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Associations of job demands and intelligence with cognitive performance among men in late life

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Abstract

Objective—To examine the association of job characteristics and intelligence to cognitive status in members of the National Academy of Sciences–National Research Council Twins Registry of World War II veterans.

Methods—Participants (n = 1,036) included individuals with an assessment of intelligence based on Armed Services testing in early adulthood. In late adulthood, these individuals completed the modified Telephone Interview for Cognitive Status (TICS-m) and occupational history as part of an epidemiologic study of aging and dementia. Occupational history was coded to produce a matrix of job characteristics. Based on factor analysis, job characteristics were interpreted as reflecting general intellectual demands (GI), human interaction and communication (HC), physical activity (PA), and visual attention (VA).

Results—Based on regression analysis of TICS-m score covarying for age, intelligence, and years of education, higher levels of GI and HC were independently associated with higher TICS-m performance, whereas higher PA was independently associated with lower performance. There was an interaction of GI and intelligence, indicating that individuals at the lower range of intellectual aptitude in early adulthood derived greater cognitive benefit from intellectually demanding work.

Conclusions—Intellectually demanding work was associated with greater benefit to cognitive performance in later life independent of related factors like education and intelligence. The fact that individuals with lower intellectual aptitude demonstrated a stronger positive association between work and higher cognitive performance during retirement suggests that behavior may enhance intellectual reserve, perhaps even years after peak intellectual activity.

Research has demonstrated that intellectually engaging job demands during adulthood are associated with better cognitive performance in later life, whereas low intellectual demands and manual labor demands are associated with worse cognitive performance, even after controlling for the effects of age and education.[1,2] A study of occupational differences between twin pairs examined both intellectual and physical job demands, and found that higher levels of intellectual job demands were associated with a modest improvement in cognitive status over a 7-year period, whereas higher physical demands were associated with a modest decline over the same interval.[3]

Research on the reciprocal relationship between job complexity and cognitive function found that better performance on a measure of intellectual flexibility in early life was associated with more intellectually complex employment, and this ongoing exposure to

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intellectually complex activity appeared to augment cognitive functioning over time.[4] This finding suggests that job complexity may be a proxy for intelligence, and that it is underlying intelligence, rather than job complexity, that influences cognitive performance in later life. As a result, a key point to address in understanding the beneficial effects of job complexity is whether they exist independent of intelligence.

Explanations of the relationship between job characteristics and cognitive function in late life often focus on the concept of cognitive reserve, and intelligence emerges as an important issue here as well. Cognitive reserve theory asserts that some individuals have greater capacity than others to function effectively in the context of age-related cognitive decline—whether normal or pathologic—because of advantageous biologic mechanisms or methods of compensation.[5] One study found that individuals from disadvantaged childhood backgrounds who experienced upward mobility in education and income during adulthood demonstrated better cognitive test performance than their childhood peers who did not have upward mobility, while individuals with high childhood socioeconomic status and downward mobility in education and income in adulthood performed worse than similar individuals who experienced high socioeconomic status throughout their life.[6] Although this study suggests that enduring positive or negative qualities of lifestyle and environment in adulthood may influence cognitive performance in later life, it does not address a specific mechanism of change like job complexity or account for the role of underlying intelligence in cognitive outcome. Innate intelligence is one of the biologic factors that is believed to promote cognitive reserve,[7] while intellectually stimulating job characteristics are hypothesized to promote cognitive reserve by either 1) augmenting or diversifying neural pathways or 2) facilitating more efficient or adaptive use of cognitive processing.[5] One issue that would clarify the effects of complex activity on cognitive reserve is whether individuals actually perform better on cognitive testing in older adulthood due to lifetime job demands, or whether cognitive test performance is instead a function of intelligence. The goal of the current study was to estimate the relationships of early adult intelligence and subsequent adult job complexity to cognitive performance in later life, based on a sample of elderly individuals who completed an intellectual assessment in early adulthood as part of their Armed Services enlistment. If intellectually complex job demands are associated with better cognitive function in older adulthood, this relationship should be independent of underlying intelligence. We additionally examined whether the association between intellectual complexity and cognitive function differs by level of intellectual aptitude.

