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ORIGINAL ARTICLE

Longitudinal associations of effort and reward at work with changes in cognitive function: evidence from a national study of U.S. workers

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Abstract

Purpose This study aimed to examine longitudinal associations of workplace effort and reward with changes in cognitive function among United States workers.

Methods Data from the national, population-based Midlife in the United States (MIDUS) study with a 9-year follow-up were used. Validated workplace effort and reward scales were measured at baseline, and cognitive outcomes (including composite cognition, episodic memory, and executive functioning) were measured with the Brief Test of Adult Cognition by Telephone (BTACT) at baseline and follow-up. Multivariable linear regression analyses based on generalized estimating equations (GEE) examined the longitudinal associations under study.

Results Among this worker sample of 1,399, after accounting for demographics, socioeconomics, lifestyle behaviors, health conditions, and job control, high reward at baseline was associated with increased composite cognition (regression coefficient: 0.118 [95% CI: 0.049, 0.187]), episodic memory (0.106 [0.024, 0.188]), and executive functioning (0.123 [0.055, 0.191]) during follow-up. The joint exposure of 'high effort and high reward' was also associated with increased composite cognition (0.130 [0.030, 0.231]), episodic memory (0.131 [0.012, 0.250]), and executive functioning (0.117 [0.017, 0.216]), while the combination of 'low effort and high reward' was associated with increased composite cognition (0.106 [0.009, 0.204]) and executive functioning (0.139 [0.042, 0.235]).

Conclusion Findings suggest that workplace high reward is related to improved cognitive scores among United States workers. Future research should investigate larger cohorts over longer timespans and expand into disease outcomes such as dementia. If these findings emerge as causal, relevant workplace rewards to promote worker cognitive health should be considered.

Keywords Cognition · Effort-reward imbalance · Episodic memory · Executive functioning · Psychosocial work factors · Work stress

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Introduction

Changes in cognition are expected to occur among older adults (Harada et al. 2013), with decreased cognitive function and cognitive impairment being associated with increased risks of decreased quality of life, hospitalization, disability, dementia, and mortality (Chen et al. 2022). In the aging United States (U.S.) population, the group aged 65 years and older experienced its greatest growth between 2010 and 2020. Despite U.S. labor projections estimating that the workforce will grow slower due to population aging, the group of older workers aged 55 years and above is expected to increase in proportion by 2031 (Dubina et al. 2022). Thus, occupational health practice and research must consider the cognitive health of this growing group of aging workers, in line with frameworks for productive aging at work and *Total Worker Health* (Schulte et al. 2018).

Cognition, which is composed of interdependent domains of varying complexities, includes episodic memory, which involves the recall of lived experiences, as well as the domain of executive functioning, which encompasses problem-solving abilities and control of multiple cognitive subdomains (Harvey 2019). Deficits in episodic memory and executive functioning manifest in dementia and may be predictive of Alzheimer's disease (AD) (Harvey 2019). In the U.S., the estimated prevalence of AD in adults aged 65 and above is 10.8%; 6.7 million (Alzheimer's Association 2023). In 2023, healthcare costs related to dementia and AD were estimated at $345 billion, projected to grow to nearly one trillion dollars by 2050 (Alzheimer's Association 2023). Although identified midlife risk factors for dementia include health conditions such as cardiovascular disease, depression, and lifestyle behaviors (Livingston et al. 2020), the role of work remains unclear and warrants further investigation.

It has been reported that stress among older adults has been both negatively and positively associated with different domains of cognitive function (Mikneviciute et al. 2022). Although work stress has been associated with physical and mental health conditions (Niedhammer et al. 2021), research examining cognition suggests that the psychosocial work environment may be cognitively stimulating (Nexø et al. 2016). Two specific, well-established models, the job demand-control (JDC) model by Karasek (1979) and effort-reward imbalance (ERI) model by Siegrist (1996), have been studied with cognitive function in worker populations. The JDC model consists of two major components, job demand (primarily psychological workload) and job control (i.e., decision-making authority) (Karasek 1979). Multiple studies, for instance, in Europe and North America, suggest that high job control and active work, i.e., the combination of high demand and high control, were associated with higher cognitive function and may be protective factors against cognitive decline (Andel et al. 2011; Duchaine et al. 2021; Pan et al. 2019; Zhuo et al. 2021), while high strain work (i.e., the combination of high demand and low control) was associated with decreased cognitive function (Dong et al. 2018). The ERI model is comprised of effort, juxtaposed with reward (including pay, job promotion, esteem, and job security) on the basis of a reciprocal exchange (Siegrist 1996). Up to now, research on the relationship between ERI and cognitive function has been far less studied, with mixed and inconclusive findings. One longitudinal study with a six-year follow-up period in Germany suggested that high effort and high reward were associated with slower cognitive decline (Riedel et al. 2017). In a cross-sectional investigation in France, low reward (among men) and high effort (among women) were associated with reduced verbal memory, but not with other components of cognitive function (Siegrist et al. 2019). One large four-year prospective cohort study in Europe combining data from 12 countries observed a non-significant increase of incident dementia risk due to high reward (Tan et al. 2023). Finally, one recent longitudinal study in Canada revealed that both high effort and high reward at baseline were associated with better cognitive performance 17 years later (Duchaine et al. 2023). To the best of our knowledge, evidence about ERI and cognition from the U.S. has not been reported yet.

