* score. In the *digits backward recall* task, respondents were read a set of numbers and asked to recall them back to the interviewer in reverse order. The task was repeated up to seven times, each time with a longer series of numbers. That task was ended after the seven number series or after two series with incorrect recall responses. After standardizing the scores on all

three measures to have a mean of zero and a standard deviation of one, the three measures were summed. This summed scale was then re-standardized so that regression coefficients could be interpreted as the standard deviation change in this memory-ability variable as the result of a one-unit increase in the independent variable.

2.2.2: Early-life SES

We measured *Early-life SES* using a Social Origins Score original created by Belsky et al. (2018), in which information on parental education, parental occupation, household income, and household receipt of public assistance were derived from the parent interview at Wave I of Add Health. For this measure, principal component analysis was performed with these four measures, and the first principal component explained 53 percent of the variance. Using the factor loadings from this principal component, a score of early-life SES was created for each respondent in the Add Health sample with data available on at least two of the four measures. Scores were then Z-transformed within the Add Health sample to have a mean of zero and a standard deviation of one.

2.2.3: Young-adult SES

To measure SES in young adulthood, we used four variables from Wave IV of Add Health when the cohort was ages 24-32. *Respondent education* was self-reported at Wave IV. Responses were categorized as "Less than High School", "High School Diploma", "Some College", and "College Degree or more". *Income* is the reported individual earnings of the respondent in the last full calendar year. Values of *income* were log-transformed to account for a strong right skew. *Welfare receipt* was a dichotomous variable indicating reported receipt of public assistance since becoming an adult. Finally, *occupational prestige*, was measured according to the method proposed by Hauser and Warren (1997). Using SOC codes linked to the reported occupations of the Add Health respondents, scores computed by Hauser and Warren describing the average income and education of job holders in the Census were linked to the respondents. This linkage was facilitated using the crosswalk provided by the University of Wisconsin Center for Demography and Ecology (Fredrick and Hauser 2010). Scores of occupational prestige were Z-transformed to have a mean of zero and a standard deviation of one.

2.2.4: Occupational cognitive stimulation

We used four variables to directly measure the cognitive stimulation of occupations, of which two were provided by respondents on the Add Health survey at Wave IV, while the other two were integrated into the analytic dataset from the data provided by O*NET. The first respondent-reported item, *repetitive work*, is a question asking respondents directly how repetitive the tasks required for their job are. The second self-reported item, *job-task freedom*, asked respondents to state how much freedom they have to make decisions about the tasks they perform at their work and how they do these tasks. Both these respondent-reported variables were asked on a four-point Likert scale from "None or almost none of the

time" to "All or almost all of the time", coded on a range of 0-3. The additional occupational cognitive stimulation variables of *analytic skills of occupation* and *social interaction of occupation* were created from outside data linked to Add Health respondents from the Occupational Information Network (O*NET) database. Both variables were created using multiple independent items that measured the importance of various daily tasks required for a given occupation. Using a content model provided by O*NET, mean scores were created from individual job-task items within conceptual "constructs" that defined the broader domains of skills defined by the individual tasks. Those constructs that best measured occupational analytic demands and frequency of social interaction were then re-averaged within each occupation. As a result, both *analytic skills of occupation* and *social interaction of occupation* are measured on a continuous scale from 1-5, with higher values indicating greater need to use analytic skills and engage in social interaction respectively. A full description of the individual items and O*NET constructs used in the creation of these variables can be found in the **Supplemental Materials**.

2.2.5: Adolescent verbal cognitive ability

We used scores from the Add Health Picture Vocabulary Tests (AHPVT) administered to respondents during the Wave I survey. An abridged, computerized version of the Peabody Picture Vocabulary Test-Revised (PPVT), the AHPVT tested the overall vocabulary knowledge of the adolescents by requiring respondents to match illustrations to words that best fit together (Harris 2013). The abridged AHPVT has been found to be highly correlated with the full version of the Peabody Picture Vocabulary test (PPVT) (Halpern et al. 2000) and the scores correlate with IQ-test measures of verbal cognition at r=0.9 and with measures of fluid cognition at r>0.5 (Hodapp and Gerken 1999). Responses were age-standardized and recorded on a scale from 14-146.

2.2.6: Covariates

Covariates include respondents' age (in years), gender, race/ethnicity, immigrant status, marital status, and current employment status.

