Domains of cognitive function in early old age: which ones are predicted by pre-retirement psychosocial work characteristics?

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What this paper adds:

- Certain psychosocial work environments may be associated with cognitive health after retirement
- Little research has focused on relationships between dimensions of the psychosocial work environment and post-retirement cognitive outcomes in specific domains
- Exposure to jobs with low psychological control was associated with prolonged deficits in executive function, psychomotor speed, phonemic fluency, and semantic fluency after retirement
- These relationships were partially, but not fully, explained by workers' pre-retirement socioeconomic status
- Findings suggest that lack of cognitive engagement at work may be associated with long-term cognitive impairment, in addition to the impact of classically stressful working conditions on cognitive outcomes.

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Abstract

Background: Psychosocial work characteristics may predict cognitive functioning after retirement. However, little research has explored specific cognitive domains associated with psychosocial work environments. Our study tested whether exposure to job demands, job control, and their combination during working life predicted post-retirement performance on eight cognitive tests.

Methods: We used data from French GAZEL cohort members who had undergone post-retirement cognitive testing (n=2,149). Psychosocial job characteristics were measured on average four years before retirement using Karasek's Job Content Questionnaire (job demands, job control, demand-control combinations). We tested associations between these exposures and post-retirement performance on tests of executive function, visual-motor speed, psycho-motor speed, verbal memory, and verbal fluency using OLS regression.

Results: Low job control during working life was negatively associated with executive function, psychomotor speed, phonemic fluency, and semantic fluency after retirement (p's<.05) even after adjustment for demographics, socioeconomic status, health and social behaviours, and vascular risk factors. Both passive (low-demand, low-control) and high-strain (high-demand, low-control) jobs were associated with lower scores on phonemic and semantic fluency when compared to low-strain (low-demand, high-control) jobs.

Conclusions: Low job control, in combination with both high and low job demands, is associated with post-retirement deficits in some, but not all, cognitive domains. In addition to work stress, associations between passive work and subsequent cognitive function may implicate lack of cognitive engagement at work as a risk factor for future cognitive difficulties.

Keywords: cognition, retirement, occupational stress

Introduction

Given lack of effective treatments for cognitive impairment at older ages, much research has explored modifiable determinants of later-life cognitive function. Psychosocial workplace conditions represent one such risk factor because of their ubiquity and their association with cardiovascular disease (CVD), which shares vascular risk factors with cognitive impairment.[1]

One prominent measure of these conditions is the Karasek demand-control model, in which combinations of psychological demands and control exert influences on health.[2] Although CVD is the most-studied outcome of job demands and control,[3] the construct is associated with several long-term health conditions, including depression, fatigue, and functional health.[4 5] The demand-control combination may also be a risk factor for long-term cognitive impairment. High-demand, low-control (known as high-strain) work has been associated with cognitive deficits in some, but not all, studies; overall, low control shows more consistent association with cognitive impairment than does high demands.[6] In addition to job strain, other psychosocial work conditions associated with later-life cognitive outcomes include occupational complexity (with people, data, and things) that rewards cognitive effort and decision-making,[7] work organizational factors such as working hours,[8] and environmental enrichment.[9]

Most studies of demand-control combinations and health have focused on high-strain jobs. But from a neuropsychological perspective, passive (low-demand, low-control) jobs may be risk factors for future cognitive impairment as well; the latter portion of the demand-control matrix is not well-studied in relation to cognitive function in later life. The plausibility of this association is suggested by the occupational complexity literature, which points to evidence that cognitive stimulation at work promotes intellectual flexibility and stability.[10] Cognitive reserve theories, which suggest that aspects of life experience such as education protect individuals from experiencing symptoms of early cognitive decline, also implicate lack of cognitive engagement in cognitive impairment.[11 12]

While much research has focused on predictors of clinical dementia or global cognitive function [13], few studies have tested associations between such exposures and more than one domain of cognition.

A more nuanced understanding of domains that are (and are not) associated with prior exposure to certain working conditions would help explain mechanisms linking occupational conditions and cognitive health in later life. Such findings would point to elements of work environments that could be enhanced or modified to preserve cognitive function. Although a few studies of the demand-control model have examined multiple domains of cognitive function,[14 15] association with key domains such as processing speed have not been tested.

