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Effect of overtime work on cognitive function in automotive workers

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Objective The present investigation examined whether increased overtime work predicts impairment in cognitive performance in the domains of attention, executive function, and mood.

Methods The behavioral and cognitive functions of 248 automotive workers were measured by a neurobehavioral test performance. Overtime, defined as number of hours worked greater than 8 h a day or greater than 5 d a week, was calculated from company payroll records for the week before the test day. The number of consecutive days worked before the test day was also determined.

Results Cross-sectional data analysis by multiple linear regression, after adjustment for the effects of age, education, gender, alcohol intake, repeated grade in school, acute petroleum naphtha exposure, shift worked, job type, number of consecutive days worked before the test day, and number of hours worked on the test day before the testing, demonstrated that increased overtime was significantly associated with impaired performance on several tests of attention and executive function. Increased feelings of depression, fatigue, and confusion were also associated with increased overtime work. In addition significant interaction effects were observed for job type but not for naphtha exposure.

Conclusions The findings support the hypothesis that overtime work results in impaired cognitive performance in the areas of attention and executive function and that both overtime hours and the number of consecutive days worked prior to a test day affect mood.

Key terms fatigue, machine-paced work, naphtha, neurobehavioral tests, occupational health.

Overtime work in workplaces in the United States has become increasingly common (1). Calculations for the last two decades indicate that the average employed person worked 163 h more in 1987 than he or she did in 1969 (2). These extra hours, almost a month more each year, are attributable to both more weeks of work and longer work weeks. A survey by the Bureau of Labor Statistics, in May 1985, determined that 10% of the United States workforce (10.5 million workers) worked some overtime; the average was an additional 9.6 h per week (3).

For over a century it has been recognized that long work days lead to a greater perception of fatigue by workers and to a reduction in worker efficiency (2). The role of fatigue in worker health and safety, measured in terms of accident and absenteeism rates, has been examined as a result of longer workdays (4), and several studies have explored the effects of acute or short-term fatigue (ie, over a prolonged workday) on job performance (5—7). More recent studies indicate that fatigue resulting from several days of a long work schedule [eg, a compressed work week shift (8, 9), sustained operations work such as simulated military operations (10, 11), hospital on-call service by physicians and nurses (12)] affects behavioral or psychological test performances. However, no studies have examined whether the fatigue effects of long workdays sustained over longer periods of time (ie, week or month) affect behavior and cognitive abilities. The present investigation explored the concept that overtime contributes to a state of cumulative fatigue by testing a hypothesis about the effects of overtime on cognitive function as measured by neurobehavioral tests.

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The increased work load resulting from regular overtime is considered to be one potential cause of cumulative fatigue in the workplace [defined as fatigue occurring over an extended series of work cycles in circumstances of reduced recovery and rest and different from acute and chronic fatigue (13)], as overtime can increase job intensity and can disrupt an adequate recovery process. Based on a brain-behavior model in which fatigue is perceived as a stressor by the central nervous system (CNS) and on the observed fatigue effects (due to one or several long workdays) on cognitive abilities and job performance described in the literature (for a review see reference 14), it was predicted that cumulative fatigue from overtime affects the specific behavioral domains of simple and complex attention, executive function, and affect. It was predicted also that performance on tasks that require subject motivation for completion (eg, computer-based tests) would be more likely to be affected. Memory function and language abilities were not expected to be affected. Few studies have described overtime as a potential stressor and contributor to cumulative fatigue. None have calculated the actual overtime hours worked for each worker under study. In an experimental study by Rosa & Colligan (15), the limits of extended workdays were tested by requiring the subjects to work a fairly rigorous work schedule of five 12-h days (20 h overtime per week) to increase the chance of detecting work-rest differences in performance on a battery of cognitive and perceptual-motor tasks. During the week-long schedule, impairments in test performance were observed when compared with performance on rest days. However, the authors suggested that "except for occasional overtime situations, such a schedule would normally not occur [p 306]." The present investigation tested the primary hypothesis that increased overtime work (ie, number of overtime hours worked in the 7 d prior to the test day) would be associated with poorer performance on specific neurobehavioral tests in a cohort of automotive workers employed at a plant where overtime was an integral part of work scheduling. The effect of the total number of consecutive days worked before the test day on test performance was evaluated also. In addition, the effect of working a high-strain job [eg, machine-paced, assembly-line work (16)] and of increased acute exposure to the petroleum distillate naphtha on the assessment of fatigue effects from overtime hours worked was examined.

Subjects and methods

Study design

The study was designed primarily to investigate the neurobehavioral effects of petroleum naphtha exposure in a group of automotive workers over a two-year period prospectively; the decision to examine the potential effect of overtime on neurobehavior was made following the year 1 field testing when it was noted that many subjects were working high numbers of overtime hours. Retrospectively, it was observed that the number of overtime hours worked had been two times higher on the average in year 1 than in year 2 (14); this paper describes the examination of the effect of overtime work on cognitive function with data collected in year 1.

