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## Work stress and perceived memory: longitudinal insights from the job demand-control and effort-reward imbalance models

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### ABSTRACT

Two psychosocial work models, job demand-control (JDC) and effort-reward imbalance (ERI), have been studied in relation to health and cognition, but to a limited extent with subjective memory. This study aimed to evaluate longitudinal associations of JDC and ERI with changes in subjective memory among United States (U.S.) workers from the population-based Midlife in the United States (MIDUS) study. Among 1,538 U.S. workers, generalised estimating equations analyzed associations of independent and joint JDC and ERI categorizations at baseline (2004–2006) with changes in subjective memory composite scores from baseline to follow-up (2013–2014). Multivariable modelling accounted for demographic, socioeconomic, lifestyle, health, and psychosocial work factors. In the fully adjusted models, high job control (regression coefficient: 0.151 [95% CI 0.038, 0.264],  $p = 0.0088$ ), “high demand and high control” (0.164 [0.015, 0.312],  $p = 0.0313$ ), high reward (0.289 [0.174, 0.405],  $p < .0001$ ), “low effort and high reward” (0.288 [0.130, 0.446],  $p = 0.0004$ ), and “high effort and high reward” (0.288 [0.128, 0.448],  $p = 0.0004$ ) were associated with increased subjective memory. Work-related control and reward were positively associated with subjective memory changes across nine years among a U.S. worker cohort. Future research may support workplace environment improvements to promote cognitive health.

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## Introduction

Concerns about subjective memory, which is the self-perception of one’s memory ability (Cavanaugh et al., 1998), may be indicative of Alzheimer’s disease (Arvanitakis et al., 2019) and relevant to cognitive health. In contrast to objective memory, which is measured by performance on encoding, storage, and retrieval tests (Cullum et al., 2024), subjective memory focuses on an individual’s beliefs of memory performance (Cavanaugh et al., 1998), and has been associated with emotional regulation (Heffner et al., 2022) and self-efficacy (Gopi & Madan, 2024). In United States (U.S.) research, both subjective and objective memory measures were predictive of different Alzheimer’s disease biomarkers (John et al., 2020; Risacher et al., 2022). Specifically among older adults, subjective memory complaints may indicate cognitive vulnerability, as such complaints have been associated with faster cognitive decline, greater altered brain

structure (Dhana et al., 2022), and were predictive of memory performance decline (Lee & Foster, 2023). Notably, subjective memory issues may be experienced as early as midlife, based on 2015–2020 U.S. data in which an estimated ten percent of adults aged 45 years and older perceived overall cognitive decline (Taylor et al., 2018; Wooten et al., 2023), but over half (52.7%) did not report these concerns to a healthcare professional (Wooten et al., 2023).

A large number of modifiable risk factors during midlife have been identified in relation to dementia, but work-related factors have rarely been included (Livingston et al., 2020), despite the growing proportion of U.S. workers in midlife. By 2033, an estimated 61.84 million workers will be within the age range of 45–64, representing one-third of the U.S. workforce (U.S. Bureau of Labor Statistics, 2024). Workers may be exposed to various hazards with differing impacts on cognitive health (Byrne et al., 2020;

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Gavelin et al., 2022), and psychosocial characteristics involving organisational influences on individual experiences at work may exert beneficial or adverse effects on cognition (Nexø et al., 2016; Then et al., 2014).

Two psychosocial work-related models, Job Demand-Control (JDC; Karasek, 1979) and Effort-Reward Imbalance (ERI; Siegrist, 1996) are each composed of dual concepts to identify psychosocial work environments with relevance to health. JDC and ERI are two complementary theoretical models of a health-adverse psychosocial work environment that have received extended attention in international occupational health research. Job demand and job control comprise the JDC model (Karasek, 1979), while effort and reward constitute the ERI model (Siegrist, 1996). Both job demand and effort involve work stressors of workload, work conflict, and time pressure (Karasek, 1979; Siegrist, 1996). Job control, composed of subcategories of decision authority and skill discretion, include a worker's perceived decision-making freedom and ability to develop and use skills (Karasek, 1979). Reward entails work benefits such as social esteem, job promotion and job security, and financial pay (Siegrist, 1996). Both models propose the pairing of their respective concepts to comprehensively understand the psychosocial work environment. Whereas "demand" and "effort" are two highly correlated notions (differing by the fact that "effort" addresses the subjective interpretation of and reaction to extrinsic challenges, while "demand" focuses on objective characteristics of the challenge), the main theoretical difference between JDC and ERI concern "control" versus "reward". Both notions offer a direct link between elements of the working context and the psychobiologic responses of distinct brain circuits. "Control" emphasises an important sociological aspect of autonomous activity at work. It is linked to the stress-physiological concept of "threat to, or loss of control", which was shown to activate the hypothalamic-pituitary adrenocortical stress axis in the organism, with adverse long-term consequences for health (Henry & Stephens, 1977). In contrast, "reward" focuses on core material and non-material occupational resources obtained in response to efforts spent (money, job security, promotion prospects, appreciation). An imbalance between high effort spent and low reward obtained in turn is highly stressful as it violates a basic principle of social exchange, the reciprocity between "give" and "take". Specific circuits of the brain reward system respond to this threat, again activating the main bodily stress axes (Schultz, 2006).

The respective components of JDC and ERI may be combined to describe the psychosocial work environment. In the case of JDC, these are (1) high job demand and low job control, or "high strain"; (2) high job demand and high job control, or "active work"; (3) low job demand and low job control, or "passive work"; and (4) low job demand and high job control, or "low strain" (Karasek, 1979). Concerning ERI, relevant combinations are (1) "high effort and

low reward"; (2) "high effort and high reward"; (3) "low effort and low reward"; and (4) "low effort and high reward" (Siegrist, 1996). Either model theoretically assumes that distinct combinations of these variables exert stronger effects on health outcomes than single variables (Siegrist, 1996).