The present study aims to test the separate and combined associations between job demands and job control with multiple domains of cognitive function after retirement. We hypothesized that exposure to high-demand, low-control (high-strain) jobs, indicating high work stress, as well as low-demand, low-control (passive) jobs, indicating lack of engagement at work, would be associated with worse performance in domains of verbal fluency, visual-motor speed, and executive function at older ages. These hypotheses are based on evidence to date of the long-term impact of both cognitive disengagement and stress on cognitive function in occupational and non-occupational settings and on prior studies of domains of cognitive function associated with psychosocial occupational conditions.[6 14 15]

Methods

Sample: The study was conducted in GAZEL, a cohort of 20,625 French workers now retired from the national gas and electricity company. The cohort was assembled in 1989 and has been followed since, drawing data from annual self-report questionnaires, company administrative records, and occasional in-person health examinations. Detailed information regarding this cohort is available elsewhere.[16]

We use data from GAZEL participants undergoing cognitive examinations in 2010. Of the 7,890 who lived in the testing centers' catchment areas and thus were eligible for this study, 3,828 initially responded to the invitation to participate but only 2,962 of those older than 55 years (the age cutoff for inclusion) were ultimately tested. We eliminated 43 people not yet retired at testing. Of the 2,919 who were eligible and were tested, 2,149 (74%) had exposure data and were included in analyses. Please see Supplemental Figure A for a flowchart of inclusion.

Outcome: Cognitive function. Our outcome of interest was multiple dimensions of post-retirement cognitive function. Neuropsychologists administered a battery of tests to participants. The Digit Symbol Substitution Test (DSST) subscale of the Wechsler Adult Intelligence Scale measures general cognitive function and the score was the number of items completed correctly.[17] The Mini-Mental State Exam (MMSE) measures general cognitive function and orientation and the score is the number of questions answered correctly.[18] The Free and Cued Selective Reminding Tests (FCSRT)-Immediate and –Delayed measure verbal memory and the score is the number of items on a list that were correctly recalled.[19]. Phonemic fluency was assessed as the number of words starting with "F" generated in one minute, and semantic fluency was assessed as the number of animal types generated in one minute.[20] Trailmaking Tests A and B (TMT-A/B assessed time in seconds to complete visual-motor speed and executive function tasks respectively).[21 22] All tests are scored so that higher scores indicate better cognitive function. During analysis, all tests are converted to standardized regression coefficients so that the magnitude of effects is comparable across tests.

Exposure: Psychosocial working conditions. Workplace psychosocial exposures were assessed using the modified French version of the Karasek Job Content Questionnaire (JCQ).[23] The JCQ measures perceptions of job control (assessing control over work time and tasks; 9 items; α=0.77) and job demands (assessing constraints imposed by expectations for fast, intense, or excessive work; 9 items; α=0.80). For each item, workers are asked whether they strongly agree, agree, disagree, or strongly disagree with a statement; an example of a statement is "My work requires me to be creative." Items are reverse-scored when applicable. Scores for items in each subscale are summed.

To quantify the psychosocial work environment, we first analysed each dimension (demands and control) continuously. Both were normally distributed in the sample. Second, we dichotomized those continuous scores at the sample median for each subscale, classifying each person as low or high on that dimension. We then categorized participants into four quadrants based on their demand and control categories: low-demand/low-control ("passive"), low-demand/high-control ("low strain"), high-demand/high-control ("active"), and high-demand/low-control ("high strain").[2] We opted to use quadrants of demand and control, rather than testing for interaction between continuous scores on these dimensions, based on evidence of specific health risk factors and outcomes associated with each of the four quadrants.[24] Low-strain work was chosen as the reference group based on evidence that this quadrant is expected to yield the most favorable health outcomes of the four quadrants.[24]

The JCQ was administered in 1997 and 1999 self-report questionnaires. Individuals reported on the job held at the time of the questionnaire. Because not all individuals respond to each questionnaire, we maximized the proportion of individuals with exposure information by either taking 1997 or 1999 Karasek scores completed prior to retirement or, if both 1997 and 1999 scores were available and completed prior to retirement, taking the average score. This follows the convention of other GAZEL studies.[4 25] We observed normal distribution of scores for demands (mean 23, standard deviation [SD] 4, range 9-36) and control (mean 72, SD 10, range 24-96).