METHODS

Participants

Participants were enrolled in the Duke Twins Study of Memory in Aging, and were members of the National Academy of Sciences–National Research Council Registry of World War II veteran male twins, born from 1917 to 1927. The sample of individuals in the current study (n = 1,036) had known scores on either the Army General Classification Test (AGCT) or the General Classification Test (GCT), which was administered to US military service inductees in the early 1940s as a “test of general learning ability.” Included in this sample were 272 twin pairs for which information was available on both members of the pair, and 62.5% were monozygotic (identical) twin pairs.

Participant selection

As part of the Duke Twins Study, surviving and consenting participants were administered a telephone cognitive status assessment every 3 to 4 years beginning in 1990 as part of a screening and assessment protocol for dementia. Individuals were included in this study if they 1) completed the cognitive status assessment up to the third assessment wave (1996–

1998), which was when occupational history was obtained; and 2) were nondemented at the time of cognitive assessment and do not carry a current diagnosis of dementia in our ongoing study.

Measures

Modified telephone interview for cognitive status (TICS-m)—The TICS[8] and its modified form[9] provide a brief assessment of cognitive status that can be administered via the telephone. The TICS-m was designed to assess global cognitive status in a manner similar to the Mini-Mental State Examination (MMSE),[10,11] but it is enhanced by additional content, including immediate and delayed recall of a 10-item word list. The TICS-m produces scores ranging from 0 to 50, is highly correlated with the MMSE,[12] and has high test-retest reliability.[9,12]

Armed services intelligence tests—The AGCT was administered at the time of Army enlistment, while the GCT was administered to Naval enlistees.[13] These tests were designed to assess intellectual aptitude without heavy reliance on education beyond early elementary school.[13,14] Reliability coefficients (split-half and alternate forms) are greater than $r = 0.90$ for both tests.[13,14] Both tests are strongly correlated with education ($r = 0.65$ to 0.73).[15,16] These measures correlated with other tests of intelligence or general intellect, including the Wechsler-Bellevue Intelligence Scale, the Wechsler Adult Intelligence Scale, the Otis Self-Administering Test of Mental Ability, the revised version of the Army Alpha Test, and the ACE Psychological Exam ($r = 0.79$ to 0.90).[17,18] Test scores for the AGCT ($n = 521$) and the GCT ($n = 515$) were part of a larger sample that was standardized to a common metric with a mean of 10 and SD of 1. The assumption underlying this common standardization was that the two tests would not have differed in their mean scale measures had both been administered on a common scale, which was based on the fact that the population distributions of each test were very similar in shape. We jointly refer to the scores from these tests as AGCT/GCT scores.

Occupational coding methodology

Occupational information was collected from a series of questions administered during telephone interviews, including 1) longest-held job, 2) job title, 3) specific job duties, 4) type of industry, and 5) beginning and ending year for the job. These responses were used to assign specific occupational classifications from the Dictionary of Occupational Titles (DOT), 4th edition.[19] The DOT was initially published in 1939 and has been the primary source of occupational information in the United States for several decades. The revised fourth edition was published in 1991 and contains descriptions of 12,740 occupations. Each occupation is identified by a unique nine-digit code. Each job in the DOT was systematically analyzed by a trained job rater along several domains, including several ratings of "worker attributes that contribute to successful job performance" (page 1-1, The Revised Handbook for Analyzing Jobs).[20] These worker characteristics included 1) complexity of work with data, people, and things, 2) general educational development, 3) specific vocational preparation, 4) aptitudes, 5) temperaments, and 6) physical demands and environmental conditions. Extended job ratings were obtained from the DOT authors.[19] DOT classification was done by one of two trained data technicians adhering to written procedures and decision rules to ensure coding reliability. A subsample of 449 occupations was independently coded by both technicians to estimate coding reliability. Because matching to the entire nine-digit DOT code would yield an inappropriate index of reliability,[21] we based our estimates on several relevant attributes, including complexity of work with 1) data, 2) people, and 3) things, 4) reasoning development, 5) mathematical development, 6) language development, 7) specific vocational preparation, and 8) strength. Based on Fleiss' intraclass correlation formula,[22] we found moderately high interrater reliability for each of these eight characteristics (r = 0.85 to 0.90).