Longitudinal studies have explored both JDC and ERI psychosocial work models with objective cognitive function, but with differing results between the two models. For JDC in the U.S., high job demand and low job control (Dong et al., 2018), and the combinations of "high demand and high control" (active work) and "low demand and low control" (passive work; Agbenyikey et al., 2015), as well as "high demand and low control" (high strain), have been associated with decreased memory performance (Agbenyikey et al., 2015; Andel et al., 2015). In previous work focused on ERI and cognitive function changes in the Midlife in the United States (MIDUS) study, perceived work-related high reward and the combination of "high effort and high reward" at baseline were associated with increased episodic memory (Guardiano et al., 2024). Other Canadian and German longitudinal research with JDC and ERI findings did not specifically measure memory but have related high effort or demand and high reward with higher cognitive function (Duchaine et al., 2023; Riedel et al., 2017). Further investigation into the potential effects of each model on subjective memory is needed in the context of the growing U.S. worker population in midlife.

Limited research has specifically investigated the ERI and JDC models with the outcome of subjective memory among worker populations. A few JDC studies with cross-sectional and longitudinal findings from Europe (Rijs et al., 2015; Stenfors et al., 2013) and cross-sectional results from the U.S. (Grzywacz et al., 2016) suggest that high job control, represented by occupational complexity, was associated with better subjective memory (Grzywacz et al., 2016), while high job demand was associated with worse subjective memory (Rijs et al., 2015; Stenfors et al., 2013). However, none of these studies evaluated JDC concepts as joint combinations, as recommended by Karasek (1979). Furthermore, these studies were limited and inconsistent with measurements for subjective memory, and accounted for age, sex, and education but not factors such as race, marital status, physical activity, and social support covariates in analyses adjustments (Grzywacz et al., 2016; Rijs et al., 2015; Stenfors et al., 2013).

To the best of our knowledge, no publications have evaluated the relationship between ERI and subjective memory, and no previous studies have comprehensively accounted for the associations of JDC and ERI psychosocial work characteristics with subjective memory among a worker population. To fill in this gap, this study aims to explore the longitudinal associations of JDC and ERI psychosocial work characteristics at baseline with subjective memory changes between baseline and follow-up among a middle-aged U.S. worker population. We

hypothesise that among this U.S. sample, work with high demand or effort will be associated with worse subjective memory outcomes, while high control and high reward will be associated with better subjective memory outcomes.

## Materials and methods

### Study design, setting, and study population

MIDUS is a national, population-based, longitudinal study that was first conducted in 1995–1996 (MIDUS I), followed by two follow-up survey waves in 2004–2006 (MIDUS II; Ryff et al., 2021) and in 2013–2014 (MIDUS III; Radler, 2014; Ryff et al., 2019). MIDUS collected health, psychological, and social data (Marmot et al., 1998) among participants aged 24–74 selected through random digit dial sampling (Radler, 2014). For this study, MIDUS II in 2004–2006 was set as the baseline because of the availability of the psychosocial work variables of interest (Li et al., 2021), with MIDUS III in 2013–2014 as the follow-up about nine years later. All participants gave informed consent. This current study was determined exempt from review by the University of California, Los Angeles Institutional Review Board, IRB#24-001361, and was performed in accordance with the Declaration of Helsinki.

### Sample selection

Originally, 4,963 individuals participated in MIDUS II. Almost half of the MIDUS II participants ( $n = 2,313$ ; 46.60%) were working and working for pay. Among these workers, 2,190 had complete data on all ERI and JDC items. After assessing for complete data on covariates, there were 2,155 participants. Then, there were 2,134 worker participants that possessed complete data on subjective memory in MIDUS II, and among this group, 1,684 followed up in MIDUS III, demonstrating a follow-up rate of 78.91%. Supplementary analysis was conducted to compare the characteristics of participants that followed up with those lost to follow-up (Supplemental Table 1). The final analytic sample consisted of 1,538 workers with complete data on ERI, JDC, covariates, and subjective memory at baseline in MIDUS II, along with complete subjective memory data at follow-up in MIDUS III (Figure 1).

### Independent variables: psychosocial work characteristics

Psychosocial work variables for JDC and ERI were measured at MIDUS II baseline. The items for JDC were analogous to Karasek et al.'s (1998) Job Content Questionnaire, with five items for psychological job demand and nine items for job control (Matthews et al., 2023). ERI was operationalised using validated proxy measures, with five items for mental effort that were synonymous with the psychological job demand items, and seven