Weighted descriptive statistics for the analytic sample can be found in **Table 1**. **Table 1** also includes a column for the bivariate correlation coefficients between young-adult working memory and each independent variable. All independent variables are significantly correlated with young-adult working memory at the .05-level, with the exception of non-Hispanic "Other" racial status and being unemployed, but not looking for work. All correlation coefficients are in the expected direction.

Table 1: Weighted Descriptive Statistics (n=12,129)

	Wave	Mean/Prop.	Std. Dev	Min.	Max.	Bivariate correlation with working memory
Young-adult working memory	IV	0.03	1.40	-3.08	4.71	-
Early-life SES	I	0.04	1.88	-5.59	3.51	0.24*
Respondent Education	IV					
Less than high school		0.08				-0.18*
High school diploma		0.17				-0.15*
Some college		0.43				-0.02*
College degree		0.32				0.25*
(log)Income	IV	9.49	3.71	0.00	13.73	0.07*
Welfare receipt	IV	0.23				-0.12*
Occupational prestige	IV[+]	-.01	1.39	-2.03	2.26	0.24*
Repetitive work	IV	1.89	1.27	0	3	-0.13*
Job-task freedom	IV	1.91	1.31	0	3	0.06*
Analytic skills of occupation	IV[+]	3.30	0.53	2.17	4.12	0.20*
Social interaction of occupation	IV[+]	3.60	0.51	2.39	4.46	0.15*
Adolescent verbal cognitive ability	I	102.46	19.12	14	146	0.35*
Age	IV	28.28	2.56	24	32	-0.07*
Female	I	0.49				0.11*
Currently married	IV	0.45				0.05*
Race/ethnicity	I					
Non-Hispanic white		0.71				0.19*
Non-Hispanic black		0.14				-0.16*
Hispanic		0.11				-0.10*
Non-Hispanic other		0.04				-0.00
Immigrant Status	I					
Foreign-born		0.04				-0.06*
Native-born, immigrant parents		0.10				-0.03*
Native-born, native parent(s)		0.86				0.06*
Employment Status	I					
Employed		0.83				0.05*
Unemployed, looking for work		0.07				-0.07*
Unemployed, not looking for work		0.10				-0.01

[+]Data linked to reported occupation at Wave IV
* $p<0.05$, two-tailed test.

2.3: Analytic Strategy

We estimated Ordinary Least Squares (OLS) regressions to examine the associations between life course SES, occupation, and young adulthood working memory. We built models by adding the independent variables in a stepwise fashion to test each hypothesis. Specifically, Model 1 regressed working memory on early-life SES; Models 2-4 included respondent education, economic capital, and occupational prestige, respectively. Model 5 then added occupational cognitive stimulation. And the final model included adolescent verbal cognitive ability. In all models, we included covariates as controls and used sample weights and cluster robust standard errors to account for Add Health's complex survey design.

2.4: Results

Results from the regression analyses can be found in **Table 2**. Models 1-4 test our first hypothesis regarding the associations between working memory and SES across the life course. Model 1 shows a significant association between early-life SES and young-adult working memory, with a one standard deviation improvement in early-life SES resulting in an estimated .143 standard deviation increase in working memory in young-adulthood ($p<.001$). In Model 2, with the inclusion of respondent education, the coefficient for early-life SES was reduced by 54 percent, with subsequent, smaller reductions in the coefficient being seen as other adulthood SES variables were included into the model. However, the association between early-life SES and young-adult working memory remained significant through Model 5. For respondents' young-adult SES, Models 2, 3, and 4 show that most measures of education, economic capital, and occupational prestige are positively associated with young-adult working memory, with the exceptions of welfare receipt in all models and income after adjusting for occupational prestige. In all, we found support for Hypothesis 1 which suggests the *Accumulation of Risks* process linking life-course SES and working memory in young adulthood.

Model 5 tests our second set of hypotheses regarding the role of occupational cognitive stimulation in predicting young-adult working memory and mediating the association between both early-life SES and young-adult SES and the dependent variable respectively. Results show that the degree of social interaction inherent to an occupation is significantly associated with young-adult working memory, with a one-unit increase in occupational social interaction (on the scale from 1-5) being associated with a .086 standard deviation increase in young-adult working memory ($p<.05$), controlling for all other covariates. This finding supports Hypothesis 2a for one specific type of occupational cognitive stimulation (social interaction). The inclusion of occupational cognitive stimulation measures in Model 5 only slightly attenuated the association between life-course SES and working memory, suggesting no significant mediation effect, as was hypothesized in Hypothesis 2b, but rather largely independent effects of both SES and occupational social interaction.