Covariates

We adjusted for covariates associated with cognitive function and potentially related to working conditions. Occupational grade during the year of demand-control assessment was extracted from company records and classified across three standard categories: executive, manager/foreman, and low-wage worker [26]; retirement year, birth year, and gender were also extracted from this database. Education was collected at study baseline and dichotomized into less than secondary school versus secondary school completion and above.

We included several social, behavioural, and health factors collected by self-report in 2010: social factors (current marital status: married/cohabiting versus all other; years since retirement at testing); health factors (depressive and anxious symptoms, dichotomized into depressed/not depressed;[27] alcohol consumption, categorized as non-drinker, light drinker, moderate drinker, heavy drinker; smoking status, categorized as current smoker/current non-smoker); and self-reported vascular risk factors[28] (hypertension, high cholesterol, history of myocardial infarction, diabetes mellitus, and body mass index in kg/m^2; BMI). All vascular risk factors were dichotomous (yes/no) except BMI, which was categorized (normal weight/underweight, overweight, obese).

Statistical analyses

We used OLS regression to model predictors of each cognitive test score. First, we modelled associations between continuous demands and each cognitive outcome; second, we modelled associations between continuous control and each outcome; third, we modelled associations between quadrants of demands and control and each outcome. For each set of analyses, we adjusted for covariates sequentially: Model 1 is adjusted for age and gender. Model 2 is adjusted for Model 1 covariates plus education and occupational grade. Model 3 is adjusted for Model 2 covariates plus alcohol, smoking, marital status, depression, and vascular risk factors.

We then tested for statistical interaction between gender and job strain. For models in which the gender-job strain interaction was statistically significant at the 0.05 level, we stratified by gender.

All analyses were performed using SAS 9.4 (SAS Institute, Cary, NC).

Results

Approximately 32% of participants had passive jobs and 21% had high-strain jobs; 22% were low-strain and 25% were active. We first examined distribution of socioeconomic, demographic, and health factors (Table 1). Approximately half had less than a high school education, but as testing occurred close to retirement and nearly all people were promoted during their tenure, only about 7% had low-wage jobs at exposure assessment. About three-quarters were men and nearly half were either overweight or obese. At testing, the average age was 64.50 (SD 2.86) years and participants had been retired for 8.41 (SD 3.17) years. The mean age at retirement was 56.09 (SD 2.51); in the cohort, retirement age is statutory and is calculated based on physical difficulty of work across one's career.[29]

[Table 2]

All outcomes were collected and analysed as continuous variables. Except for FCSRT tests and MMSE, scores were normally distributed in the sample [Table 2]. Due to left skewness of the latter variables, we initially cubed them to normalize them for analysis. However, as associations in models using cubed outcomes were not substantively different from models using the untransformed variables and were difficult to interpret, we present untransformed results here for comparability with other tests.

[Table 2]

First, we tested associations between job demands and each outcome, adjusting successively for demographic, socioeconomic, and behavioural/vascular covariates [Table 3]. In age- and gender-adjusted models, we found that increasing job demands were significantly associated with better performance on Trailmaking Test B (B 0.002; SE 0.001; p=0.005) (Table 2). However, the association was attenuated to non-statistical significance after adjusting for SES (p=0.356). In contrast, increasing job demands were associated with worse DSST performance in fully adjusted models (B -0.122; SE 0.057; p=0.033).

Next, we tested associations between increasing job control and each cognitive outcome [Table 3]. In general, we found stronger associations between control and cognitive outcomes, compared with demands. Better performance on three of eight cognitive tests remained significantly associated with higher job control after adjustment for all covariates: Trailmaking Test B (B 0.001; SE 0.000; p=0.020), phonemic fluency (B 0.037; SE 0.013; p=0.006), and semantic fluency (B 0.033; SE 0.011; p=0.002). Both DSST and MMSE were significantly associated with higher job control in age- and gender-adjusted models, but associations were not robust to adjustment for SES markers. Associations between short-term and long-term recall (FCSRT-Immediate and -Delayed) and job control were not statistically significant. Of note, high job control is considered a positive occupational condition [24]; thus, the corollary of these findings is that lower job control is associated with worse performance. When we broke job control into its component parts (skill discretion and decision authority), both components had associations with similar cognitive outcomes (Supplemental Table 4), although associations between skill discretion and Trailmaking Tests A and B reached statistical significance (0.052 and 0.009 respectively, while associations between decision authority and Trailmaking Tests A and B did not (p=0.086 and 0.085 respectively).