The growing relevance of cognitive function among workers and the previously described research gaps in the field of occupational health prompt this present study. Therefore, we aimed to examine the longitudinal associations of the psychosocial work environment based on the ERI model at baseline with subsequent changes in cognitive function scores across nine years among workers in the U.S., after adjustment for demographic, socioeconomic, lifestyle, health, and other psychosocial work characteristics.

Methods

Study Design, setting, and Study Population

We used data from the Midlife in the United States (MIDUS) study, a national longitudinal study of health and well-being among U.S. adults. The MIDUS study was initiated in 1995–1996 (MIDUS I), and followed up in 2004–2006 (MIDUS II) and 2013–2014 (MIDUS III) (Radler 2014). In addition to the MIDUS II and MIDUS III main survey waves, participants were eligible for other projects, including the Cognitive Projects (Radler 2014). The MIDUS II and MIDUS III Cognitive Projects measured cognitive functioning (Ryff and Lachman 2023a, b). Our study focused on the data from MIDUS II (Ryff et al. 2021) as the baseline, due to the availability of validated psychosocial work (Li et al. 2021) and cognitive data (Ryff and Lachman 2023a). Cognitive data from MIDUS III (Ryff and Lachman 2023b) was used as follow-up.

The University of California Los Angeles Institutional Review Board (IRB#22-001975) reviewed this analytic research project and approved for exemption. This study followed the Declaration of Helsinki guidelines and the Strengthening the Reporting of Observational Studies in Epidemiology (STROBE) reporting guideline.

Sample inclusion criteria were working participants with complete data on ERI and covariates in MIDUS II, as well as cognitive measures in MIDUS II and III. Out of the original 4,963 participants in MIDUS II, 46.60% ($n = 2{,}313$) were identified as working and working for pay. Among these workers, 102 were missing data on ERI and 31 were missing data on covariates, resulting in 2,180 participants with complete ERI and covariate data. In relation to cognitive outcomes, 1,507 workers participated in both MIDUS Cognitive Projects II and III, and 108 did not have complete data on cognitive function. The final study sample included 1,399 participants (Fig. 1).

Measures

Effort and reward

The exposure of psychosocial work factors at baseline in MIDUS II was operationalized using five items for mental effort and seven items for work-related reward, with Cronbach's alpha 0.76 for both scales "effort" and "reward." Previous studies have demonstrated the reliability and validity of these two proxy measures for ERI in the MIDUS study (Li et al. 2021; Matthews et al. 2022b; Wege et al. 2024). The effort and reward scores were each dichotomized according to their medians to create low level ("low effort" and "low reward" reference groups) and high level ("high effort" and "high reward") groups. In line with the model's hypothesis, where joint effects of the components exert additional independent effects on health outcomes (Siegrist 1996), four independent categories with dichotomized scores were computed: "low effort and low reward" (reference group); "high effort and low reward"; "low effort and high reward"; and "high effort and high reward" (Riedel et al. 2017).