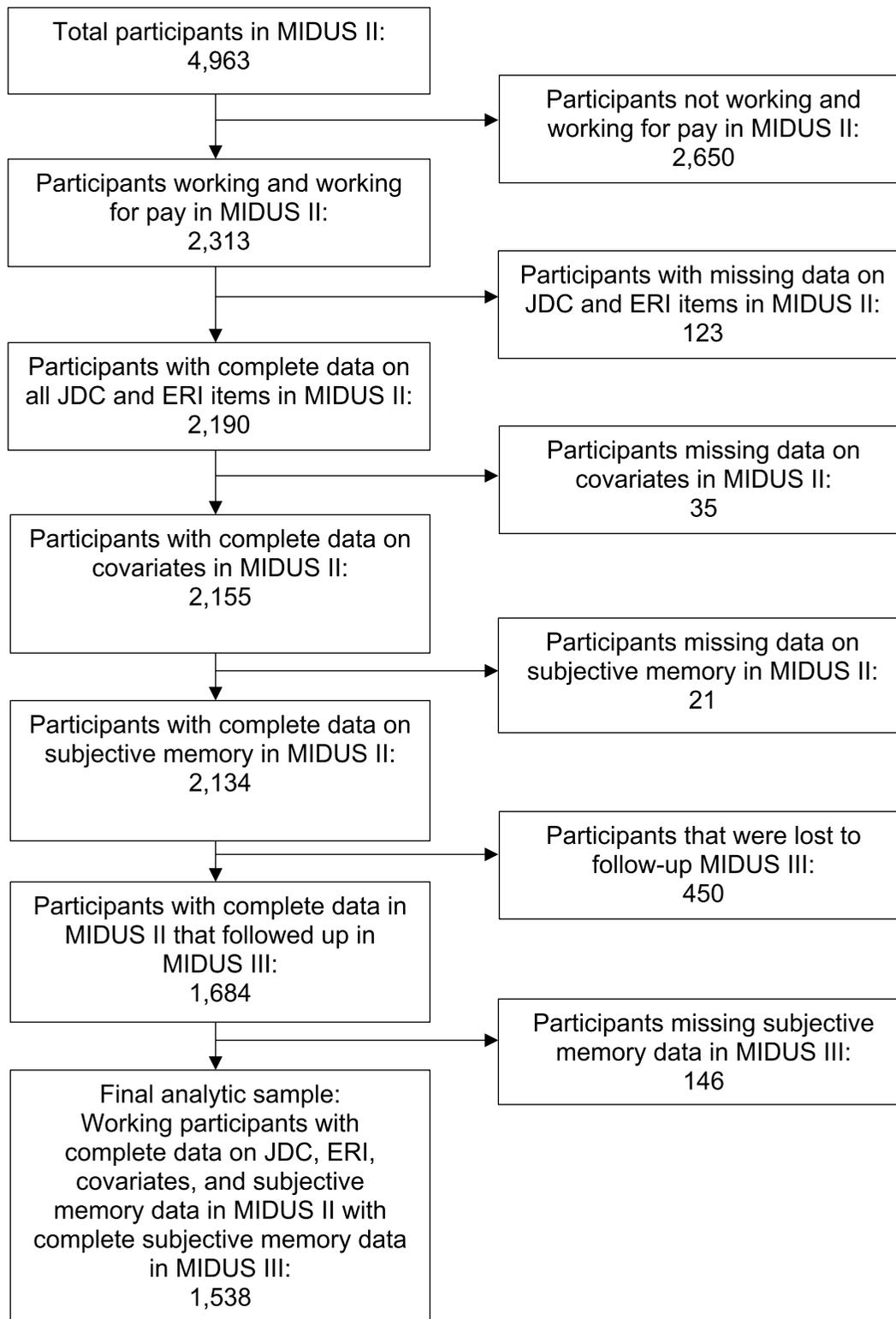
items for reward (Li et al., 2021; Matthews et al., 2022; Wege et al., 2024). The five items for psychological job demand / mental effort evaluated intensity, demands, time, and interruptions (Li et al., 2021; Matthews et al., 2023). Job control was composed of six items for decision authority and three items for skill discretion, which included decision input at work and learning new things (Matthews et al., 2023). The seven items for reward involved job promotion, esteem, and job security (Li et al., 2021). In this study, Cronbach's alphas were 0.76 for demand/effort and 0.76 for reward, which were in line with a previous validation study of ERI in MIDUS (Li et al., 2021), and 0.85 for job control.

To form "high" and "low" independent categories, the scores from the job demand/effort, job control, and reward scales were dichotomised according to the median, with "low demand/effort", "low control", and "low reward" as the reference groups. Subsequently, these "high" and "low" groups were combined to create joint groups: "low demand and low control" (reference group); "high demand and low control"; "low demand and high control"; and "high demand and high control" for JDC, and "low effort and low reward" (reference group); "high effort and low reward"; "low effort and high reward"; and "high effort and high reward" for ERI (Guardiano et al., 2024; Riedel et al., 2017).

### Dependent variables: subjective memory

The primary outcome of a composite subjective memory score was based on three items measured in MIDUS II and MIDUS III, calculated using a previous technique by Dewitte et al. (2021). The first item evaluated perceived memory compared to peers using the self-rating prompt, (1) "Compared to other people your age, how would you rate your memory?", with five response options ranging from "excellent" to "poor". The other two items, (2) "I don't remember things as well as I used to" and (3) "There's not much I can do to keep my memory from going downhill" were both seven-point prompts with responses ranging from "strongly agree" to "strongly disagree". These latter two items were derived from the Personality in Intellectual Aging Contexts Inventory, and represent aspects of an individual's personality – morale and locus of control (Lachman et al., 1982). To create the composite subjective memory score, the first item on self-rated memory compared to others was reverse-scored and rescaled from a five-point scale to a seven-point scale using linear transformation and then was averaged with the scores of the other two scales. Therefore, higher composite subjective memory scores represented better subjective memory. The Cronbach's alpha in this study was 0.61 in MIDUS II and 0.64 in MIDUS III, which are comparable to the Cronbach's alphas of 0.60–0.62 in the Dewitte et al. (2021) study.

An alternate subjective memory score, utilised by Lee (2014) for MIDUS II data, was evaluated in supplementary



**Figure 1.** Sample flowchart.

analysis, which obtained the mean of two items: the first item of subjective memory in comparison to peers used in the above technique, as well as an additional item of subjective memory in comparison to five years (“How would you rate yourself today compared to five years ago – memory?”). Both items were on a five-point scale

ranging from “excellent” to “poor”, which were then reverse-scored in this study so that a higher mean score indicated better subjective memory. The study by Lee (2014) had a Cronbach’s alpha of 0.63 among a MIDUS II sample, while in this study, the Cronbach’s alpha was 0.61 in MIDUS II and 0.62 in MIDUS III.