[Table 3]

Last, we tested associations between demand-control combinations and the domains of cognitive function (Table 4), using low-strain participants as the reference group.

We found no statistically significant associations between active (high-demand, high-control) work and any cognitive outcome. In age- and gender-adjusted models, passive work was significantly associated with lower scores on five tests: TMT-A (B -0.045; SE 0.014; $p=0.001$), TMT-B (B -0.038; SE 0.009; $p=0.001$), DSST (B -2.115; SE 0.057; $p<0.0001$); phonemic fluency (B -1.029; SE 0.323; $p=0.002$), and semantic fluency (B -1.021; SE 0.254; $p<0.0001$). However, SES adjustment attenuated associations to non-significance for TMT-B, DSST and phonemic fluency. After adjusting for behavioural and vascular risk factors, only semantic fluency remained associated with passive work (B -0.072; SE 0.261; $p=0.006$).

High-strain (high-demand, low-control) work was associated with reduced functioning on similar tests as passive work in minimally adjusted models: TMT-A, DSST, phonemic fluency, and semantic fluency. However, high-strain work was somewhat more robust to adjustment for covariates than was passive work; it was significantly associated with lower scores on both phonemic fluency (B -0.897, SE 0.365; $p=0.016$) and semantic fluency (B -0.770; SE 0.285; $p=0.007$) in fully adjusted models. Again, we observed no significant associations between demand-control quadrants and either FCSRT test, transformed or untransformed.

[Table 4]

Given evidence of statistical interaction between gender and job demands and control for certain cognitive outcomes, we conducted gender-stratified analyses when such interactions were statistically significant (Supplementary Tables 1 and 2). We found that certain relationships were present among men, but not among women: among men, increased job control was associated with better scores on the DSST, and high-strain jobs were associated with worse DSST performance. Conversely, we found that certain relationships were present among women, but not among men: among women, increased control was associated with worse scores on the FCSRT-Immediate, passive work was associated with better scores on FCSRT-Immediate and Delayed, active jobs were associated with better performance on FCSRT-Immediate and Delayed, and high-strain jobs were associated with better FCSRT-Immediate and Delayed scores.

Discussion

We found that low job control during working life was negatively associated with performance in several cognitive domains after retirement: executive function, psychomotor speed, phonemic fluency, and semantic fluency; associations were robust to adjustment for SES, health and social behaviours, and vascular risk factors. Both passive and high-strain jobs were associated with lower scores on verbal fluency. However, associations between demand-control combinations and other domains of cognitive function were largely attenuated to non-statistical significance following adjustment for SES.

Many studies of the demand-control model and chronic disease outcomes have proposed stress response as the mechanism linking greater work-related stress with poorer health. Our findings extend on this research by pointing to the possibility that biological processes underpinning associations between job characteristics with cognitive function are unique because certain stressors—such as having high job demands—may be as mentally stimulating as they are stress response-provoking, particularly in combination with relatively high job control (i.e., active jobs), hence leading to positive or null findings in relation to cognitive and dementia outcomes.[30] However, other stressors—such as lack of autonomy—may be true risk factors for dementia.[31]

A few studies[14 15] have examined associations between the demand-control model and specific dimensions of cognitive function. Elovaino et al. (2009) found similar associations between verbal fluency and low control as were seen in the present study, whereas Agbenikey et al (2015) found decline in verbal learning and memory. Although we did not find association with the latter domains, our study measured incident cognitive function while theirs measured decline. But aside from those papers, most studies of job characteristics and cognitive function have either examined a single cognitive domain or have used clinical outcomes, such as Alzheimer's disease diagnosis. Our extensive battery of cognitive tests permits a nuanced analysis of neurobiological processes underpinning previously observed associations.