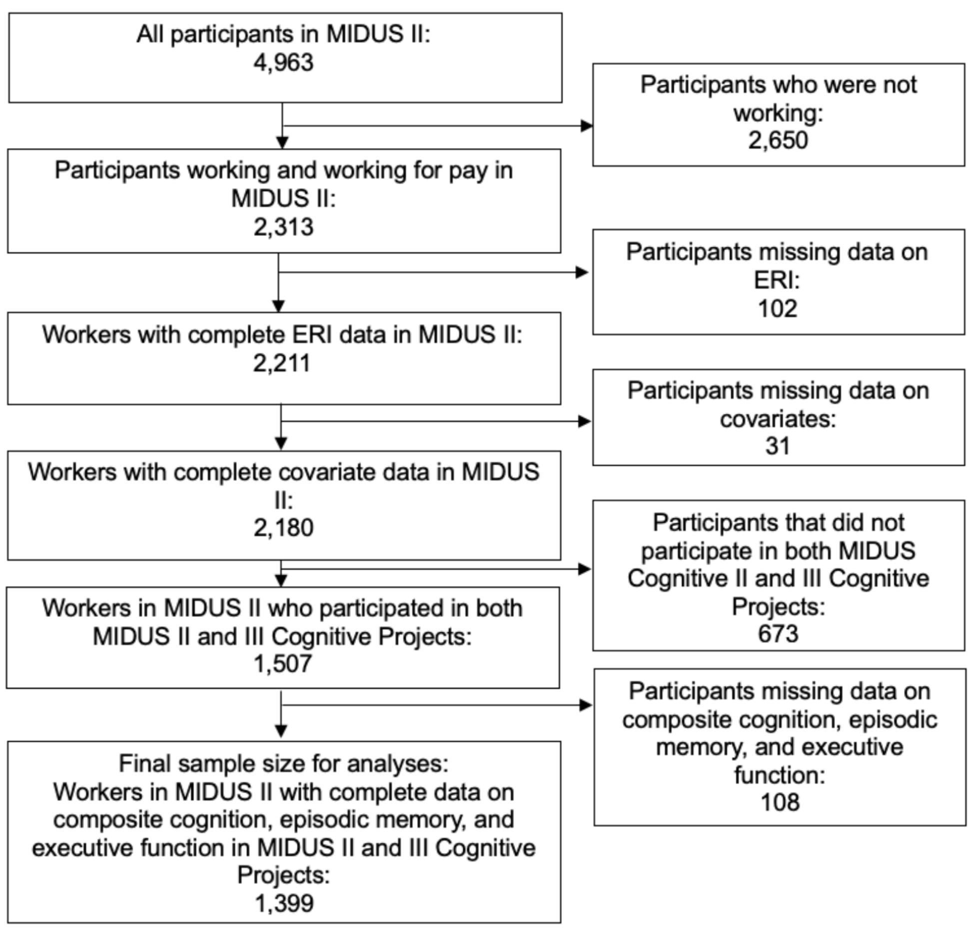

Fig. 1 Sample size selection

Cognitive measures

The MIDUS II and III Cognitive Projects used the Brief Test of Adult Cognition by Telephone (BTACT) (Lachman et al. 2014). The BTACT was conducted in this order of seven subtests for their corresponding cognitive domains: (1) immediate word list recall for episodic verbal memory, (2) backward digit span for working memory, (3) category fluency for executive functioning and verbal ability and speed, (4) Stop and Go Switch Task (SGST) for reaction time, attention, task switching, and inhibitory control, (5) number series for fluid intelligence or reasoning, (6) backward counting for processing speed, and (7) delayed word list recall for episodic verbal memory or forgetting (Lachman et al. 2014). Additional details regarding BTACT administration and subtest components are described elsewhere (Lachman et al. 2014). Notably, most tests were scored by total correct items, corresponding to better cognitive function, but SGST scores were based on reaction times, and thus lower SGST scores indicate higher cognitive performance (Lachman 2019; Lachman et al. 2014; Ryff et al. 2009). The BTACT demonstrated convergent and discriminant validity (Lachman et al. 2014).

The cognitive composite score was created from z-score standardization of six of the aforementioned subtests, except the SGST, which was used for the executive functioning factor score (Lachman 2019; Ryff et al. 2009). Z-score standardization has been employed for cognitive test batteries to address the heterogeneity of multiple cognitive tests (Andrade 2021). In MIDUS II, the composite cognition variable was based on the total sample, and for each participant, a z-score was calculated from each of the six subtests (Ryff et al. 2009). These six z-scores were then averaged into a composite score that was standardized to a z-score (Ryff et al. 2009). In MIDUS III, the composite cognition z-score calculations were standardized to the MIDUS II mean and standard deviation, allowing for longitudinal analysis (Lachman 2019). Higher composite cognition values correspond with higher global cognitive function, which has been applied in previous MIDUS studies exploring cognitive decline (D'Amico et al. 2023; Otaiku 2022).

The episodic memory and executive functioning scores resulted from factor analyses and the z-score standardization process applied to all seven BTACT subtests (Lachman 2019; Lachman et al. 2014; Ryff et al. 2009). Episodic memory was developed from the immediate and delayed recall tests, and executive functioning was calculated from backward digit span, category fluency, number series, backward counting, and the reverse score of the SGST (Lachman 2019; Lachman et al. 2014; Ryff et al. 2009). Higher scores reflected higher levels of cognitive function (DiBlasio et al. 2021; Lachman et al. 2014).

Covariates

Selected covariates of age, sex, race, marital status, educational attainment, annual household income, current smoking, alcohol consumption, physical exercise, cardiovascular disease, and depression have been previously related with cognitive function, cognitive impairment, or dementia (Livingston et al. 2020).