## Covariates

Covariates included mean age, sex (male; female), and demographic, socioeconomic, lifestyle-related, health, and psychosocial work factors, which were selected for their relevance in cognitive health (Gupta, 2021; Harada et al., 2013; Hedges et al., 2019; Jennings et al., 2022; Kelly et al., 2017; Levine et al., 2021; Livingston et al., 2020; Marden et al., 2017). Marital status was categorised as (1) “married”; (2) “never married”; and (3) “other”, which included those that were separated, divorced, and widowed. Racial groups were formed as (1) “White”; (2) “Black”, composed of individuals that were Black and/or African American; and (3) “Other”, which included Native American or Alaska Native Aleutian Islander or Eskimo, Asian, Native Hawaiian or Pacific Islander, and other. Education consisted of three categories: (1) “high school or less”; (2) “some college”, which included participants that attended some years of college without a degree, completed two-year college or vocational school, or obtained an associate’s degree; and (3) “university or more”, which encompassed graduates of four-year or five-year college or graduate school, and recipients of bachelor’s, master’s, doctoral, or professional degrees. Annual household income in U.S. dollars (USD) was divided into three brackets: (1) less than 60,000; (2) 60,000–99,999; and (3) equal to or greater than 100,000. For factors related to lifestyle, smoking use was determined with a binary yes/no response to current regular cigarette smoking, and alcohol consumption was categorised as (1) “none or light” and (2) “moderate or heavy”, which were calculated based on prompts of alcoholic beverage consumption frequency and a formula using an estimated 0.08 g% blood alcohol concentration (Corbin et al., 2014). Leisure-time physical activity (LTPA) groups were “high” for moderate or vigorous exercise of at least once a week, and otherwise “low”. Social support was evaluated as the perceived support of family (four-item), friends (four-item), and spouse or partner (six-item; University of Wisconsin - Madison Institute on Aging, 2010; Walen & Lachman, 2000). The social support score was the mean of at least two of the three scales, a technique that was previously conducted in other MIDUS study publications, with higher scores indicating higher social support (Creaven et al., 2020; Elliot et al., 2018). Health conditions were determined with binary yes/no responses to any history of myocardial infarction or stroke for cardiovascular disease, and depressed affect and anhedonia for symptoms of major depression. Job control and reward, as previously mentioned for psychosocial work independent variables, were included as covariates in quartile form.

## Analysis

Characteristics of the sample at MIDUS II baseline were assessed using frequencies for categorical variables and means and standard deviations (SDs) for continuous

variables. Longitudinal analyses of psychosocial work and changes in subjective memory were performed with generalised estimating equations (GEE; Liang & Zeger, 1986), which account for the repeated measures of subjective memory within participants (Ziegler & Vens, 2014). Prior to the GEE analyses, correlation analysis was conducted between the subjective memory outcomes in MIDUS II and MIDUS III to check the within-persons correlation using the correlation coefficient and *p*-value. GEE produced multivariable linear regression models with adjustments for variables at baseline. First, for each respective psychosocial work model, demand and control were mutually adjusted for each other at baseline, and likewise for effort and reward (Model 0). Then, for covariate adjustments at baseline, Model I additionally adjusted for age; Model II additionally adjusted for sex, marital status, and race; Model III additionally adjusted for educational attainment and annual household income; Model IV additionally adjusted for smoking, alcohol consumption, LTPA, and social support; and Model V additionally adjusted for cardiovascular disease and depression. Lastly, Model VI additionally adjusted for the appropriate psychosocial work variable: reward for the analyses of JDC and subjective memory, and job control for the analyses of ERI and subjective memory. This technique of mutual adjustment demonstrates the respective independent relationships of JDC and ERI with the health outcome (Wang et al., 2022). GEE generated output of regression coefficients, 95% confidence intervals (95% CIs), and *p*-values, with positive coefficients indicating increased subjective memory and negative coefficients representing decreased subjective memory.

Supplementary analyses utilised Chi-square tests for categorical variables and *t*-tests for continuous variables in the comparison of participants that followed up in MIDUS III and those that did not. GEE multivariable linear regression models were developed for the analyses of the psychosocial work characteristics with the alternate subjective memory measure. SAS Analytics Software version 9.4 (SAS Institute, Cary, NC, USA) was the statistical programme used for analyses.

## Results

Table 1 displays an overview of the sample’s characteristics at MIDUS II baseline for this study. The sample was predominantly middle aged with mean age of 51.18 (*SD* = 9.12) years. About half (51.50%) were female participants, almost three-quarters (74.19%) were married, and the majority (93.24%) was White. For educational attainment, 48.05% completed at least university level, followed by 27.83% with some college, and 24.12% with high school or less. The sample was approximately divided by thirds for the income categories, with 36.28% earning less than 60,000 USD, 32.38% with 60,000–99,999 USD, and 31.34% with equal to or greater than 100,000 USD. For characteristics related to lifestyle, most participants (87.06%) did not