Factor analysis of DOT work characteristics

The DOT factors used in the current study were derived from previous work, where they are described in greater detail.[3] Factor 1 was labeled general intellect (GI) and included job characteristics with positive loadings for complexity with data and people (DOT digits 4 and 5), reasoning, language, and mathematics aptitude, and greater time spent in specific vocational preparation. Factor 2 was labeled human interaction and communication (HI), and had small positive loadings on several interpersonal characteristics, but was more notable for negative factor loadings for technical or object-related complexity. Factor 3 was labeled physical activity (PA) and included characteristics such as strength and multiple physical movements. Factor 4 was labeled visual attention (VA), including field of vision and distance vision.

Statistical methods

Statistical analysis included examination of descriptive statistics and demographic variables, bivariate correlations of intellectual aptitude with occupational factors, and multivariate analysis of factors predicting TICS-m performance. Using the TICS-m as the dependent variable, we ran linear regression models with each of the occupational factors as an independent variable, with covariates of age, years of education, and AGCT/GCT score. Education was categorized with three levels: 1) <10 years (9.9% of sample), 2) 11 to 12 years (37.1% of sample), and 3) >12 years (53% of sample). We modeled the interaction of each occupational factor by AGCT/GCT score and education. In these models, we adjusted our measures of statistical significance to account for lack of independence among the twin pairs in the sample using an M-estimation procedure based on iteratively re-weighted least squares.[23,24] We also estimated the incremental proportion of variance (r^2) in TICS-m performance attributable to individual occupational factors by adding each factor separately to a regression model in which the covariates of age, AGCT/GCT, and education were held constant. We also conducted the same models using conditional linear regression that was dependent on twin pair for those pairs where data were available for each twin (n = 544).

RESULTS

Participant characteristics are shown in table 1. Bivariate correlations revealed that most of the four occupational complexity factors were modestly but significantly associated with AGCT/GCT and education, and that most occupational factors were intercorrelated (table 2). The correlations indicate that the occupation factor GI had the highest correlation to intelligence among these job characteristics.

Multivariate regression models indicated that higher levels of GI and HC were each significantly associated with higher levels of TICS-m performance, whereas higher levels of PA were associated with lower levels of TICS-m performance (table 3). There were no interactions between job factors and education level, and the only significant interaction with intellect was with GI. This interaction indicated that individuals with lower AGCT/GCT scores demonstrated a greater increase in cognitive performance associated with jobs high in general intellectual demands than did individuals at higher levels of intellect (figure). Multivariate modeling of the covariates of age, AGCT/GCT, and education to predict TICS-m performance indicated that these variables accounted for approximately 22% of the variance in this outcome measure. The addition of GI and the interaction of GI × AGCT/GCT increased the amount of variance in TICS-m accounted for by the model by approximately 2%, which is approximately the amount of variance accounted for by age by the model. Incremental variance for each of the other occupational variables was less than 1%.

Conditional linear regression models (i.e., twin-pair-dependent) revealed no association between occupational factors and cognitive performance within twin pairs.

DISCUSSION

We found that higher levels of intellectually demanding or socially engaging work during adulthood were associated with a higher level of cognitive function later in life, and that more physically demanding work was associated with a lower level of cognitive function. This relationship held true after controlling for the effects of age and two factors—education and intelligence—that are associated with both intellectual job demands and late-life cognitive performance. The relationship between cognitive performance and intellectually complex work did not vary by education level, but there was an interaction with AGCT/GCT indicating that a history of intellectually demanding work was associated with better cognitive performance in late life at lower levels of intelligence relative to higher levels. To our knowledge this is the first study to examine the association between job characteristics and cognition while also accounting for the influence of intellect in early life. These findings support the notion that intellectually demanding work is more than a proxy for education or intellect, and that it produces an independent association with cognitive performance in later life.