Age was used as a continuous variable in the analysis. The remaining covariates were categorical: sex (male, female), race/ethnicity (White, Black, Others), marital status (married, never married, other), educational attainment (high school or less, some college, university degree or more), annual income (USD < 60,000; 60,000 to 99,999; ≥100,000), current smoking (yes, no) alcohol consumption (no or light; moderate or heavy), physical exercise (low, high), and self-reported physician-diagnosed cardiovascular disease including myocardial infarction and stroke, as well as major depression. Additionally, to account for other psychosocial work factors, job control was measured with a standard nine-item scale in the MIDUS study (Matthews et al. 2022a) and included in this analysis due to its association with better cognitive performance in several studies (Andel et al. 2011; Pan et al. 2019; Zhuo et al. 2021).

Statistical analyses

Descriptive statistics summarized the sample characteristics at baseline in MIDUS II, using means and standard deviations for continuous variables, and frequencies for categorical variables. Longitudinal analyses used generalized estimating equations (GEE) linear regression (Liang and Zeger 1986), due to the high correlation between the repeated MIDUS II and MIDUS III cognitive function measurements within participants. The independent and joint effects of effort and reward on three outcomes – composite cognition, episodic memory, and executive function – were examined using regression models. The reported regression coefficients and their 95% confidence intervals (CIs) quantified the effects on changes in cognitive function between baseline in MIDUS II and follow-up in MIDUS III. After the unadjusted crude model, several multivariable models were developed to adjust for covariates at baseline accordingly: Model I adjusted for age in years; Model II additionally adjusted for sex, marital status, and race/ethnicity; Model III additionally adjusted for educational attainment and annual household income; Model IV additionally adjusted for smoking, alcohol consumption, and physical exercise; Model V additionally adjusted for cardiovascular disease and depression; and Model VI additionally adjusted for job control. To reduce potential misinterpretation from a single model with multiple adjustments (Westreich and Greenland

Table 1 Study characteristics at MIDUS II ($n = 1{,}399$)

Variables	N (%)
Age (years, mean ± standard deviation)	51.02 ± 9.14
Sex	
Men	672 (48.03)
Women	727 (51.97)
Race	
White	1314 (93.92)
Black	35 (2.50)
Other	50 (3.57)
Marital Status	
Married	1052 (75.20)
Never Married	128 (9.15)
Other	219 (15.65)
Educational Attainment	
High School or Less	318 (22.73)
Some College	389 (27.81)
University Degree or More	692 (49.46)
Annual Household Income (US dollars)	
< 60, 000	495 (35.38)
60,000–99,999	458 (32.74)
≥ 100,000	446 (31.88)
Current Smoking	
No	1220 (87.21)
Yes	179 (12.79)
Alcohol Consumption	
No or Light	832 (59.47)
Moderate or Heavy	567 (40.53)
Physical Exercise	
Low	646 (46.18)
High	753 (53.82)
Cardiovascular Disease	
No	1374 (98.21)
Yes	25 (1.79)
Depression	
No	1285 (91.85)
Yes	114 (8.15)
Effort Group	
High	755 (53.97)
Low	644 (46.03)
Reward Group	
High	654 (46.75)
Low	745 (53.25)
Effort-Reward Imbalance Groups	
High effort + high reward	334 (23.87)
Low effort + high reward	320 (22.87)
High effort + low reward	421 (30.09)
Low effort + low reward	324 (23.16)

2013), step-by-step adjustments served to systematically control for confounding variables and to quantify the associations of effort and reward with cognitive outcomes. We also conducted crude and fully adjusted sensitivity analyses with each of the seven BTACT cognitive tests and independent and joint effort and reward. The statistical program SAS 9.4 was used to perform all analyses (SAS Institute, Cary, NC, USA).

Results

Table 1 displays the characteristics of the sample at baseline in MIDUS II, as well as mean cognitive scores in MIDUS II and III. For sociodemographic variables, the sample's mean age was 51.02 ($SD = 9.14$), and most participants were women (51.97%), White (93.92%), married (75.20%), and held a university degree or more (49.46%). The sample was approximately divided into thirds among the annual household income brackets, but 35.38% earned less than $60,000. For lifestyle characteristics, most were current nonsmokers (87.21%), abstained from or had light alcohol consumption (59.47%), and had high frequency of physical exercise (53.82%). For health conditions, the majority did not have cardiovascular disease (98.21%) or depression (91.85%). The mean score for job control was 33.46 ($SD = 5.70$, with range 12–45). With the median splits, the two levels of effort and reward were roughly equally divided; and the proportion of the four combinations of effort and reward slightly varied from 22.9 to 30.1%.

In Table 2, for cognitive scores at baseline in MIDUS II and follow-up in MIDUS III, composite cognition means were 0.37 ($SD = 0.91$) and 0.20 ($SD = 0.63$), episodic memory means were 0.25 ($SD = 0.92$) and 0.19 ($SD = 0.94$), and executive functioning means were 0.40 ($SD = 0.87$) and 0.09 (SD = 0.64), respectively. Scores for each of the seven cognitive tests at baseline and follow-up are presented in Supplementary Table 1, indicating decline of cognitive function over the nine years. These cognitive outcomes between baseline and follow-up were highly correlated ($r = 0.755$, $p < 0.0001$ for composite cognition; $r = 0.495$, $p < 0.0001$ for episodic memory; and $r = 0.761$, $p < 0.0001$ for executive functioning).