We found associations between lower job control and impaired performance in visual-motor speed (TMT-A), executive function (TMT-B), phonemic fluency (f-test), and semantic fluency (animal test). The findings that lower job control relates to speed and executive function may have relevance to subsequent risk of dementia in these participants as poor performance on these two domains has been linked to preclinical Alzheimer's disease.[32] Additionally, a recent consensus paper states that, at the group level, cognitive changes preceding Alzheimer's disease onset initially consist of subtle decreases in episodic memory.[33] The job control subscale asks questions like, "In my work, I learn new things," "My work requires me to be creative," "In my work, I have repetitive tasks," and "My work allows me to make decisions." Control thus reflects task complexity, on-going learning, and self-direction, which in non-occupational settings are protective against cognitive decline or dementia.[34] Those findings help explain our observed associations between job control and impairment in the relatively complex tasks presented by TMT-A (measuring visual-motor speed) and the verbal fluency tests, although the absolute magnitude of associations was small. The intellectual flexibility required for certain occupational tasks may promote continuation of such flexibility after retirement. Job control may also enhance executive function by promoting decision-making and reasoning,[6] an explanation supported by observed associations between lower job control and poorer TMT-B (executive function) performance.

Job demands were assessed by questions such as "My work requires me to work very fast," "My work necessitates periods of concentration," and "I am not asked to do an excessive amount of work." We found that higher job demands were associated with somewhat higher TMT-B scores but were associated with somewhat lower DSST scores. These mixed findings contrast to prior findings of high job demands and risk of cardiovascular disease and depression,[35 36] in which effects are more consistently negative. It is possible that certain mental demands at work may build cognitive reserve, forestalling development of cognitive difficulties at older ages.[37]

We explicitly examine outcomes associated with passive work, a quadrant receiving little recent attention in the epidemiologic literature, despite initial findings that it may damage health by inhibiting learning ability and contributing to learned helplessness.[24] Here, exposure to passive work was associated with lower verbal fluency, as was high-strain work. The environmental complexity hypothesis suggests that work and leisure environments that both challenge and engage participants predict better cognitive outcomes.[10 38] The latter characteristics are consistent with active (high-demand, high-control) jobs, the opposite of passive jobs. Although active jobs are fast-paced and demanding (thus exerting certain stressors), they encourage autonomous decision-making.[24] People with active jobs showed no associations with impaired cognitive function in any of our analyses despite being characterized by high job demands. In contrast, passive jobs lack both self-direction and complexity, potentially to the detriment of future brain function.[7 12]

We found that, for certain tests (the FCSRT-Immediate and Delayed and the DSST), associations were different for men and women, and in some cases the direction of association was reversed compared with the main effects. While the FCSRT tests were not significantly associated with job characteristics overall, associations did emerge when stratified by gender. Additionally, while passive work was associated with worse cognitive performance on certain tests in the overall cohort, it was associated with *better* performance among women on the FCSRT tests. This is potentially attributable to prior findings that the demand-control measures may perform differently in men and women, and that the measures may not adequately capture the psychosocial stressors to which women are exposed at work.[39]

A final notable finding was marked attenuation of associations between low-control work (whether combined with high or low demands) and most cognitive tests upon adjustment for SES, associations that had been statistically significant adjusted only for age and gender. Socioeconomic gradients in cognitive function are well-documented; education and occupation explain a substantial proportion of social disparities in older-age cognitive function.[40] This has been attributed both to direct effects (cognitive reserve, occupational complexity) and indirect effects of lifelong SES on cognitive function (early-life environments, CVD, behavioural risk factors).[41 42] The observed attenuated may have occurred because of co-variation of low job control with low SES markers. In addition, occupation-based SES may partially reflect physical and chemical occupational hazards also associated with cognitive function. However, the robustness of certain associations to adjustment for SES suggests that job conditions and SES do not fully explain observed relationships.