The current results are consistent with previous research[25] suggesting that individuals may benefit cognitively when adult accomplishments (i.e., job complexity) exceed disadvantageous socioeconomic or educational factors in early life, in this case lower intellectual ability; however, our findings do not support the converse idea that late-life cognition suffers when high intellectual ability is accompanied by low occupational complexity in adulthood. The fact that intellectually demanding work had a smaller association to cognitive performance among individuals with higher levels of intellect may reflect that individuals with higher intellectual aptitude already possess the cognitive skills that individuals with lower aptitude develop in the course of intellectually demanding work, which may make the potential gains more modest among individuals with higher intellect. One possible explanation for the lesser cognitive association to intellectually demanding work among those with higher AGCT/GCT scores is that a brief global cognitive measure like the TICS-m may have ceiling effects at the highest levels of intellect; however, no participant achieved the maximum score on this test and percentile distributions do not suggest an asymptotic distribution (table 1). It is nonetheless possible that a stronger association between cognitive performance and job demands could be found in higher intellectual strata when cognitive or intellectual function are assessed more comprehensively than with the TICS-m. From the perspective of cognitive reserve, the interaction between intellectually demanding work and early life intelligence on later cognitive status suggests maintenance of cognitive function is due to more than intellectual aptitude, and may be augmented by behaviors that engage the intellect. This study does not address the underlying mechanism for this enhancement, but it could involve biologic mechanisms like increased synaptic density, cognitive mechanisms like improved critical thinking and problem solving, or a combination of these two factors. Our study supports the notion that complex activity may allow individuals to exceed presumed limitations, as assessed by intellectual aptitude, but does not provide evidence that underutilization of intellect is cognitively harmful.

The current study has some limitations. Occupational coding was based on information abstracted from questionnaire data, which is not expected to be as accurate as information collected in an interview specifically designed to facilitate job analysis.[4] As with similar population-based studies of cognition, a high level of in-depth job analysis was not available, but previous research supports the use of information derived from DOT ratings as a valid source of occupational data in epidemiologic studies.[26,27] Because data were based on a sample of male World War II veteran twins, there may be some level of cohort effect that limits generalizability, and the current results would be complemented by research on more heterogeneous samples. We also excluded individuals with known or suspected dementia (n = 74) for two main reasons: 1) we believe that using a nondemented sample provides a more conservative test of cognitive outcomes, and 2) the underlying processes of normal aging and dementia are different enough that the inclusion of individuals with dementia may confound interpretation of the associations found among individuals who were nondemented at the time of cognitive assessment. We also did not find any associations among job demands, intellect, and cognitive performance within twin pairs, which may reflect a smaller sample size and the fact that twin pairs are highly similar within all three of these variables. Nonetheless, it is possible that unknown shared environmental and genetic factors may underlie and further explain our results. Finally, this observational study design has an unavoidable element of survivorship bias, and while it allowed us to examine associations among job demands, intellect, and cognitive performance, it does not support causal inferences about these relationships.

Finally, it is important to consider the current findings from the perspective that most individuals work during a significant proportion of their adult life and have the potential to benefit from intellectually demanding work. Future research may examine whether individuals with jobs that lack intellectual demand can derive cognitive benefits from seeking new cognitive challenges within their job or from intellectually engaging activities outside of work. It is important to address these and other issues of aging, work, and cognition in populations where individuals are projected to both live and work longer than preceding generations.

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GLOSSARY

AGCT	Army General Classification Test
DOT	Dictionary of Occupational Titles
GCT	General Classification Test
GI	general intellectual demands
HC	human interaction and communication
MMSE	Mini-Mental State Examination
PA	physical activity
TICS-m	modified Telephone Interview for Cognitive Status
VA	visual attention