Table 3 shows how independent effort and reward groups at MIDUS II baseline were associated with composite cognition, episodic memory, and executive functioning between baseline in MIDUS II and follow-up in MIDUS III. Although both high effort and high reward were associated with increased composite cognition, episodic memory, and

Table 2 Cognitive function in MIDUS II and MIDUS III

	MIDUS II Z-Score Mean (SD) and Range		MIDUS III Z-Score Mean (SD) and Range	
Composite Cognition	0.37 (0.91)	-2.30 to 3.64	0.20 (0.63)	-1.88 to 2.03
Episodic Memory	0.25 (0.92)	-1.76 to 3.63	0.19 (0.94)	-1.88 to 3.83
Executive Functioning	0.40 (0.87)	-2.82 to 3.39	0.09 (0.64)	-2.01 to 2.02

Table 3 Independent associations of effort and reward at baseline with changes in cognitive function between baseline and follow-up (β and 95% CI)

		Crude Model		Model I		Model II		Model III		Model IV		Model V		Model VI	
		Coeff. (95% CIs)	*p* value	Coeff. (95% CIs)	*p* value	Coeff. (95% CIs)	*p* value	Coeff. (95% CIs)	*p* value	Coeff. (95% CIs)	*p* value	Coeff. (95% CIs)	*p* value	Coeff. (95% CIs)	*p* value
Cognition Composite															
Effort	Low	0.000		0.000		0.000		0.000		0.000		0.000		0.000	
	High	0.145 (0.070, 0.220)	0.0002	0.077 (0.005, 0.148)	0.0351	0.084 (0.013, 0.154)	0.0200	0.012 (-0.056, 0.079)	0.7367	0.005 (-0.063, 0.072)	0.8945	0.009 (-0.058, 0.076)	0.7997	0.012 (-0.055, 0.079)	0.7261
Reward	Low	0.000		0.000		0.000		0.000		0.000		0.000		0.000	
	High	0.174 (0.099, 0.248)	< 0.0001	0.234 (0.164, 0.305)	< 0.0001	0.221 (0.150, 0.291)	< 0.0001	0.117 (0.050, 0.184)	0.0007	0.112 (0.045, 0.179)	0.0010	0.107 (0.040, 0.174)	0.0016	0.118 (0.049, 0.187)	0.0008
Episodic Memory															
Effort	Low	0.000		0.000		0.000		0.000		0.000		0.000		0.000	
	High	0.099 (0.014, 0.183)	0.0217	0.040 (-0.042, 0.123)	0.3372	0.059 (-0.019, 0.137)	0.1367	0.020 (-0.058, 0.097)	0.6169	0.015 (-0.063, 0.092)	0.7102	0.022 (-0.056, 0.100)	0.5737	0.025 (-0.054, 0.103)	0.5372
Reward	Low	0.000		0.00		0.00		0.000		0.000		0.000		0.000	
	High	0.112 (0.028, 0.196)	0.0087	0.164 (0.083, 0.246)	< 0.0001	0.171 (0.093, 0.249)	< 0.0001	0.109 (0.030, 0.188)	0.0070	0.106 (0.028, 0.185)	0.0081	0.098 (0.020, 0.176)	0.0136	0.106 (0.024, 0.188)	0.0111
Executive Functioning															
Effort	Low	0.000		0.000		0.000		0.000		0.000		0.000		0.000	
	High	0.125 (0.051, 0.198)	0.0009	0.058 (-0.013, 0.128)	0.1075	0.060 (-0.009, 0.129)	0.0883	-0.005 (-0.072, 0.062)	0.8872	-0.010 (-0.077, 0.056)	0.7583	-0.009 (-0.075, 0.058)	0.7986	-0.006 (-0.072, 0.060)	0.8599
Reward	Low	0.000		0.000		0.000		0.000		0.000		0.000		0.000	
	High	0.172 (0.098, 0.245)	< 0.0001	0.231 (0.162, 0.301)	< 0.0001	0.213 (0.144, 0.281)	< 0.0001	0.122 (0.056, 0.188)	0.0003	0.118 (0.052, 0.184)	0.0005	0.115 (0.049, 0.181)	0.0006	0.123 (0.055, 0.191)	0.0004

β coefficients (coeff.) and 95% confidence intervals (CIs)

Generalized estimating equations (GEE) linear regression

Model I: adjustment for age (years) at baseline

Model II: Model I + additional adjustment for sex, marital status, and race/ethnicity 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, and physical exercise 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 executive functioning scores in the unadjusted crude model, only high reward remained associated with increased scores in the three cognitive function scores across all models. In the fully adjusted Model VI, high reward was associated with higher scores in composite cognition (regression coefficient: 0.118 [95% CI: 0.049, 0.187]; $p = 0.0008$), episodic memory (0.106 [0.024, 0.188]; $p = 0.0111$), and executive functioning (0.123 [0.055, 0.191]; $p = 0.0004$).