Model 6, the full model, further includes adolescent verbal cognitive ability in order to test the third set of hypotheses regarding the role of early-life cognitive ability as both a confounder and mediator in the relationship between life-course SES and working memory. Adolescent verbal cognitive ability was strongly associated with young-adult working memory (b=.017; $p<.001$), and the addition of this variable substantially decreased and diminished the associations between young-adult working memory and the measures of young-adult SES, thus confounding this relationship, and the associations between young-adult working memory and early-life SES, thus mediating this relationship. Taken together, these results support Hypotheses 3a and 3c. Occupational social interaction, however, remained statistically significant and even increased in coefficient size, suggesting that adolescent verbal cognitive ability does not confound this relationship but operates more as a suppressor, providing no support for Hypothesis 3b.

Table 2: OLS Regression of Young-Adult Working Memory on Life-Course SES[a]

	Model 1 β(SE)	Model 2 β(SE)	Model 3 β(SE)	Model 4 β(SE)	Model 5 β(SE)	Model 6 β(SE)
Early-life SES	0.143***	0.066***	0.062***	0.056***	0.055***	0.021
	(0.01)	(0.01)	(0.01)	(0.01)	(0.01)	(0.01)
Young-Adult SES						
Education						
Less than high school		0.00	0.00	0.00	0.00	0.00
		-	-	-	-	-
High school diploma		0.199**	0.189**	0.180**	0.177**	0.142*
		(0.06)	(0.06)	(0.06)	(0.06)	(0.06)
Some college		0.442***	0.428***	0.388***	0.378***	0.271***
		(0.05)	(0.05)	(0.05)	(0.05)	(0.05)
College degree		0.745***	0.722***	0.610***	0.594***	0.432***
		(0.06)	(0.06)	(0.06)	(0.06)	(0.06)
Economic Capital						
Income(log)			0.010*	0.008	0.008	0.006
			(0.00)	(0.00)	(0.00)	(0.00)
Welfare receipt			-0.043	-0.033	-0.031	-0.024
			(0.03)	(0.03)	(0.03)	(0.03)
Occupational prestige				0.087***	0.081***	0.058*
				(0.02)	(0.02)	(0.02)
Occupational Cognitive Stimulation						
Repetitive work					-0.025	-0.012
					(0.01)	(0.01)
Job-task freedom					0.007	0.011
					(0.01)	(0.01)
Analytic skills of occupation					-0.028	-0.009
					(0.05)	(0.05)
Social interaction of occupation					0.086*	0.092**
					(0.03)	(0.03)
Adolescent verbal cognitive ability						0.017***
						(0.00)
Constant	0.729*	0.270	0.182	0.284	0.126	-1.529***
	(0.29)	(0.27)	(0.27)	(0.27)	(0.31)	(0.32)
Observations	12,129	12,129	12,129	12,129	12,129	12,129
R-squared	0.10	0.14	0.14	.14	0.15	0.19

[a]All models control for age, gender, race, immigrant status, and marital status
*** p<0.001, ** p<0.01, * p<0.05, two-tailed test.

3.1: Discussion

In this study, we examined the associations between a comprehensive array of indicators of life-course SES and one key measure of cognition, working memory, in young adulthood, a developmental period for which research on cognition and social determinants of cognitive functioning is scant. Our analysis contributed new knowledge about the life-course process linking SES and working memory in three ways. First, the use of prospective measures of life-course SES, including a measure of SES in

adolescence based on information supplied directly by the parents of the survey respondents and measures of SES in young adulthood, established the proper temporal order of associations under investigation and strengthened the causal inference. Second, the linkage of survey data with validated extant data on occupational characteristics allowed for the empirical test of occupational cognitive stimulation as an independent dimension of young-adult SES that can influence young-adult working memory. This has moved us one step forward to understanding potential mechanisms by which conventional measures of SES may enhance working memory and cognitive functioning in general. Finally, our study incorporated a measure of adolescent cognitive ability to further strengthen the test of the associations between life-course SES and young-adult working memory by accounting for its potential mediating role with early-life SES and its confounding role with young-adult SES in their associations with young adulthood cognitive functioning.