All the subjects recruited for the study were hourly wage, United Auto Workers (UAW) members employed in the manufacturing and calibration departments of a fuel-injector manufacturing plant. No supervisors or management personnel were assessed. Field testing was carried out at the plant during work hours. All the subjects were asked to give their informed consent, and then they completed a medical and occupational history questionnaire, submitted a urine sample for renal function tests, and underwent neuropsychological testing. An a priori selected sample of recruited subjects was outfitted with personal air monitoring devices to measure naphtha exposure throughout the workday (17). In year 1 (June 1988) of the study, a total of 248 workers was tested. The tests included in the neuropsychological battery are presented in table 1, along with the functional domains tested. For a full description of the neurobehavioral tests administered, see White et al (18). For a discussion of the renal effects and neurobehavioral effects associated with naphtha exposure among these workers, see Rocskay et al (19) and White et al (18), respectively.

In this plant, workers normally worked a fixed 8-h shift, 5 days a week (Monday — Friday) either from 0630 to 1500, 1430 to 2300, or 2230 to 0700. The subjects were scheduled for neurobehavioral testing during their time at work. Each subject was away from his or her work station for approximately 75 min to complete the study protocol, during which time plant production did not stop nor did the workers lose pay. In year 1, subjects were recruited from and tested on first and second shifts only. Overtime hours were defined as the

Table 1. Tests in the administered neuropsychological battery.

Test	Functional domain
Trail Making Test	Attention, executive function
Wisconsin Card Sorting Test	Executive function
Symbol-digit Substitution Test (a computerized task)	Visuospatial scanning, attention motor speed
Visual Reproductions	Short-term memory
Delayed Recognition Span Test	Short-term memory, attention
Pattern Memory (a computerized task)	Short-term memory
Vocabulary (a computerized task)	Intelligence, verbal abilities
Profile of Mood States: tension, depression, anger, fatigue, and confusion subscales	Mood

number of hours worked greater than 8 h a day or greater than 5 d a week in the 7 d prior to the test day. Both the overtime hours worked and the total number of consecutive days worked before the test day were calculated for each subject from company payroll records, the calculation thus providing an objective, unbiased estimate of overtime.

Statistical analyses

To examine potential confounders, Pearson's product moment correlations were calculated between the overtime and covariates. Differences in descriptive characteristics between those who worked some overtime hours and those who worked no overtime were examined using Student's t-test. To investigate the effect of overtime in the prior week on test performance, multiple linear regression models were run. We identified a set of 10 biologically and psychologically plausible factors, and this uniform set was forced to enter each model of the 24 test outcomes.

Depending on the number of subjects with histories of important confounders, some subjects were excluded from the analyses altogether. Excluded were persons who either reported a history of, or for which there were missing data regarding, the loss of consciousness or head injury (N = 12), emotional illness (N = 14), native language other than English (N = 19), or use of medications which affect concentration on test day (N = 4). Since past history of exposure to mercury was found to be a significant predictor of mood states, rather than include past mercury exposure as a covariate in the final analyses, the three subjects with a history of mercury exposure were omitted from the analyses of the Profile of Mood States (POMS).

To determine the set of covariates to include in the final regression models, first stepwise regressions were run for each outcome with approximately 25 variables considered in the literature to be potential confounders of outcome and where the P-value to enter was 0.20. The set of variables forced into the final multiple linear regression models included the two work-time measures (ie, number of overtime hours worked and number of consecutive days worked in the 7 d prior to the test day) and the continuous variables for age (years), years of education attained, length of time at work (from start time to test time) on the test day (hours), and the acute cumulative naphtha exposure on the day of testing up until the point of testing (mg-h $\cdot$ m^{-3}) (17). Whether the subject was required to repeat a grade in school (yes or no), gender (female or male), shift worked (first or second), and past history of alcohol abuse (yes or no) were entered as dummy variables. Type of job worked was also entered. The determination of type of job worked was based on categorization by job-department codes. If the subject worked in a job involving machine-paced (or assembly-line) work, job type was coded as 1; if the job involved nonmachine-related tasks or the use of a machine only to complete a task (eg, grinding), it was coded as 0. For the analysis of performance on computerized tests, familiarity to video games or computers (yes or no) was also included as a covariate. A total of 206 subjects was included in the cross-sectional multiple linear regression analyses.

Residual plots of the observed versus the model-fitted expected values tended to form a straight line for all the test outcome models and thus suggested that the model forms for each test outcome were appropriate. Collinearity between the entered covariates was evaluated by examining the correlation coefficients. A change in the magnitude of the estimated effect of overtime on test performance between the models with and without the potential confounder was considered evidence of a confounding effect. Evidence for interaction was tested by forcing the product covariate (ie, either the categorical variable for type of job worked or the continuous variable for acute naphtha exposure multiplied by overtime per week) into the model.