Table 4 presents the joint effort and reward combinations at MIDUS II baseline and their associations with cognitive function changes from MIDUS II to MIDUS III. In the crude model, all effort-reward combinations were associated with increased composite cognition and executive functioning, but only "high effort and high reward" was associated with increased episodic memory. In the fully adjusted Model VI, this category of "high effort and high reward" maintained associations with higher scores in composite cognition (0.130 [0.030, 0.231]; $p = 0.0109$), episodic memory (0.131 [0.012, 0.250]; $p = 0.0315$), and executive functioning (0.117 [0.017, 0.216]; $p = 0.0213$). The category of "low effort and high reward" was also associated with composite cognition (0.106 [0.009, 0.204]; $p = 0.0329$) and executive functioning (0.139 [0.042, 0.235]; $p = 0.0049$) after all adjustments.

Sensitivity analyses of independent effort and reward with the individual seven cognitive tests demonstrated that although effort was not associated with any of the cognitive tests, high reward was associated with high performance in five cognitive tests (Supplementary Table 2). For joint effort and reward, "low effort and high reward" was associated with high cognitive function in two cognitive tests, and "high effort and high reward" was associated with high cognitive function in three cognitive tests (Supplementary Table 3).

Discussion

Among U.S. workers, after considering demographic, socioeconomic, lifestyle, and health covariates, high reward and the combination of "high effort and high reward" were associated with increased scores on all three cognitive measures of composite cognition, episodic memory, and executive functioning. The combination of "low effort and high reward" was also associated with increased composite cognition and executive functioning after full adjustment. Moreover, these associations were maintained nearly unchanged after further adjustment for job control, which is a frequently analyzed psychosocial work factor in association with cognition (Duchaine et al. 2023; Pan et al. 2019; Zhuo et al. 2021). Sensitivity analyses using the seven cognitive test scores reinforced that high reward exerted obvious effects on longitudinal changes in cognitive function.

Previous studies on the effort-reward imbalance model and cognitive function among European worker populations have focused on different cognitive domains (Harvey 2019) of processing speed and language or verbal skills (Riedel et al. 2017; Siegrist et al. 2019), or verbal memory (Siegrist et al. 2019), which is a specific component of episodic memory (Horta-Barba et al. 2020). Across a sample of French workers, cross-sectional findings for baseline effort and reward with semantic fluency and verbal memory were weakly associated (Siegrist et al. 2019). However, according to a six-year longitudinal study (Riedel et al. 2017), high effort was associated with increased perceptual speed, and high reward was associated with both increased perceptual speed and verbal fluency among German workers; regarding effort-reward combinations, "high effort and high reward" was associated with both increased perceptual speed and verbal fluency, and the combinations of "high effort and low reward" and "low effort and high reward" were associated with increased perceptual speed, in comparison to "low effort and low reward" and after covariate adjustments (Riedel et al. 2017). In relation to dementia, another European cohort study suggested that high reward was associated with an elevated risk of incident dementia, although this result was uncertain with a wide confidence interval (Tan et al. 2023). Notably, reward was operationalized by only two items in this report (Tan et al. 2023). In the 17-year Canadian study, high effort was associated with higher global cognitive function, and high reward showed marginal positive association (Duchaine et al. 2023). However, cognitive data was measured at one follow-up and not at baseline (Duchaine et al. 2023). The findings of our longitudinal study in the U.S. on the independent effects of high reward and its joint effects with high effort in relation to increased cognitive function provide new research evidence in addition to the above-mentioned studies from Europe and Canada.

Although independent effort was positively associated with cognitive function scores, its effects were substantially attenuated after adjusting for age and education (see Models I and III), suggesting the crucial role of education when interpreting age-related cognitive decline (Seblova et al. 2020). Overall, as observed from the findings in Tables 3 and 4, adjustments for the subsequent confounding factors resulted in a substantial reduction of the original effects, thus documenting their contribution to cognitive functioning. Yet, the effects of reward on cognitive function remained consistently stable after step-by-step adjustment. The proposed independent effect of the combination of high reward with high effort was supported by three significant

Table 4 Joint associations of effort and reward at baseline with changes in cognitive function between baseline and follow-up (β and 95% CI)