**Table 1.** Sample characteristics at MIDUS II,  $n = 1,538$ .

	<i>n</i>	%
Sex		
Female	792	51.50
Male	746	48.50
Marital Status		
Married	1141	74.19
Never Married	134	8.71
Other	263	17.10
Race		
White	1434	93.24
Black	43	2.80
Other	61	3.97
Education		
High School or Less	371	24.12
Some College	428	27.83
University or More	739	48.05
Income (USD)		
<60,000	558	36.28
60,000-99,999	498	32.38
≥100,000	482	31.34
Smoking		
Yes	199	12.94
No	1339	87.06
Alcohol		
None or Light	914	59.43
Moderate or Heavy	624	40.57
Physical Activity		
Low	735	47.79
High	803	52.21
Cardiovascular Disease		
No	1512	98.31
Yes	26	1.69
Depression		
No	1412	91.81
Yes	126	8.19
	Mean	Standard Deviation
Age	51.18	9.12
Social Support	3.47	0.43

United States Dollar (USD).

currently smoke, over half (59.43%) abstained from or consumed light amounts of alcohol, 52.21% were highly physically active, and the sample's mean social support was 3.47 ( $SD = 0.43$ , range: 1.5-4). A large majority of the sample was free from cardiovascular disease (98.31%) or major depression (91.81%). For psychosocial work characteristics, as shown in Table 2, 54.03% were categorised as high job demand/effort, 55.46% as low job control, and 53.84% as low reward. For JDC joint combination groups, 28.22% classified as "high demand and low control", and for ERI joint combination groups, 30.43% were "high effort and low reward". In Table 3, the composite subjective memory score had a mean of 4.80 ( $SD = 1.25$ ) in MIDUS II and 4.64 ( $SD = 1.2$ ) in MIDUS III, and both measures were highly correlated ( $r = 0.56$ ,  $p < .0001$ ).

**Table 2.** Psychosocial work characteristics at MIDUS II.

	Mean	SD
Job Demand / Effort	12.90	3.02
Job Control	24.53	5.38
Reward	24.37	3.33
Independent Demand and Control	<i>n</i>	%
Job Demand		
High	831	54.03
Low	707	45.97
Job Control		
High	685	44.54
Low	853	55.46
Joint Demand and Control		
High Demand + High Control (active)	397	25.81
Low Demand + High Control (low strain)	288	18.73
High Demand + Low Control (high strain)	434	28.22
Low Demand + Low Control (passive)	419	27.24
Independent Effort and Reward		
Effort		
High	831	54.03
Low	707	45.97
Reward		
High	710	46.16
Low	828	53.84
Joint Effort and Reward		
High Effort + High Reward	363	23.60
Low Effort + High Reward	347	22.56
High Effort + Low Reward	468	30.43
Low Effort + Low Reward	360	23.41

Results for the associations of independent and joint JDC groups with changes in composite subjective memory are displayed in Table 4. Compared to low job control, high job control was associated with increased subjective memory after all covariate adjustments (Model VI: regression coefficient: 0.151 [95% CI 0.038, 0.264],  $p = 0.0088$ ). For JDC combinations, compared to "low demand and low control" only "high demand and high control" was associated with increased subjective memory in the fully adjusted model (Model VI: 0.164 [0.015, 0.312],  $p = 0.0313$ ). The combination of "high demand and low control" was initially significantly associated with decreased subjective memory when adjusted for demographic, socioeconomic, lifestyle, and health covariates up through Model V ( $-0.155 [-0.298, -0.011]$ ,  $p = 0.0349$ ), but the relationship was no longer significant after the adjustment for reward (Model VI:  $-0.122 [-0.264, 0.020]$ ,  $p = 0.0930$ ).

Table 5 shows the associations of independent and joint ERI groups with changes in composite subjective memory scores. After all covariate adjustments and compared to low reward, high reward was associated with

**Table 3.** Composite subjective memory scores at MIDUS II and III.

	Mean	Standard Deviation	Minimum	Maximum	MIDUS II v. MIDUS III Composite Subjective Memory Scores: Correlation Coefficient and <i>P</i> -Value
MIDUS II Composite Subjective Memory Score	4.80	1.25	1.00	7.00	0.56 <.0001
MIDUS III Composite Subjective Memory Score	4.64	1.22	1.00	7.00	

**Table 4.** Independent and joint associations of demand and control at baseline with changes in composite subjective memory between baseline and follow-up ( $\beta$  and 95% CI).

Demand- Control Groups		Composite Subjective Memory													
		Model 0		Model I		Model II		Model III		Model IV		Model V		Model VI	
		Coeff. (95% CIs)	<i>p</i> value	Coeff. (95% CIs)	<i>p</i> value	Coeff. (95% CIs)	<i>p</i> value	Coeff. (95% CIs)	<i>p</i> value	Coeff. (95% CIs)	<i>p</i> value	Coeff. (95% CIs)	<i>p</i> value	Coeff. (95% CIs)	<i>p</i> value
Demand	Low	0.000		0.000		0.000		0.000		0.000		0.000		0.000	
	High	-0.036(-0.144, 0.072)	0.5130	-0.034(-0.142, 0.075)	0.5443	-0.037(-0.146, 0.071)	0.4992	-0.051 (0.159, 0.057)	0.3509	-0.031(-0.139, 0.076)	0.5688	-0.020(-0.128, 0.088)	0.7158	0.008(-0.099, 0.115)	0.8805
Control	Low	0.000		0.000		0.000		0.000		0.000		0.000		0.000	
	High	0.325 (0.216, 0.433)	<.0001	0.324 (0.216, 0.433)	<.0001	0.327 (0.218, 0.436)	<.0001	0.291 (0.181, 0.401)	<.0001	0.250 (0.140, 0.360)	<.0001	0.254 (0.144, 0.364)	<.0001	0.151 (0.038, 0.264)	0.0088
Low demand + low control (passive)		0.000		0.000		0.000		0.000		0.000		0.000		0.000	
High demand + low control (high strain)		-0.169(-0.314, -0.025)	0.0218	-0.167(-0.311, -0.022)	0.0239	-0.177(-0.321, -0.032)	0.0164	-0.200(-0.343, -0.057)	0.0062	-0.167 (-0.311, -0.024)	0.0219	-0.155 (-0.298, -0.011)	0.0349	-0.122 (-0.264, 0.020)	0.0930
Low demand + high control (low strain)		0.158(-0.001, 0.317)	0.0516	0.156(-0.003, 0.316)	0.0543	0.152(-0.008, 0.312)	0.0618	0.104(-0.056, 0.264)	0.2012	0.080(-0.078, 0.238)	0.3188	0.087(-0.071, 0.245)	0.2822	-0.010 (-0.169, 0.148)	0.8986
High demand + high control (active)		0.292 (0.148, 0.436)	<.0001	0.296 (0.152, 0.441)	<.0001	0.295 (0.151, 0.440)	<.0001	0.244 (0.097, 0.391)	0.0011	0.224 (0.076, 0.372)	0.0031	0.238 (0.090, 0.386)	0.0017	0.164 (0.015, 0.312)	0.0313

