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Occupational complexity and lifetime cognitive abilities

OPEN

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ABSTRACT

Objective: To examine associations between complexity of main lifetime occupation and cognitive performance in later life.

Methods: Occupational complexity ratings for data, people, and things were collected from the *Dictionary of Occupational Titles* for 1,066 individuals (men = 534, women = 532) in the Lothian Birth Cohort 1936. IQ data were available from mean age 11 years. Cognitive ability data across the domains of general ability, processing speed, and memory were available at mean age 70 years.

Results: General linear model analyses indicated that complexity of work with people and data were associated with better cognitive performance at age 70, after including age 11 IQ, years of education, and social deprivation.

Conclusions: The current findings are supportive of the differential preservation hypotheses that more stimulating environments preserve cognitive ability in later life, although the continued effects into old age are still debated. Studies that have early-life cognitive ability measures are rare, and the current study offers interesting prospects for future research that may further the understanding of successful aging. *Neurology*® 2014;83:2285-2291

GLOSSARY

DOT = *Dictionary of Occupational Titles*; **g** = general cognitive ability; **LBC1936** = Lothian Birth Cohort 1936; **MHT** = Moray House Test; **PCA** = principal component analysis; **SMS1947** = Scottish Mental Survey 1947.

There is a growing body of research suggesting that more stimulating lifestyles, including more complex work environments, are associated with better cognitive outcomes in later life.¹⁻⁵ Underlying mechanisms behind this association are not fully understood, although it is suggested that more stimulating environments increase “cognitive reserve,”⁶ which subsequently protects against the effects of aging—normal⁷ or pathologic^{8,9}—on the brain. This is described by the differential preservation hypothesis.^{1,2,7} By contrast, given the stability of cognitive performance across the life course, others have highlighted that an individual’s level of engagement in complex activities might be a *consequence* of differences in prior cognitive ability.^{10,11} This latter possibility is often referred to as preserved differentiation.^{1,2}

Limitations in the literature are the absence of measures of prior cognitive ability¹⁻³ and the use of brief cognitive assessments.^{4,5} Using the *Dictionary of Occupational Titles* (DOT), participants in the Lothian Birth Cohort 1936 (LBC1936) were assigned scores summarizing the occupational complexity of their work with data, people, and things. Associations were examined between 4 cognitive domains (age 70 IQ, general cognitive ability, memory, and processing speed) and occupational complexity with data, people, and things. Cognitive ability scores from childhood were included in the analysis to establish whether associations between occupational complexity and adult cognitive ability were independent of prior ability.

Supplemental data
at Neurology.org

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METHODS Participants. The LBC1936 is a longitudinal study of aging. All participants were born in 1936, and most took part in the Scottish Mental Survey 1947 (SMS1947), a national survey completed by almost all 11-year-olds at school in Scotland. The LBC1936 comprises 1,091 participants (548 men and 543 women) who were recruited at a mean age of 69.5 years (SD = 0.8). A freely accessible protocol paper is available.¹²

Standard protocol approvals, registrations, and patient consents. Ethics permission was obtained from the Multi-Centre Research Ethics Committee for Scotland (MREC/01/0/56) and Lothian Research Ethics Committee (LREC/2003/2/29). The research was performed in compliance with the Helsinki Declaration. Written informed consent was given by all participants.

Cognitive ability. Cognitive ability was assessed at about age 70 using a battery of cognitive tests administered by trained researchers. Full details have been described previously.¹² The current study considered 4 cognitive domains at age 70: memory, processing speed, a general cognitive ability (“g”) factor, and the Moray House Test (MHT). The g, memory, and speed factors were available from previous principal component analysis (PCA) in this sample.¹³ Brief descriptions of the tests are as follows.

Participants took the MHT of general cognitive ability aged 11 years in the SMS1947. The test consists of 71 items, with a maximum score of 76, and was completed with a time limit of 45 minutes. The items included following directions, same-opposites, word classification, analogies, practical items, reasoning, proverbs, arithmetic, spatial items, mixed sentences, and cypher decoding.¹⁴ Scores on the MHT give a valid assessment of childhood cognitive ability. It was validated against the Terman-Merrill revision of the Binet Scales.¹² During the cognitive assessment at age 70, participants repeated the MHT.