Results

Study subject demographics, as well as the mean overtime worked before the test day, are presented in table 2. About 66% of the subjects worked some overtime the week before the testing, 28.6% working greater than 8 h overtime and 9.3% (n = 19) working more than 20 h; the range was from 0 to 32 h. The mean overtime hours worked the week prior to testing for the group who had worked some overtime was 11.0 (SD 6.9) h. Eighteen percent did not work the day before the test day, 13% (N = 27) worked more than four consecutive days before the test day, and one person had worked a total of 29 consecutive days before his test day.

Simple stratified analysis of the no-overtime versus the overtime groups showed that the mean test performance by the overtime group was worse than that of the no-overtime group on 15 of 24 tasks (63%) in year 1. The difference was significant (Student's t-test, $P < 0.05$) for time to complete Trails B, 2-min recall on the Delayed Recognition Span Test and the Vocabulary test.

An examination of the Pearson product moment correlations (76 correlations) indicated that only the number of consecutive days worked was strongly correlated with the number of overtime hours worked in the 7 d prior to the test day ($r = 0.529$). All the other correlations were < 0.15. Because of the degree of correlation and thus possible collinearity between the two worktime-related measures, several multiple regression models were per-

Table 2. Characteristics of the study population.

Group	Gender (% female)	Shift worked (% on shift 2)	Past history of alcohol abuse (% yes)	History of repeated grade in school (% yes)	Job category (% in machine-paced jobs)	Age (years)		Education (years)		Consecutive days worked before test day (N)		Length of work on test day before testing (h)		Acute naphtha exposure on test day [mg · (h · m^{-3})]	
						Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD
Those who worked no overtime (N = 69)	40.6	37.7	1.5	17.4	14.5	35.7	8.2	12.6	1.0	1.8	1.4	3.8	2.6	401.4	430.1
Those who worked some overtime (N = 137)	32.8	40.9	3.8	20.4	16.1	36.1	7.3	12.5	1.4	3.7	4.7*	4.3	2.7	414.1	455.2
Total cohort (N = 206)	35.6	35.9	3.4	19.2	15.9	36.0	8.5	12.5	1.3	3.1	4.0	4.2	2.7	407.9	444.4

P < 0.05 (Student's t-test for comparison between the no-overtime and overtime group).

formed for each test outcome: with both measures included in the same model (primary model), with overtime hours only, and with just the number of consecutive days worked.

In the multiple regression analyses of test performances with the primary model, overtime predicted impaired performances on time to complete Trails A, time to complete Trails B, number of successful sorts and number of errors on the Wisconsin Card Sorting Test, and percentage correct on the computerized Vocabulary test (table 3). The total proportion of variance in the test outcomes that was accounted for by the covariates in the models ranged from 6% to 30%, values consistent with others reported in the literature [eg, for computerized tests (20, 21) and for other neurobehavioral tests used in occupational epidemiologic studies (22—24)].

To demonstrate the magnitude of the effect of overtime on test performance, the percentage change in test performance predicted by the model for those working 8 and 20 h of overtime was compared with the mean test performance by the no-overtime group. These changes are presented in the last columns of table 3. Trails B and the Wisconsin Card Sorting Test were the tests most affected by the cumulative fatigue effects of overtime. Working 8 h of overtime resulted in a 19% longer response time on trails B and an 8—18% poorer performance on the Wisconsin Card Sorting Test compared with those of the persons working no overtime.

The full regression models for the test outcomes significantly associated with overtime (see the appendix) demonstrated that working 8 h of overtime resulted in a 2.5 s longer time to complete Trails A. On this task, a 10-ppm higher naphtha exposure over an 8-h period slowed response time by 2.1 s, which was comparable to the effect of working 8 h of overtime [10 ppm naphtha equals approximately 52.5 mg · m^{-3}]. For Trails B, it took almost 13 s longer for completion than for those working 8 h of overtime. The number of consecutive days worked did not significantly affect test performance (when included in either the model with or that without overtime hours), nor was there evidence of confounding by the number of consecutive days worked on test performance.

On the Wisconsin Card Sorting Test, overtime hours and the number of consecutive days worked were the only significant predictors of the number of successfully sorted cards and the number of errors made. The number of consecutive days worked was a positive predictor of performance, while increased overtime predicted poorer performance. The number of consecutive days worked did confound the effect of overtime on the Wisconsin Card Sorting Test. When the number of consecutive days was not included in the model, overtime was less associated with the number of successful sorts and the number of errors on the Wisconsin Card Sorting Test (regression coefficient for overtime per week = –0.019, P = 0.16 and 0.166, P = 0.13, respectively). The number of consecutive days worked was not a significant predictor of performance on this task in the model without overtime hours, and no significant interaction effect (between overtime hours worked and number of consecutive days) on test performance was observed.