	Crude Model		Model I		Model II		Model III		Model IV		Model V		Model VI	
	Coeff. (95% CIs)	*p* value	Coeff. (95% CIs)	*p* value	Coeff. (95% CIs)	*p* value	Coeff. (95% CIs)	*p* value	Coeff. (95% CIs)	*p* value	Coeff. (95% CIs)	*p* value	Coeff. (95% CIs)	*p* value
Cognition Composite														
Low effort + low reward	0.000		0.000		0.000		0.000		0.000		0.000		0.000	
High effort + low reward	0.113 (0.005, 0.221)	0.0408	0.062 (-0.040, 0.163)	0.2358	0.070 (-0.030, 0.170)	0.1721	-0.002 (-0.097, 0.093)	0.9672	-0.007 (-0.102, 0.088)	0.8857	0.000 (-0.095, 0.094)	0.9930	0.002 (-0.093, 0.096)	0.9756
Low effort + high reward	0.137 (0.027, 0.247)	0.0147	0.217 (0.113, 0.321)	< 0.0001	0.205 (0.102, 0.308)	< 0.0001	0.101 (0.004, 0.198)	0.0405	0.099 (0.003, 0.195)	0.0434	0.097 (0.001, 0.193)	0.0480	0.106 (0.009, 0.204)	0.0329
High effort + high reward	0.318 (0.210, 0.427)	< 0.0001	0.311 (0.210, 0.412)	< 0.0001	0.304 (0.204, 0.404)	< 0.0001	0.128 (0.029, 0.227)	0.0113	0.117 (0.018, 0.215)	0.0206	0.116 (0.018, 0.214)	0.0210	0.130 (0.030, 0.231)	0.0109
Episodic Memory														
Low effort + low reward	0.000		0.000		0.000		0.000		0.000		0.000		0.000	
High effort + low reward	0.034 (-0.084, 0.153)	0.5695	-0.009 (-0.124, 0.105)	0.8736	0.031 (-0.077, 0.139)	0.5681	-0.007 (-0.114, 0.100)	0.9029	-0.009 (-0.116, 0.099)	0.8763	0.004 (-0.104, 0.112)	0.9412	0.005 (-0.103, 0.113)	0.9225
Low effort + high reward	0.039 (-0.085, 0.164)	0.5380	0.107 (-0.013, 0.228)	0.0801	0.139 (0.026, 0.252)	0.0158	0.079 (-0.034, 0.191)	0.1701	0.080 (-0.032, 0.191)	0.1614	0.077 (-0.034, 0.188)	0.1718	0.084 (-0.028, 0.197)	0.1414
High effort + high reward	0.210 (0.086, 0.334)	0.0009	0.204 (0.084, 0.324)	0.0009	0.229 (0.116, 0.342)	< 0.0001	0.128 (0.012, 0.245)	0.0309	0.121 (0.005, 0.237)	0.0416	0.120 (0.005, 0.236)	0.0412	0.131 (0.012, 0.250)	0.0315
Executive Functioning														
Low effort + low reward	0.000		0.000		0.000		0.000		0.000		0.000		0.000	
High effort + low reward	0.127 (0.022, 0.232)	0.0182	0.077 (-0.023, 0.176)	0.1296	0.074 (-0.024, 0.171)	0.1396	0.009 (-0.084, 0.102)	0.8505	0.004 (-0.089, 0.097)	0.9348	0.007 (-0.086, 0.100)	0.8904	0.008 (-0.085, 0.101)	0.8656
Low effort + high reward	0.175 (0.068, 0.281)	0.0013	0.253 (0.153, 0.353)	< 0.0001	0.228 (0.129, 0.327)	< 0.0001	0.138 (0.043, 0.233)	0.0046	0.134 (0.040, 0.229)	0.0054	0.132 (0.038, 0.227)	0.0062	0.139 (0.042, 0.235)	0.0049
High effort + high reward	0.296 (0.189, 0.403)	< 0.0001	0.289 (0.189, 0.389)	< 0.0001	0.273 (0.174, 0.371)	< 0.0001	0.117 (0.019, 0.215)	0.0192	0.108 (0.010, 0.205)	0.0307	0.107 (0.009, 0.204)	0.0320	0.117 (0.017, 0.216)	0.0213

β coefficients (coeff.) and 95% confidence intervals (CIs)

Generalized estimating equations (GEE) linear regression

Model I: adjustment for age (years) at baseline

Model II: Model I + additional adjustment for sex, marital status, and race/ethnicity 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, and physical exercise 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 regression coefficients that were partly higher than those observed for reward alone (Table 4).