General cognitive ability (g) scores were obtained from the first unrotated component of a PCA of 6 Wechsler Adult Intelligence Scale-III UK subtests¹⁵: Letter-Number Sequencing, Matrix Reasoning, Block Design, Digit Symbol, Digit Span Backward, and Symbol Search.

Processing speed scores were similarly derived by PCA of Symbol Search,¹⁵ Digit Symbol,¹⁵ inspection time,¹⁶ and simple and choice reaction time.¹⁷ An overall score for memory was derived by PCA of memory measures from the Wechsler Memory Scale-III UK¹⁸: Logical Memory (immediate and delayed recall), Spatial Span (forward and backward), and Verbal Paired Associates (immediate and delayed recall).

Occupational complexity. Participants’ main lifetime occupation was obtained at the age 70 testing session. The occupational titles were matched to occupations listed in an online resource, the *DOT*,¹⁹ a catalog of occupations used in the United States between 1939 and 1977. In the fourth edition of the *DOT*, published in 1977, more than 12,000 occupations were rated based on observations by job analysts. The *DOT* classifies occupations based on a 9-digit code (i.e., 092.227-010, primary school teacher). The fourth, fifth, and sixth digits represent occupational complexity with data, people, and things, respectively. Complexity ratings are summarized in table 1. In the *DOT*, the most complex jobs are coded “0”; for ease of comprehension, scores have been reversed so a higher score reflects greater complexity. Occupational complexity scores were assigned to 1,066 of the 1,091 participants. Of the 25 who could not be assigned codes, 6 reported nongainful occupations (housewife), 8 gave multiple occupations, and the remaining 11 reported careers that were not classified in the *DOT* (for example, “facilities manager”). *DOT* classification was completed by one researcher (E.L.S.). A subsample of 111 occupations was recoded by the same researcher and by an independent coder to check intra- and interrater reliability using a 2-way random model intraclass correlation²⁰ (see table e-1 on the *Neurology*[®] Web site at Neurology.org).

Deprivation. Participants were assigned a deprivation score based on matching their postcode to the Scottish Index of Multiple Deprivation (SIMD), a standardized relative ranking of geographic data areas published by the Scottish Executive,²¹ compiled from information about crime, education, access to services, etc. The rankings range from 1 (most deprived) to 6505 (least deprived), which have been previously collapsed in the LBC1936 to an 8-point scale.²²

Years of education. The number of years of full-time education was recorded at interview at age 70.

Statistical analyses. Analyses were performed using IBM SPSS version 19.0 (IBM Corp., Armonk, NY). General linear models were used to examine associations between occupational complexity with data, people, and things, and cognitive ability. The three occupational complexity factors were tested separately for associations with cognition, before being entered into the models simultaneously. Cognitive abilities were age 70 IQ (MHT), g factor, processing speed, and memory. Four models were fitted to the data, each including adjustments for confounding factors. Model 1 included age and sex as covariates; model 2 additionally included age 11 IQ; model 3 additionally included years of education; and the final model also included deprivation. Effect sizes are reported here as partial η^2 (η^2_p).

RESULTS Participant characteristics are shown in table 2. While men and women did not significantly differ on age, education, or deprivation, men held more complex jobs with data (men mean = 4.2, female mean = 3.1), although they did not significantly differ on the other complexity variables. Women scored higher on the MHT at age 11 whereas men had significantly higher scores for processing speed and g factor at age 70. Men and women’s scores for age 70 IQ and memory did not significantly differ.