Generalised estimating equations (GEE) linear regression with  $\beta$  coefficients (coeff.) and 95% confidence intervals (CIs).

Model 0: mutual adjustment for demand and control at baseline.

Model I: Model 0 + additional adjustment for age (years) at baseline.

Model II: Model I + additional adjustment for sex, marital status, and race at baseline.

Model III: Model II + additional adjustment for educational attainment and annual household income at baseline.

Model IV: Model III + additional adjustment for smoking, alcohol consumption, physical exercise, and social support at baseline.

Model V: Model IV + additional adjustment for cardiovascular disease and depression at baseline.

Model VI: Model V + additional adjustment for reward at baseline.

**Table 5.** Independent and joint associations of effort and reward at baseline with changes in composite subjective memory between baseline and follow-up ( $\beta$  and 95% CI).

Effort-Reward Groups		Composite Subjective Memory													
		Model 0		Model I		Model II		Model III		Model IV		Model V		Model VI	
		Coeff. (95% CIs)	<i>p</i> value	Coeff. (95% CIs)	<i>p</i> value	Coeff. (95% CIs)	<i>p</i> value	Coeff. (95% CIs)	<i>p</i> value	Coeff. (95% CIs)	<i>p</i> value	Coeff. (95% CIs)	<i>p</i> value	Coeff. (95% CIs)	<i>p</i> value
Effort	Low	0.000		0.000		0.000		0.000		0.000		0.000		0.000	
	High	0.011(−0.096, 0.117)	0.8442	0.005(−0.101, 0.112)	0.9238	0.001(−0.106, 0.108)	0.9891	−0.013(−0.120, 0.094)	0.8117	−0.001(−0.108, 0.106)	0.9854	0.008(−0.099, 0.115)	0.8824	−0.002(−0.109, 0.105)	0.9751
Reward	Low	0.000		0.000		0.000		0.000		0.000		0.000		0.000	
	High	0.443 (0.336, 0.549)	<.0001	0.447 (0.339, 0.554)	<.0001	0.448 (0.340, 0.555)	<.0001	0.408 (0.298, 0.518)	<.0001	0.352 (0.241, 0.465)	<.0001	0.343 (0.231, 0.455)	<.0001	0.289 (0.174, 0.405)	<.0001
Low effort + low reward		0.000		0.000		0.000		0.000		0.000		0.000		0.000	
High effort + low reward		0.004(−0.142, 0.150)	0.9574	0.0001 (−0.146, 0.146)	0.9992	−0.009(−0.154, 0.137)	0.9085	−0.028 (−0.173, 0.117)	0.7046	−0.012 (−0.157, 0.132)	0.8670	0.004(−0.142, 0.149)	0.9600	−0.003 (−0.148, 0.142)	0.9676
Low effort + high reward		0.435 (0.282, 0.588)	<.0001	0.441 (0.286, 0.595)	<.0001	0.437 (0.283, 0.592)	<.0001	0.390 (0.235, 0.546)	<.0001	0.339 (0.184, 0.494)	<.0001	0.338 (0.182, 0.493)	<.0001	0.288 (0.130, 0.446)	0.0004
High effort + high reward		0.453 (0.302, 0.605)	<.0001	0.452 (0.301, 0.603)	<.0001	0.449 (0.298, 0.600)	<.0001	0.395 (0.240, 0.550)	<.0001	0.351 (0.195, 0.507)	<.0001	0.351 (0.195, 0.507)	<.0001	0.288 (0.128, 0.448)	0.0004

Generalised estimating equations (GEE) linear regression with  $\beta$  coefficients (coeff.) and 95% confidence intervals (CIs).

Model 0: mutual adjustment for effort and reward at baseline.

Model I: Model 0 + additional adjustment for age (years) at baseline.

Model II: Model I + additional adjustment for sex, marital status, and race at baseline.

Model III: Model II + additional adjustment for educational attainment and annual household income at baseline.

Model IV: Model III + additional adjustment for smoking, alcohol consumption, physical exercise, and social support at baseline.

Model V: Model IV + additional adjustment for cardiovascular disease and depression at baseline.

Model VI: Model V + additional adjustment for job control at baseline.

increased composite subjective memory (Model VI: 0.289 [0.174, 0.405],  $p < .0001$ ). For the joint combinations, compared to “low effort and low reward”, the two combinations of “low effort and high reward” (Model VI: 0.288 [0.130, 0.446],  $p = 0.0004$ ) and “high effort and high reward” (Model VI: 0.288 [0.128, 0.448],  $p = 0.0004$ ) were each associated with increased composite subjective memory.