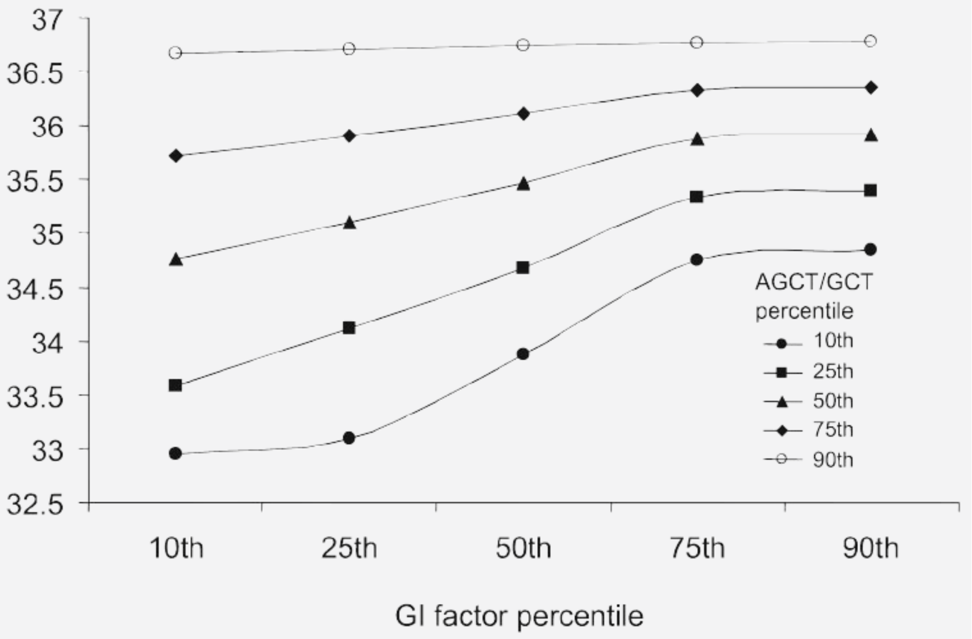

Figure.

Representation of fitted interaction of Army General Classification Test/General Classification Test (AGCT/GCT) and general intellectual demand (GI) factor relative to mean modified Telephone Interview of Cognitive Status (TICS-m) score

Fitted at mean age 71.75 years and education group 12+ years. Predicted TICS-m = 34.097 − 0.261 × age + 1.867 × AGCT/GCT + 0 × (education = 12+) − 1.291 × (12 ≥ education ≥ 11) − 2.598 × (10 ≥ education) + 5.294 × GI − 0.460 × GI × AGCT/GCT.

Table 1

Participant characteristics (n = 1,036)

		Percentiles				
Variable	**Mean (SD)**	**10**	**25**	**50**	**75**	**90**
Age, y	71.75 (2.39)	69	70	71	73	75
Education, y	13.72 (2.92)	11	12	13	16	18
Job years	33.28 (10.18)	19	27	35	40	45
Factor GI	1.31 (0.88)	0.09	0.74	1.43	2.02	2.29
Factor HC	0.06 (1.21)	−1.56	−0.91	0.23	1.05	1.58
Factor PA	0.17 (1.32)	−1.05	−0.71	−0.46	0.85	2.21
Factor VA	0.22 (1.32)	−1.10	−0.62	−0.11	0.75	2.06
AGCT/GCT	10.26 (0.99)	9.04	9.71	10.36	10.89	11.41
TICS-m	34.34 (4.74)	28	31	35	38	40

Percentiles provided to portray distribution of variables.

Job years = years worked in primary occupation; GI = general intellectual demands; HC = human interaction and communication; PA = physical activity; VA = visual attention; AGCT/GCT = Army General Classification Test/General Classification Test (mean = 10, SD = 1); TICS-m = modified Telephone Interview of Cognitive Status.

Table 2

Correlations among intelligence, occupational factors, and education

	GI	HC	PA	VA	Education
AGCT/GCT	0.388	0.120	−0.230	−0.109	0.517
GI		0.437	−0.428	−0.309	0.562
HC			−0.379	−0.043^{NS}	0.176
PA				0.165	−0.384
VA					−0.113

GI = general intellectual demands; HC = human interaction and communication; PA = physical activity; VA = visual attention; AGCT/GCT = Army General Classification Test/General Classification Test; NS = not significant, all other $p < 0.001$.

Table 3

Regression coefficients for association of job demands to cognitive performance (modified Telephone Interview for Cognitive Status)

Variable	**b**	***p***
General intellectual demands	5.294	<0.001
General intellectual demands × AGCT/GCT (interaction)	−0.460	<0.001
Human interaction and communication	0.212	0.039
Physical activity	−0.271	0.007
Visual attention	0.044	0.635

Age and education were significant (<0.001) as covariates in each model.

AGCT/GCT = Army General Classification Test/General Classification Test.