Bivariate correlations (table e-2) revealed that the occupational complexity factors were significantly intercorrelated. Participants with more complex work

Table 1 Description of occupational complexity levels with data, people, and things

Data	People	Things
6 Synthesizing	8 Mentoring	7 Setting up
5 Coordinating	7 Negotiating	6 Precision working
4 Analyzing	6 Instructing	5 Operating-controlling
3 Compiling	5 Supervising	4 Driving-operating
2 Computing	4 Diverting	3 Manipulating
1 Copying	3 Persuading	2 Tending
0 Comparing	2 Speaking-signaling	1 Feed-offbearing
	1 Serving	0 Handling
	0 Taking instructions-helping	

Reference for *Dictionary of Occupational Titles*. Rating scales have been reversed for the current study, so a higher score reflects greater complexity.

Table 2 Characteristics of study population

	Total sample (N = 1,066)		Male (n = 534)		Female (n = 532)		t	p
	Mean	SD	Mean	SD	Mean	SD		
Age, y	69.6	0.8	69.6	0.8	69.6	0.8	-0.1	0.88
Education, y	11.0	1.3	11.0	1.2	11.0	1.1	0.3	0.78
Deprivation	6.3	2.9	6.3	2.0	6.7	2.2	1.3	0.18
Retired, %	95.8		95.8		95.8		1.61	0.11
Age 11 IQ	100	15.0	99.0	15.9	101.0	14.0	-2.2	0.01
Age 70 IQ	100	14.7	100.6	15.0	99.5	14.4	1.2	0.72
g Factor	0.0	1.0	0.043	1.032	-0.043	0.966	1.4	0.04
Processing speed	00.0	1.0	-0.012	1.070	0.012	0.924	-0.4	0.01
Memory	0.0	1.0	-0.060	1.070	0.061	0.980	-2.0	0.45
Complexity with data	3.6	1.6	4.2	1.5	3.1	1.6	11.6	0.00
Complexity with people	2.6	2.0	2.5	1.5	2.6	1.9	-0.8	0.43
Complexity with things	3.0	2.6	3.0	2.8	2.9	2.4	1.0	0.34

Abbreviation: g = general cognitive ability.

with data and people tended to have jobs with lower complexity with things ($r = -0.17$ and -0.36 respectively, $p < 0.001$). In addition, individuals who had occupations characterized by greater complexity of work with data or people tended to have better cognitive performance at age 70 ($r = 0.16$ – 0.29), while participants who held occupations rated as more complex with things tended to have lower cognitive ability scores in later life (except processing speed).

General linear models. Models with individual occupational complexity factors. Four univariate general linear models were fitted for each cognitive domain separately (table 3). Complexity with data, people, and things were considered separately to examine the individual contributions of each cognitive variable. In the first models (age- and sex-adjusted), all complexity factors were significantly associated with all cognitive domains (with the exception of complexity with things and memory). Participants who held the most complex

Table 3 General linear models with individual occupational complexity factors

Complexity variable	Cognitive variable	Unadjusted		Model 1		Model 2		Model 3		Model 4	
		p	η^2_p	p	η^2_p	p	η^2_p	p	η^2_p	p	η^2_p
Data	Age 70 IQ	0.000	0.10	0.000	0.10	0.000	0.03	0.13	0.02	0.260	0.02
	g Factor	0.000	0.10	0.000	0.10	0.000	0.03	0.000	0.02	0.001	0.02
	Processing speed	0.000	0.06	0.000	0.06	0.001	0.02	0.006	0.02	0.022	0.02
	Memory	0.000	0.04	0.000	0.05	0.412	0.01	0.680	0.00	0.675	0.00
People	Age 70 IQ	0.0000	0.15	0.000	0.20	0.000	0.05	0.000	0.03	0.001	0.03
	g Factor	0.000	0.13	0.000	0.13	0.000	0.04	0.001	0.03	0.003	0.02
	Processing speed	0.000	0.07	0.000	0.07	0.005	0.01	0.288	0.01	0.465	0.01
	Memory	0.000	0.08	0.000	0.08	0.005	0.02	0.107	0.01	0.112	0.01
Things	Age 70 IQ	0.000	0.03	0.000	0.04	0.141	0.01	0.187	0.01	0.201	0.01
	g Factor	0.000	0.03	0.000	0.03	0.559	0.01	0.507	0.01	0.674	0.00
	Processing speed	0.000	0.03	0.000	0.03	0.394	0.01	0.289	0.01	0.337	0.01
	Memory	0.012	0.02	0.070	0.01	0.543	0.01	0.523	0.01	0.495	0.00

Abbreviations: η^2_p = partial η^2 ; g = general cognitive ability.