One limitation is that individuals are not randomly assigned to psychosocial work characteristics, but possibly self-select into certain jobs based on cognitive abilities, introducing selection bias. This is a limitation of all observational studies of associations between job characteristics and cognitive function. Our demand-control measure was taken relatively late in the career, and only at one time point, on average at age 52 and four years before retirement. Assessment of psychosocial work environment at multiple points during working career would be preferable. As our sample is relatively young and healthy, lack of association between our exposures and certain cognitive tests could also be explained by metrological properties of neuropsychological tests and also floor and ceiling effects. We also do not have baseline measures of cognitive function. Although controlling for education and occupational grade may alleviate this issue to some extent, we still cannot refute the possibility of reversed causality or cognitive selection into jobs as possible alternate explanations.

However, a strength is our use of a longitudinal cohort study with objectively-assessed cognitive outcome data and exposure data that was collected prospectively with respect to the outcome. Additionally, we included strong controls for social and vascular risk factors, a weakness of prior studies. Another strength is that education and occupation are less tightly intertwined in GAZEL than in other cohorts because many workers hired in their early twenties as less-educated blue-collar workers were promoted to executives by the end of their careers.[43] Thus, later-life psychosocial job characteristics are not mere proxies for educational attainment, itself a strong predictor of later-life cognitive function.

Conclusions

Although not conclusive, our study indicates that low-control jobs during working life may be associated with subtle impairments in cognitive function in early old age. As such jobs are primarily occupied by the less-educated—who are already at risk for poor cognitive function, potentially exacerbated by adverse occupational conditions[43]—interventions to improve psychosocial working conditions may reduce social disparities in cognitive function at older ages.

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Conflicts of interest: None to declare.

Contributorship statement: ES co-generated hypotheses, conducted statistical analyses, and drafted the manuscript. RA provided guidance on theoretical and statistical approaches and edited the manuscript. MG and MZ edited the manuscript. CB co-generated hypotheses and edited the manuscript.

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Table 1: Occupational, demographic, and health characteristics of the study sample (n=2149). Years refer to the year that the variable was collected; for reference, GAZEL baseline was in 1989, exposure data was collected 1997-1999, and cognitive outcomes were assessed in 2010.

	n/mean	**%/SD**
Educational attainment, 1989		
Less than HS	1140	53.05
HS or above	1009	46.95
Job category, 1997-1999		
Executive	982	45.7
Manager/professional	1003	46.67
Lower-wage	161	7.49
Gender, 1989		
Man	1642	76.41
Woman	507	23.59
Depressive/anxious symptoms, 2009		
Not depressed or anxious	1870	87.02
Depressed or anxious	279	12.98
Smoking status, 2010		
Nonsmoker	2006	93.35
Current smoker	143	6.65
Alcohol consumption, 2010		
Non-drinker	246	11.45
Light drinker	1195	55.61
Moderate drinker	527	24.52
Heavy drinker	181	8.42
BMI, 2010		
Normal/underweight	1030	47.93
Overweight	916	42.62
Obese	203	9.45
High cholesterol, 2010		
No	1596	74.27
Yes	553	25.73
Diabetes, 2010		
No	2047	95.25
Yes	102	4.75
History of MI, 2010		
No	2116	98.46
Yes	33	1.54
Marital status, 2010		
Not married/cohabiting	320	15.43
Married/cohabiting	1754	84.57
Mean age at testing	64.50	2.86
Mean years since retirement	8.41	3.17

Table 2: Distribution of demand-control scores and cognitive test scores in the sample

Cognitive Test	Mean	SD	Min	25%	Median	75%	Max
Job content questionnaire dimensions							
Demands	22.93	3.66	9	21	23	25	36
Control	72.28	9.68	24	66	72	78	96
Cognitive tests							
General cognitive status (**MMSE)**	28.36	1.37	21	28	29	29	**30**
Psychomotor speed (**DSST)**	48.73	9.67	0	42	48	55	88
Verbal memory (short-term recall) (**FCSRT Immediate)**	45.59	3.34	11	45	47	48	48
Verbal memory (delayed recall) (**FCSRT Delayed)**	15.53	0.99	2	15	16	16	16
Phonemic fluency	14.29	4.23	2	11	14	17	30
Semantic fluency	22.79	5.33	0	19	23	26	42
Visual-motor speed (**TMT-A)**	0.67	0.23	0.08	0.53	0.67	0.83	2.18
Executive function (**TMT-B)**	0.33	0.14	0.00	0.25	0.34	0.43	1.00

Table 3: Standardized associations (β, SE) between job demands, job control, and eight different continuous cognitive outcomes.