Results show support for our hypothesis that both early-life and young adult measures of SES are associated with young-adult working memory, in line with the *Accumulation of Risks Model* that previously was found in studies of older populations (Horvat et al. 2014; Landy et al. 2017; Luo and Waite 2005; Lyu 2015; Lyu and Burr 2016, Marden et al. 2017; Richards and Sacker 2005). Our research also adds to the existing literature by integrating occupation as a key measure of SES in influencing cognitive function. We found a positive association between the social skills necessary to perform the tasks required of a job and young-adult working memory. This occupational factor and education were both independently associated with young-adult working memory in contrast to previous studies that have found that either education or occupational factors associated with cognitive stimulation explained measures of adult cognitive functioning (Dekhtyar et al. 2015; Staff et al. 2016). Our findings also differed from those of previous studies when it came to specific aspects of occupations that were associated with working memory in adulthood. While we found support for an association between young-adult working memory and occupational social interaction, the analysis by Dekhtyar and colleagues did not. Conversely, these researchers found support for an association between occupational analytic complexity and cognition, while we did not. However, the sample used by Dekhtyar and colleagues differed significantly from our sample by age, birth cohort, and country, so perhaps these factors contributed to our contrasting findings.

Surprisingly, our study found no association between either self-reported task repetition (a relationship hypothesized to be negative) or self-reported job task freedom (a relationship hypothesized to be positive) and working memory, as has been found in previous research (Andel et al. 2005; Karp et al. 2009; Kröger et al. 2008; Marquie et al. 2010; Potter et al. 2007; Siedler et al. 2004). This may indicate that the negative effect of repetitive or low control jobs on cognitive functioning does not come to fruition until later in the life course. Research that has found evidence of the relationship between cognition and

these occupational factors has largely utilized samples of individuals later in their career or post-retirement. The possible long-term effect of repetitive work or low job control on cognition may not be evident in this sample due to their younger age.

Exploring the life-course relationship between SES, occupational stimulation, and young-adulthood memory further, we found evidence that adolescent verbal cognitive ability explained a portion of the association between young adult SES and young-adult working memory, suggesting that adolescent verbal cognitive ability, at least partially, influences young-adult working memory through its ability to shape SES in adulthood. Interestingly, our results showed that inclusion of adolescent verbal cognitive ability increased the association between social interaction of an occupation and young-adult working memory, indicating a suppression effect. This may suggest that the association between early-life cognitive ability and the social intensity of an occupation is not necessarily positive. This notion is consistent with previous work that has found that workers in the service industry report significantly better health than those in managerial positions (Fujishiro et al. 2010). While the authors of this study could only speculate as to why this was the case, our findings indicate the social nature of these jobs may play a role, though it should be noted that these authors were studying self-reported health, not measures of working memory. Finally, we found that the association between early-life SES and young-adult working memory was mediated entirely through adolescent verbal cognitive ability. This finding suggests that the primary mechanism through which early-life SES is associated with later-life cognitive functioning is through its role in the development of cognitive reserve and cognitive functioning in childhood and adolescence.

We acknowledge several study limitations. First, the Add Health Picture Vocabulary Tests does not tap into the same cognitive constructs as the cognitive tests used to measure respondents' working memory in young adulthood. For this reason, these measures cannot be considered identical tests of cognition repeated across both waves of Add Health in this study. However, the Peabody Vocabulary Test has been found to be an acceptable proxy for more advanced tests of intelligence in childhood (Hodapp and Gerken 1999). Second, respondents in the Add Health sample are likely to still be transitioning through the workforce due to their young ages at Wave IV (average age 28). As a result, the occupations captured here may just be temporary as individuals experience upward job mobility. However, given that our study was the first to investigate life-course correlates of cognition in young adulthood, this limitation is inherent to studying this population. Finally, measures of cognition at only one point in adulthood, taken at the same time in which occupations were self-reported, is a potential limitation. Moreover, our measure of cognition, working memory, is limited to only one domain of global cognitive function. This may partially explain why our findings differed from previous work using measures of cognitive functioning in different cognitive domains.