Data = complexity with data; people = complexity with people; things = complexity with things. Models considered complexity with data, people, and things as independent variables (separately), with each cognitive variable as a dependent variable.

Model 1 included age and sex as covariates; model 2 additionally included age 11 IQ; model 3 additionally included years of education; model 4 additionally included deprivation.

jobs with data, people, or things tended to score more highly across the cognitive domains examined. The largest effect sizes were observed for age 70 IQ with complexity with data and people ($\eta^2_p = 0.10$ and 0.20 , respectively). These effects were heavily attenuated by the addition of age 11 IQ. In the final models, the only surviving associations were for complexity with data, which remained significantly associated with age 70 IQ ($\eta^2_p = 0.02$), g factor ($\eta^2_p = 0.02$), processing speed ($\eta^2_p = 0.02$), and complexity with people, which was significantly associated with age 70 IQ ($\eta^2_p = 0.03$) and g factor ($\eta^2_p = 0.02$). Participants with occupations characterized by higher complexity with data or people tended to have better scores for general cognitive ability, and those with more complex jobs with data also tended to have better processing speed scores. There were no associations with any of the cognitive domains and complexity with things in the fully adjusted models.

Models with the 3 occupational complexity factors entered simultaneously. The results of the main analyses with data, people, and things entered simultaneously are displayed in table 4. Examination of the models including interaction terms revealed no significant interactions between any of the occupational complexity factors and sex; the results were therefore not separated by sex, and interactions were not included in subsequent analyses.

The first models (age- and sex-adjusted) revealed that all occupational complexity factors were associated with performance on all cognitive domains; that is, people who had occupations characterized by higher complexity tended to perform better. The

largest effect sizes were for the associations between complexity with people and age 70 IQ ($\eta^2_p = 0.06$) and g factor scores ($\eta^2_p = 0.06$). The addition of age 11 IQ substantially attenuated these effects. Surviving associations were seen for complexity of data, which remained significantly associated with age 70 IQ, g factor, and processing speed. Complexity with people remained significantly associated with age 70 IQ, g factor, and memory. The associations of complexity with people and g factor and memory survived full adjustment (both $\eta^2_p = 0.02$); participants with occupations rated as more complex with people tended to perform better in terms of their cognitive ability. Complexity with data remained positively associated with g factor and processing speed in the final model, although this was slightly attenuated by the addition of deprivation (both $\eta^2_p = 0.01$). No effects of complexity with things across any of the cognitive domains survived the addition of age 11 IQ.

DISCUSSION The present study's findings support the hypothesis that higher complexity of work is associated with later-life cognitive performance. In the LBC1936, individuals who held occupations with higher levels of complexity with data and people had better cognitive performance at age 70. After controlling for early-life cognitive ability, years of education, and deprivation, individuals with occupations characterized with higher complexity of work with people remained significantly associated with g factor and memory scores. Effects of complexity of work with data remained significant

Table 4 General linear models with all occupational factors entered simultaneously