	Job demands (continuous)			Job control (continuous)		
	β	(SE)	P	β	(SE)	P
Mini-Mental State Exam						
M1: age, gender[a]	0.037	(0.021)	0.092	0.064	(0.022)	0.004
M2: M1+education, occupation[b]	0.001	(0.022)	0.958	0.001	(0.024)	0.965
M3: M2+social, vascular risks[c]	0.001	(0.023)	0.677	-0.004	(0.024)	0.854
Trailmaking Test A						
M1: age, gender[a]	0.019	(0.021)	0.387	0.095	(0.022)	<.0001
M2: M1+education, occupation[b]	-0.007	(0.022)	0.749	0.054	(0.024)	0.021
M3: M2+social, vascular risks[c]	-0.005	(0.023)	0.817	0.048	(0.024)	0.051
Trailmaking Test B						
M1: age, gender[a]	0.060	(0.021)	0.005	0.126	(0.022)	<.0001
M2: M1+education, occupation[b]	0.020	(0.022)	0.356	0.059	(0.024)	0.012
M3: M2+social, vascular risks[c]	0.027	(0.022)	0.225	0.055	(0.024)	0.023
FCSRT[d]-Immediate[†]						
M1: age, gender[a]	0.026	(0.022)	0.231	0.000	(0.022)	0.984
M2: M1+education, occupation[b]	0.010	(0.022)	0.660	-0.032	(0.024)	0.180
M3: M2+social, vascular risks[c]	0.008	(0.023)	0.696	-0.042	(0.024)	0.086
FCSRT[d]-Delayed						
M1: age, gender[a]	0.038	(0.022)	0.079	0.018	(0.022)	0.428
M2: M1+education, occupation[b]	0.024	(0.022)	0.287	-0.010	(0.024)	0.697
M3: M2+social, vascular risks[c]	0.027	(0.023)	0.239	-0.015	(0.025)	0.547
Digit Symbol Substitution Test[†]						
M1: age, gender[a]	-0.004	(0.021)	0.852	0.094	(0.022)	<.0001
M2: M1+education, occupation[b]	-0.051	(0.021)	0.016	0.021	(0.023)	0.343
M3: M2+social, vascular risks[c]	-0.046	(0.022)	0.034	0.02	(0.023)	0.479
Phonemic fluency						
M1: age, gender[a]	0.025	(0.022)	0.259	0.114	(0.022)	<.0001
M2: M1+education, occupation[b]	-0.011	(0.022)	0.617	0.060	(0.023)	0.011
M3: M2+social, vascular risks[c]	-0.009	(0.023)	0.676	0.068	(0.024)	0.006
Semantic fluency						
M1: age, gender[a]	0.016	(0.021)	0.458	0.131	(0.022)	<.0001
M2: M1+education, occupation[b]	-0.025	(0.022)	0.250	0.067	(0.023)	0.004
M3: M2+social, vascular risks[c]	-0.026	(0.022)	0.247	0.075	(0.022)	0.002

[a] Adjusted for age and gender

[b] Adjusted for age, gender, educational attainment, and occupational grade at testing

[c] Adjusted for age, gender, educational attainment, occupational grade at testing, depressive and anxious symptoms, smoking status, alcohol consumption, BMI, high cholesterol, diabetes, history of myocardial infarction, years since retirement at testing, and marital status

[d] Free and Cued Selective Reminding Test

[†] Significant statistical interaction between exposure and participant sex

Table 4: Standardized associations (β, SE) between job strain quadrants and eight different continuous cognitive outcomes.