3.2: Conclusion

Despite its limitations, the study sheds new light on the importance of stimulating environments for cognitive health across the first half of the life course. Even in adulthood, activities that stimulate the mind can contribute to cognitive reserve, and research has shown that exposures to mentally stimulating environments in adulthood are beneficial for cognition and can delay cognitive decline (Cheng 2016; La Rue 2010). For those at highest risk of early cognitive decline, including those with low levels of educational attainment or employment in jobs with limited social complexity, active steps aimed at promoting cognitive stimulation beyond the job could potentially counter the disadvantage they face due to their SES or occupation. Our results indicate that the most beneficial form of cognitive stimulation is that which comes from social interaction. Future work should investigate how SES and cognitive ability across the life course are associated with not only young-adult cognition, but also how these factors influence trajectories of cognition across the middle part of the life course, using a global measure of cognitive function. While extensive work has been done on trajectories of cognitive decline and their social correlates, these studies have overwhelmingly focused on elderly populations. One reason for this has been limited longitudinal data in the U.S. context. However, the continuous accumulation of on-going and future studies such as the Add Health project should make this avenue of research possible. The finding that the positive association between early-life SES and young-adult working memory is primarily a function of how early-life SES translates into cognitive ability in adolescence indicates that increased efforts to enhance cognitive ability in childhood may result in higher cognitive function in adulthood, regardless of family SES.

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Supplemental Materials:

Creation of the occupation-level variables

For each item on the O*NET occupational survey, respondents reported the importance of a given task on a five-point Likert scale from 1-5, in which 1 was "Not important" and 5 was "Extremely important". Responses across all respondents within an occupation were averaged, leading to a single importance score for each item from 1 to 5. Using these items, O*NET has created a content model in which individual items are conceptually grouped together under larger constructs.

Within the current study, the variable *Analytic Skills of Occupation* was created using the constructs of "Process", "Complex Problem Solving", and "Practical Intelligence"; for *Social Interaction of Occupation*, the constructs utilized were "Interpersonal Interaction" and "Communicating and Interacting". A list of each individual O*NET item used in the creation of these constructs can be found in **Table 3**. Within each occupational category, the mean of all the items within a construct was taken and used as a value for the construct. For the final variables used in this study, the mean of all relevant constructs was taken, leading to a final value of analytic skills and social interaction necessary for each occupation. For these variables, higher values correspond to greater use of each of these skills.

Table 3: Description of O*NET variables used in the present study

Occupation Variable	O*NET Construct	Individual O*NET Item
Analytic Skills	Process	Critical Thinking • Using logic and reasoning to identify the strengths and weaknesses of alternative solutions, conclusions or approaches to problems.
		Active Learning • Understanding the implications of new information for both current and future problem-solving and decision-making.
		Learning Strategies • Selecting and using training/instructional methods and procedures appropriate for the situation when learning or teaching new things.
		Monitoring • Identifying complex problems and reviewing related information to develop and evaluate options and implement solutions.
	Complex Problem Solving	Complex Problem Solving • Identifying complex problems and reviewing related information to develop and evaluate options and implement solutions.
	Practical Intelligence	Innovation

		• Job requires creativity and alternative thinking to develop new ideas for and answers to work-related problems.
		Analytical Thinking • Job requires analyzing information and using logic to address work-related issues and problems.
Social Interaction	Interpersonal Orientation	Cooperation • Job requires being pleasant with others on the job and displaying a good-natured, cooperative attitude.
		Concern for Others • Job requires being sensitive to others' needs and feelings and being understanding and helpful on the job.
		Social Orientation • Job requires preferring to work with others rather than alone, and being personally connected with others on the job.
	Communicating and Interacting	Interpreting the Meaning of Information for Others • Translating or explaining what information means and how it can be used.
		Communicating with Supervisors, Peers, or Subordinates • Providing information to supervisors, co-workers, and subordinates by telephone, in written form, e-mail, or in person.
		Communicating with Persons Outside Organization • Communicating with people outside the organization, representing the organization to customers, the public, government, and other external sources. This information can be exchanged in person, in writing, or by telephone or e-mail.
		Establishing and Maintaining Interpersonal Relationships • Developing constructive and cooperative working relationships with others, and maintaining them over time.
		Assisting and Caring for Others • Providing personal assistance, medical attention, emotional support,

		or other personal care to others such as coworkers, customers, or patients.
		Selling or Influencing Others • Convincing others to buy merchandise/goods or to otherwise change their minds or actions.
		Resolving Conflicts and Negotiating with Others • Handling complaints, settling disputes, and resolving grievances and conflicts, or otherwise negotiating with others.
		Performing for or Working Directly with the Public • Performing for people or dealing directly with the public. This includes serving customers in restaurants and stores, and receiving clients or guests.