Supplementary analyses using the two-variable mean for subjective memory are displayed in Supplemental Tables 2-4. The mean subjective memory score in MIDUS II was 3.12 ( $SD = 0.65$ ) and 3.10 ( $SD = 0.65$ ) in MIDUS III, and both measures were correlated ( $r = 0.51$ ,  $p < .0001$ ; Supplemental Table 2). Supplemental Tables 3 and 4 contain multivariable model results of changes in mean subjective memory with JDC and ERI, respectively. For findings from the fully adjusted models, high job control was associated with increased mean subjective memory (Model VI: 0.067 [0.009, 0.124],  $p = 0.0232$ ). The combination of “high demand and low control” was associated with decreased mean subjective memory (Model VI:  $-0.100$  [ $-0.174$ ,  $-0.027$ ],  $p = 0.0074$ ). The combination of “high demand and high control” was significantly associated with increased mean subjective memory (Model V: 0.085 [0.009, 0.162],  $p = 0.0280$ ), until the adjustment for reward (Model VI: 0.050 [ $-0.027$ , 0.127],  $p = 0.2022$ ). High reward was associated with positive increase in mean subjective memory (Model VI: 0.152 [0.094, 0.211],  $p < .0001$ ). Both “low effort and high reward” (Model VI: 0.143 [0.062, 0.223],  $p = 0.0005$ ) and “high effort and high reward” (0.129 [0.049, 0.210],  $p = 0.0017$ ) were associated with increased mean subjective memory.

## Discussion

Among a U.S. population-based sample of midlife workers followed over almost a decade, psychosocial work characteristics of high job control, “high demand and high control”, high reward, “low effort and high reward”, and “high effort and high reward” were associated with positive changes in a composite subjective memory measure over about nine years after adjusting for demographic, socioeconomic, lifestyle-related, health, and psychosocial work factors. High reward, as an independent category and as both its joint combinations, consistently maintained these associations throughout all model adjustments. Likewise, independent high control and only its joint combination of “high demand and high control” were associated with increased subjective memory in the fully adjusted models. Study findings suggest that high levels of control and reward in the workplace strengthen positive perceptions of cognitive health, contributing to previous evidence on high control and better subjective memory (Grzywacz et al., 2016; Stenfors et al., 2013), and high reward and improved cognition (Duchaine et al., 2023; Guardiano et al., 2024; Riedel et al., 2017).

In neuroscience research of generalised control and reward, control has been positively related with objective episodic memory (Maggio et al., 2019), while reward and memory may be connected through a value-motivated relationship (Knowlton & Castel, 2022). In a sample of U.S. older adults, the interaction between locus of control and hippocampal volume suggests that control beliefs are positively associated with objective episodic memory performance, particularly among participants with lower hippocampal volume (Zahodne et al., 2018). High levels of control may promote adaptation processes in response to cognitive change (Lee, 2016), which may also illustrate how the combination of “high demand and high control”, or active work, relates to improved subjective memory. Working with high demands may compel individuals to adapt and make changes in life (Dixon et al., 2019), and in conjunction with a sense of mastery from control beliefs (Lee, 2016), may foster autonomy and predispose individuals towards more positive perceptions of memory as they adapt to the aging process. Additionally, memory ability, sensitised and motivated by reward, has engaged midbrain reward regions, ventral striatum, hippocampus, and parahippocampal cortex (Frank et al., 2019). Motivation towards reward is a mechanism that contributes to memory formation processes (Weinstein, 2023), which may underlie the consistent relationships of high reward with both increased subjective memory in this study and objective memory in previous research (Guardiano et al., 2024). The current findings present links of control and reward with perceived memory in the context of the workplace, prompting further investigation on the psychosocial effects of the work environment on cognitive health.

Additionally, the two complementary conditions of stressful psychosocial work environments, lack of control and lack of reward in demanding situations, activate bodily stress axis via limbic circuits. Reward frustration, in particular, evokes emotional pain in the insula (Singer et al., 2004), documenting the sensitivity of the brain’s reward circuitry to the experience of broken promise (Baumgartner et al., 2009). Chronic stress responses, elicited by the conditions mentioned, are likely to reduce attention and awareness due to the predominance of unfavourable events, thus reducing the salience of memory. Moreover, they negatively impair the retrieval of explicit memories and cognitive processes involved in complex reasoning (Calvo & Gutiérrez-García, 2016). Additional transdisciplinary research is needed to unravel underlying processes.

Furthermore, the mutual adjustment of JDC and ERI provided some insight into the independent effects of these psychosocial work models on subjective memory. Adjusting for reward in Model VI attenuated the relationships of high job control and “high demand and high control” with increased subjective memory, but these associations remained significant. However, “high demand and low control” was no longer significantly

associated with decreased subjective memory after adjusting for reward. For ERI, the associations of high reward, “low effort and high reward”, and “high effort and high reward” with increased subjective memory persisted after the adjustment for job control. Results identify reward as a possible confounder in the relationship between high strain work and subjective memory. In contrast, adjusting for job control did not nullify the associations of ERI with subjective memory. This study suggests ERI as the more robust psychosocial work model compared to JDC in explaining changes in perceived memory among this U.S. worker sample. Other research on psychosocial work and health has demonstrated ERI as more predictive of other health outcomes after mutual adjustment with JDC (Wang et al., 2022).

This study’s findings on high control and improved subjective memory align with other MIDUS research exploring general and work-related control with subjective memory. A longitudinal study on components of overall control beliefs and subjective memory complaints in MIDUS I and II determined that high mastery was associated better subjective memory while high constraints predicted worse subjective memory (Lee, 2016). The cross-sectional study on MIDUS II data that examined cross-sectional associations of JDC with subjective memory differed in methods, with the operationalizations of job demand and substitution of occupational complexity for job control using a job exposure matrix, and the use of a single item on subjective memory in comparison to peers (Grzywacz et al., 2016). Despite these approach differences, the previous study’s positive association of higher occupational complexity with perceived memory (Grzywacz et al., 2016) was further developed in this current study’s longitudinal findings of self-reported high job control and increased subjective memory from a three-item composite variable.