The concept of reward has a basis in neuroscience, in which the meso-limbic dopamine reward circuit in the brain is involved with cognitive control, reward anticipation and motivation, and decision-making (Weinstein 2023). Regarding memory, reward motivation is reciprocally related (Weinstein 2023), and reward sensitivity contributes to motivational selectivity, which may preserve or increase cognition (Knowlton and Castel 2022). When motivated by reward, executive functioning focus and resource allocation are increased (Pessoa 2009). Overall, the premise of a cost-benefit relationship motivating cognitive processing suggests that the incentive of reward increases cognitive effort and efficiency (Sandra and Otto 2018). Our findings on positive associations of work-related reward with cognitive function, which parallel neuroscience research, also reinforce the relevance of cognition as a notable and long-term health issue among workers.

The positive association of high reward with cognitive function in our study may have relevance in current U.S. work environments, and advocates for further inquiry into workers' experiences of reward and cognitive health in the workplace. Trends of U.S. work values prior to the COVID-19 pandemic prioritized reward concepts of high income, high job security, and promotion opportunity, despite challenges to obtain these work rewards (Kalleberg and Marsden 2019). However, in the context of recent U.S. occupational shifts such as working from home, the high turnover phenomenon of the "Great Resignation" among workers, and economic changes, workplaces may further evaluate individual worker perceptions and organizational practices regarding the element of reward – including the components of finances, job security, and esteem, as demonstrated in the ERI model. While our study provides an insight into a potential influence of high reward in promoting cognitive health, more research is needed among other worker populations and work settings. If continued research coincides with these findings, work organizations may consider implementing multi-faceted rewards, such as financial well-being encompassing monetary pay, but also workplace benefits, assistive programs, and flexible work schedules (Despard 2023), as well as fostering supportive work environment cultures, to realize possible cognitive benefits of high reward in workplaces.

Several limitations need to be addressed in our study. First, the findings of our study should be interpreted with caution. A number of longitudinal studies with multiple repeated measures suggested that changes in or cumulative exposure to psychosocial stressors at work and behavioral factors were more powerful in predicting future cognitive performance (Duchaine et al. 2021; Lindwall et al. 2012), and time-varying analysis is a preferable approach to account for these changes (Lanza and Linden-Carmichael 2021). However, due to lack of data, the baseline data of psychosocial work characteristics and covariates were used in our regression modeling, which may pose a risk of exposure misclassification. Yet, another study revealed a high degree of stability of effort-reward imbalance over a period of seven years (Leineweber et al. 2019). Furthermore, the sample majority of the MIDUS study was predominantly White and married, and thus may restrict the generalizability of the findings. Additionally, we did not conduct sex-stratified analysis, which was performed in some prior studies (Duchaine et al. 2023; Siegrist et al. 2019). However, interaction analysis suggested there were no sex differences in the associations of effort and reward with all cognitive measures in this study (data not shown). Finally, although the BTACT was validated and had collected cognitive data in a brief 20-minute period, the telephone administration was limited to auditory and verbal assessments (Lachman et al. 2014).

Study strengths include its population-based longitudinal design, with a long follow-up period of nearly a decade. The measure for ERI has been validated in previous research (Li et al. 2021; Siegrist et al. 2004). The GEE statistical approach also accounted for the correlations between repeated outcome measures and a number of covariates at baseline (Liang and Zeger 1986). Notably, this is the first study to examine the associations of effort and reward with changes in cognitive function among a sample of U.S. workers. This study's findings highlighted the component of reward in relation to three different measures of cognitive function.

Conclusion

Across a follow-up period of nine years in the U.S., psychosocial work exposures involving high reward were associated with increased cognitive function among workers. Policy implications of these study findings include the implementation of relevant rewards within work organizations. Future research may examine longitudinal associations of time-varying effort and reward among larger population-based samples over longer follow-up intervals, and may incorporate measures related to manifested disease outcomes, such as dementia.

Supplementary Information The online version contains supplementary material available at https://doi.org/10.1007/s00420-024-02081-z.

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Author contributions Conceptualization, JL and JS; methodology, JL and MG; data management, TAM, SL, and MG; data analysis, MG and JL; writing—original draft preparation, MG and JL; writing—review and editing, TAM, SL, OAA and JS; supervision, JL; project administration, JL and MG; funding acquisition, MG and JL. All authors have read and agreed to the published version of the manuscript.

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Data availability The MIDUS II and III datasets and Cognitive Projects are available for download from the University of Michigan Inter-university Consortium of Political and Social Research (ICPSR): https://www.icpsr.umich.edu/web/pages/NACDA/midus.html (Accessed on 4th March 2024).

Declarations

Ethics approval This study was reviewed and approved for exemption by the University of California Los Angeles Institutional Review Board (IRB#22-001975) and followed the Declaration of Helsinki guidelines, as well as the Strengthening the Reporting of Observational Studies in Epidemiology (STROBE) reporting guideline.

Consent to participate The MIDUS study and Cognitive Projects obtained informed consent from all participants before their participation.

Conflict of interest The authors have no relevant financial or non-financial interests to disclose.

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