	Low strain	Passive			Active			High strain		
		β	SE	P	β	SE	P	β	SE	P
Mini-Mental State Exam										
M1: age, gender[a]	(ref)	-0.05	(0.02)	0.075	0.01	(0.03)	0.615	-0.03	(0.03)	0.272
M2: M1+education, occupation[b]	(ref)	-0.01	(0.03)	0.853	-0.01	(0.03)	0.868	-0.01	(0.03)	0.697
M3: M2+social, vascular risks[c]	(ref)	-0.01	(0.03)	0.794	-0.01	(0.03)	0.848	-0.003	(0.03)	0.913
Trailmaking Test A										
M1: age, gender[a]	(ref)	-0.09	(0.03)	0.001	-0.02	(0.03)	0.554	-0.06	(0.03)	0.020
M2: M1+education, occupation[b]	(ref)	-0.06	(0.03)	0.042	-0.03	(0.03)	0.324	-0.05	(0.03)	0.071
M3: M2+social, vascular risks[c]	(ref)	-0.05	(0.03)	0.074	-0.02	(0.03)	0.397	-0.04	(0.03)	0.122
Trailmaking Test B										
M2: M1+age, gender	(ref)	-0.09	(0.02)	0.001	0.02	(0.03)	0.452	-0.01	(0.03)	0.636
M3: M2+educ, occ	(ref)	-0.04	(0.03)	0.126	0.00	(0.03)	0.998	0.01	(0.03)	0.739
M4: M3+social, vascular	(ref)	-0.04	(0.03)	0.153	0.001	(0.03)	0.942	0.02	(0.03)	0.470
FCSRT[d]-Immediate[†]										
M1: age, gender[a]	(ref)	-0.01	(0.03)	0.655	0.02	(0.03)	0.415	0.001	(0.02)	0.962
M2: M1+education, occupation[b]	(ref)	0.01	(0.03)	0.789	0.01	(0.03)	0.623	0.01	(0.02)	0.723
M3: M2+social, vascular risks[c]	(ref)	0.01	(0.03)	0.757	0.01	(0.03)	0.722	0.02	(0.03)	0.399
FCSRT[d]-Delayed[†]										
M1: age, gender[a]	(ref)	-0.03	(0.03)	0.327	-0.01	(0.03)	0.687	0.00	(0.03)	0.979
M2: M1+education, occupation[b]	(ref)	-0.01	(0.03)	0.793	-0.01	(0.03)	0.490	0.01	(0.03)	0.789
M3: M2+social, vascular risks[c]	(ref)	-0.01	(0.03)	0.649	-0.03	(0.03)	0.367	0.01	(0.03)	0.661

Digit Symbol Substitution Test[†]										
M1: age, gender[a]	(ref)	-0.10	(0.03)	0.0002	0.002	(0.03)	0.940	-0.07	(0.03)	0.007
M2: M1+education, occupation[b]	(ref)	-0.05	(0.03)	0.068	-0.02	(0.03)	0.395	-0.04	(0.03)	0.060
M3: M2+social, vascular risks[c]	(ref)	-0.05	(0.03)	0.070	-0.02	(0.03)	0.444	-0.04	(0.03)	0.104
Phonemic fluency										
M1: age, gender[a]	(ref)	-0.09	(0.03)	0.002	0.01	(0.03)	0.775	-0.09	(0.03)	0.002
M2: M1+education, occupation[b]	(ref)	-0.05	(0.03)	0.069	-0.01	(0.03)	0.671	-0.07	(0.03)	0.011
M3: M2+social, vascular risks[c]	(ref)	-0.06	(0.03)	0.058	-0.01	(0.03)	0.639	-0.07	(0.03)	0.016
Semantic fluency										
M1: age, gender[a]	(ref)	-0.11	(0.03)	<.0001	0.02	(0.03)	0.470	-0.09	(0.03)	0.001
M2: M1+education, occupation[b]	(ref)	-0.07	(0.03)	0.016	0.00	(0.03)	0.988	-0.07	(0.03)	0.011
M3: M2+social, vascular risks[c]	(ref)	-0.08	(0.03)	0.006	-0.01	(0.03)	0.634	-0.07	(0.03)	0.008

[a] Adjusted for age and gender

[b] Adjusted for age, gender, educational attainment, and occupational grade at testing

[c] Adjusted for age, gender, educational attainment, occupational grade at testing, depressive and anxious symptoms, smoking status, alcohol consumption, BMI, high cholesterol, diabetes, history of myocardial infarction, years since retirement at testing, and marital status

[d] Free and Cued Selective Reminding Test

[†] Significant statistical interaction between exposure and participant sex