Cognitive variable	Complexity variable	Unadjusted		Model 1		Model 2		Model 3		Model 4	
		p	η^2_p	p	η^2_p	p	η^2_p	p	η^2_p	p	η^2_p
Age 70 IQ	Data	0.000	0.05	0.000	0.04	0.025	0.02	0.073	0.01	0.091	0.01
	People	0.000	0.05	0.000	0.06	0.021	0.02	0.114	0.01	0.144	0.01
	Things	0.000	0.03	0.000	0.04	0.113	0.01	0.149	0.01	0.165	0.01
g Factor	Data	0.000	0.05	0.000	0.04	0.004	0.02	0.016	0.02	0.034	0.01
	People	0.000	0.06	0.000	0.06	0.002	0.03	0.026	0.02	0.046	0.02
	Things	0.000	0.03	0.000	0.03	0.192	0.01	0.224	0.01	0.292	0.01
Processing speed	Data	0.000	0.05	0.000	0.03	0.010	0.02	0.026	0.02	0.044	0.01
	People	0.021	0.02	0.017	0.02	0.796	0.01	0.819	0.00	0.903	0.00
	Things	0.000	0.03	0.000	0.03	0.123	0.01	0.153	0.01	0.173	0.01
Memory	Data	0.000	0.03	0.000	0.03	0.051	0.01	0.90	0.01	0.094	0.01
	People	0.000	0.05	0.000	0.05	0.004	0.02	0.032	0.02	0.032	0.02
	Things	0.001	0.02	0.009	0.02	0.123	0.01	0.128	0.01	0.127	0.01

Abbreviations: η^2_p = partial η^2 ; g = general cognitive ability.

Data = complexity with data; people = complexity with people; things = complexity with things. All models included complexity with data, people, and things as independent variables, with each cognitive variable as a dependent variable. Model 1 included age and sex as covariates; model 2 additionally included age 11 IQ; model 3 additionally included years of education; model 4 additionally included deprivation.

for g factor and processing speed. The effects were small, accounting for approximately 1% to 2% of the variance, comparable to other predictors such as the association between smoking and cognition in later life in the LBC1936.²³ The findings are consistent with those reported previously^{2-4,24,25} and provide support for occupational complexity as a modest predictor of cognitive performance in later life, independently of prior ability.

Given that most attenuation of the association between occupational complexity and cognitive ability occurred after the addition of age 11 IQ (the reduction in effect size being approximately 50%–66%), the findings additionally provide evidence of preserved differentiation. That is, engagement in complex activities (in this case occupationally complex) is partly a consequence of the lifetime stability of cognitive ability. However, the findings further show evidence of differential preservation. That is, engaging in complex environments, such as those characterized by complex occupational demands, may help to preserve cognitive function in later life and could be one of many factors that account for individual differences in cognitive performance in older age. The current study benefits by being able to address the likelihood of preserved differentiation; while the effects of occupational complexity were indeed attenuated by the addition of early-life ability, some subtle, significant effects remained. It is important to note this attenuation, because it suggests that studies not accounting for prior ability may overestimate the beneficial effect of complex occupational environments on later cognition. Notwithstanding this caveat, the current results suggest that occupational complexity slightly benefits later-life cognitive performance, independently of the lifelong stability of cognitive ability. Direct causation cannot be inferred from the current study; however, previous studies have shown reciprocal effects between level of ability and occupational complexity.^{25,26}

Mechanisms underlying how occupational demands may affect cognitive abilities are disputed. One theory is that complex lifestyles increase the amount of cognitive or brain reserve. It has been suggested that environmental factors, such as occupational complexity, may affect a person's cognitive abilities by increasing structural brain reserve, increasing neural efficacy, or alternatively may help to utilize compensatory pathways.⁶ Recent findings suggest that there are multiple biological pathways that mediate the relationship between stimulating lifestyles and cognitive abilities, through which stimulating lifestyles may have protective effects against pathology²⁷ or indeed normal aging.

Complexity of work with people had the largest association with 2 of the 4 cognitive domains. This corresponds to recent research exploring associations between social engagement and cognitive aging. It

has been postulated that greater levels of social engagement and social support are associated with a lower risk of cognitive impairment in later life.^{28–30} A similar study²⁴ found that, in a sample of male twins, having a job that had a high degree of social engagement was a significant predictor of later-life ability. In the current study, complexity with people was associated with both memory and g factor. It is possible that it is this “social” aspect of occupational complexity with people that may be an important determinant of later-life cognitive functioning.