The lack of significant results for independent high demand in this study reflects the inconsistency of job demand findings in previous studies. In North American research, one U.S. study related high demand with poor objective memory performance (Dong et al., 2018), but one Canadian study connected high demand with higher overall objective cognition (Duchaine et al., 2023). Most recently, a study in Taiwan indicated that high levels of physical job demands were protective against dementia risk, but psychological demand had a null association (Yang et al., 2025). Future research may clarify possible divergent effects of psychological and physical demand on cognitive outcomes.

Based on currently available literature, no study has explored the ERI model with subjective memory. Overall, this study’s findings support the existing research on ERI and objective cognitive function. Previously, independent high reward was associated with increased cognitive function in other cognitive domains among European workers (Riedel et al., 2017), and with positive changes in cognition and episodic memory among U.S. workers (Guardiano et al., 2024). Among the two studies that evaluated joint

ERI categorizations, both “high effort and high reward” and “low effort and high reward” have been positively associated with cognitive function, although only “high effort and high reward” was specifically related to the outcome of increased objective episodic memory (Guardiano et al., 2024; Riedel et al., 2017). Reward and effort combinations may have differing effects depending on cognitive domains, but high reward appears to exert positive effects on both objective and subjective cognitive measures.

Supplementary analyses evaluated selection bias by comparing participants who followed up in MIDUS III with those lost to follow-up (Supplemental Table 1), and explored longitudinal associations of JDC and ERI with an alternative subjective memory measure encompassing an individual’s perceived memory compared to others and compared to self from the previous five years (Supplemental Tables 3 and 4; Lee, 2014). Participants lost to follow-up were more likely to not be currently married, attain less than a university degree, earn lower income, smoke, have cardiovascular disease, and perceive lower social support, reward, and job control. Previous research has highlighted that factors such as socioeconomic status potentially influence the relationship between psychosocial work and cognitive health (Elovainio et al., 2009). Future studies may further evaluate study populations with the characteristics of those lost to follow-up, and their experiences of psychosocial work and memory.

Supplementary analyses on the alternative mean subjective memory measure (Supplemental Tables 3 and 4) demonstrated ERI results that were consistent with the primary analyses on the composite subjective memory measure: high reward, “low effort and high reward”, and “high effort and high reward” were all associated with increased mean subjective memory. For JDC, findings on high control and increased mean subjective memory reflected the primary analyses, but for joint combinations, “high demand and low control” was associated with decreased mean subjective memory, differing from the positive association of “high demand and high control” with composite subjective memory in the primary analyses. Notably, the composite subjective memory formulated by Dewitte et al. (2021) used items representing morale and locus of control (Lachman et al., 1982), and thus may also reflect workers’ personalities or coping abilities. In contrast, the two-item approach by Lee (2014) were derived from the external comparison to others, and the internal comparison to self in past time. Across cognition literature, measurements for subjective cognitive decline have been varied and inconsistent, involving reports of decline and current cognition, and comparisons between decline and current cognition (Wion et al., 2022). The composite subjective memory measure (Dewitte et al., 2021) additionally integrated perceived memory in the context of the individual’s locus of control (Lachman et al., 1982). The differences in subjective memory results may indicate differences in the compositions of the

subjective memory outcomes, warranting continued investigation of subjective memory dimensions.

Limitations of this study must be considered in the interpretations of these findings. While statistical testing and multivariable modelling provided results for causal inference, the psychosocial work characteristics may not necessarily be causatively related to the subjective memory outcomes. The stability of the subjective memory mean scores in MIDUS II and III may indicate possible ceiling effects or resilience factors among this study's sample, the latter which may be further explored in future research. Although subjective memory measures may be relevant in understanding cognitive health, these measures do not represent nor replace the comprehensive clinical neuropsychological examination. Due to the availability of data and the MIDUS survey wave structure, this study was restricted to the two survey waves and cannot represent changes in psychosocial work or subjective memory between the survey waves. Results may not be generalisable to other worker populations or subgroups.

For strengths of this study, the GEE analyses accounted for the repeated subjective memory measures and provided population-level estimates (Pekár et al., 2018) for U.S. workers. As self-reported cognitive decline has been related to later preclinical Alzheimer's disease, the use of subjective memory measurements demonstrate higher feasibility, lower participant burden, and lower expenses compared to objective cognitive testing (Ávila-Villanueva et al., 2018). As the first exploration of subjective memory involving the ERI model, this study provides insight into occupational factors during midlife that may influence cognitive health.

## Conclusion

In this study of a U.S. population-based sample of midlife workers followed over almost a decade, psychosocial work characteristics of high job control, "high demand and high control", high reward, "low effort and high reward", and "high effort and high reward" were associated with positive changes in a composite subjective memory measure. Findings were adjusted for potential confounders and were replicated by an alternative measurement of subjective memory. If supported by further evidence, these results might promote the utilisation of subjective memory assessment to screen for additional cognitive evaluation and instruct organisational measures to prevent mental decline and promote health in an aging workforce.

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No potential conflict of interest was reported by the author(s).

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## Data availability statement

The data that support the findings of this study are openly available from the Inter-university Consortium for Political and Social Research (<https://www.icpsr.umich.edu/web/NACDA/series/203>). Program code and scripts for statistical packages are available from the corresponding author upon request.

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