Sex differences have not been explored before in the literature despite apparent sex differences in occupations.³¹ It might be expected that because men, especially given the generation of the current study's participants, tended to have more-demanding occupations, they might also have had a slight cognitive advantage in old age. However, the current study found no significant effects of sex by any of the occupational complexity factors. Further exploration of male and female occupations revealed some differences. The most common occupations held by women were clerical (secretaries, etc.), teaching, and nursing. Within these occupations, teaching had the highest rating for complexity with people and made up approximately 10% of female careers (3% of male). For men, managerial, supervisory, and company directors were the most common positions with the highest ratings for complexity with people. So, although the careers that men held with higher levels of complexity with people were qualitatively different to women, the levels of complexity with people remained equivalent.

The study has some limitations. Occupational complexity is a hypothesized construct and *DOT* codes are based on national survey data and may not fully express an individual's engagement in their career. A self-reported measure might better reflect this. In addition, the complexity with things variable had a particularly skewed distribution; analyses were completed with a dichotomized things variable, which was not associated with any of the cognitive variables, although some of the main findings were slightly altered. Given these small changes, it is important that the current results are replicated in other cohorts with prior cognitive ability data, occupational ratings, and cognition in old age.

Furthermore, the *DOT* codes were derived from 1970 US census data, which may not be directly applicable to a UK sample, although previous epidemiologic research has supported the use of these as valid measures of occupational complexity.^{4,32} A small proportion of the sample was not coded for occupational complexity, mostly because the occupations they reported were not classified in the *DOT*; their number was small and their exclusion from analysis would be unlikely to have affected the main findings.

In addition, occupational duration was not available. If occupational characteristics affect important life outcomes (such as cognitive ability or change), length of exposure might be an important factor. Because the current study did not have access to these data, it is an open question of whether there is a dose-response effect in the association between occupational complexity and cognition. Given the sample size, and therefore the statistical power of the current study, traditional statistical cutoffs would be likely to afford results of statistical significance even when effect sizes were very small. As previously acknowledged, the effect sizes are similar to those in prior literature examining other determinants of cognitive aging. The cohort also represents a healthier subset of the SMS1947; this “survivor” effect may have restricted the range of cognitive outcome scores. Finally, age 11 IQ explains approximately 50% of variance in cognitive performance in later life,³³ but probably does not fully capture peak adult cognition, because of cognitive development that takes place between age 11 and cognitive maturity.

The availability of early-life ability measures is a rare advantage of the study. It is a relatively large sample, and the narrow age of the participants is an advantage because it avoids the confounding effects of chronological age and cohort. Compared with other studies in the literature, the LBC1936 study has a broad battery of cognitive assessments. A further strength of the study is that it is ongoing. Planned follow-ups exploring the continuing effects of complexity of lifetime work throughout old age will be possible and may help further our understanding of the conditions that promote healthy cognitive aging. Future studies will have the opportunity to additionally include brain imaging measures, which may give insight into neurologic mechanisms linking occupational characteristic to later-life cognitive change.

In summary, the current study supports an association between more complex lifetime occupations and better cognitive abilities in later life. Of note, the evidence in favor of the differential preservation of cognitive abilities has been examined in the context of accounting for the likelihood of persevered differentiation, a major issue in the search for determinants of cognitive aging.

AUTHOR CONTRIBUTIONS

E.L. Smart: study concept and design, data acquisition, coding of occupational complexity ratings, analysis and interpretation, drafting and revising the manuscript. A.J. Gow: study concept and design, analysis and interpretation, and revising the manuscript. I.J. Deary: study concept, study management, discussion of analysis and interpretation, and revising the manuscript.

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DISCLOSURE

The authors report no disclosures relevant to the manuscript. Go to Neurology.org for full disclosures.

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This Week's *Neurology*[®] Podcast



Physician burnout: A neurologic crisis (see p. 2302)

This podcast begins and closes with Dr. Robert Gross, Editor-in-Chief, briefly discussing highlighted articles from the December 9, 2014, issue of *Neurology*. In the second segment, Dr. Ted Burns talks with Dr. Bruce Sigsbee about his paper on physician burnout. Dr. James Addington then reads the e-Pearl of the week about colloid cysts. In the next part of the podcast, Dr. Stacey Clardy focuses her interview with Dr. Joseph Dalmau on his career as a neurologist.

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