Working 8 h of overtime predicted an increased number of errors on the vocabulary task. Machine-paced work also predicted a worse performance on this task (ie, working in a machine-paced job was similar to the effect of working 14 h of overtime). Naphtha exposure was a significant predictor of performance on the vocabulary task, although in the opposite direction: higher exposure predicted better performance. As with the Wisconsin Card Sorting Test, working an increased number of consecutive days before testing predicted a better performance on this task when included in the model along with the number of overtime hours. The number of consecutive days worked was not a significant predictor of performance on this task in the model without overtime

Table 3. Results of the multiple regression analyses[a] for the effect of overtime categorized by functional domain.

Test	Regression coefficient	95% confidence interval	Model r^2	Predicted % change from no-overtime mean	
				8 h overtime	20 h overtime
Attention, executive function					
Trails A					
Time to complete	0.31	0.04—0.58	0.16	8.4	20.9
Number of errors	0.001	−0.007—0.0009	0.08		
Trails B					
Time to complete	1.6	0.66—2.5	0.19	18.5	46.2
Number of errors	0.025	−0.02—0.07	0.12		
Wisconsin Card Sorting Test					
Number of successful sorts	−0.036	−0.07—−0.005	0.06	8.7	21.8
Number of total errors	0.28	0.03—0.53	0.06	18.0	45.0
Visuospatial/visuomotor skills					
Symbol-digit Substitution Test[b]					
Percent correct	0.008	−0.05—0.07	0.16		
Response time	0.11	−0.01—0.22	0.30	3.7	9.2
Memory					
Visual Reproductions					
Immediate recall	−0.013	−0.007—0.04	0.08	.	.
Delayed recall	0.004	−0.06—0.06	0.12	.	.
Delayed Recognition Span Test					
Verbal span	0.001	−0.05—0.05	0.10	.	.
Verbal total score	−0.008	−0.03—0.02	0.10	.	.
15-s recall	−0.019	−0.05—0.02	0.19	.	.
2-min recall	−0.017	−0.06—0.02	0.13	.	.
Spatial span	0.004	−0.06—0.06	0.07	.	.
Spatial total score	0.002	−0.03—0.03	0.09	.	.
Pattern Memory Test[b]					
Percent correct	−0.11	−0.38—0.15	0.13	.	.
Response time	0.021	−0.03—0.07	0.12	.	.
Intelligence, basic abilities					
Vocabulary[b]					
Percent correct	−0.55	−0.84—−0.26	0.28	5.7	14.6

[a] Each model included age, gender, years of education, time at work on test day, shift worked, alcohol abuse, history of repeated grade, number of consecutive days worked, acute naphtha exposure, overtime hours, and job type. The models run for computerized tests also included familiarity with computers.
[b] Computerized test.

hours, nor was there evidence of confounding by consecutive days on test performance.

Overtime was not significantly associated with increased feelings of tension, depression, anger, fatigue and confusion on the POMS when included in the primary model. However, both worktime variables were predictive of mood changes when entered separately into the models (table 4).

Machine-paced work predicted impaired performances on Trails B (increased number of errors made), percentage correct on the Symbol-digit Substitution Test, percentage correct on the computerized Vocabulary test, and the Delayed Recognition Span Test. But a comparison of the different models demonstrated that type of job did not confound the earlier described effects of overtime. There was a significant interaction between job

Table 4. Effect of overtime hours worked and number of consecutive days worked prior to test day on Profile of Mood States.

Mood	Overtime hours		Number of consecutive days worked	
	Regression coefficient	95% confidence interval	Regression coefficient	95% confidence interval
Tension	0.044	−0.09—0.18	0.171	−0.08—0.42
Depression	0.120	0.03—0.21	0.208	0.04—0.38
Anger	0.081	−0.04—0.21	0.291	0.05—0.53
Fatigue	0.164	0.03—0.30	0.307	0.05—0.56
Confusion	0.112	0.01—0.21	0.198	0.01—0.39

[a] Each model included age, gender, years of education, time at work on test days prior to the testing, shift worked, alcohol abuse, history of repeated grade, acute naphtha exposure, and job type.

type and overtime on percentage correct on the computerized Vocabulary test and the number of errors made on Trails B. On the Vocabulary test, nonmachine-paced workers performed significantly worse as they worked more overtime (regression coefficient for overtime –0.636). For the number of errors on Trails B, machine-paced workers made significantly more errors as they worked more overtime (regression coefficient 0.180).

No significant interaction was observed between acute naphtha exposure and overtime observed for any of the tests associated with overtime hours, nor was significant interaction or confounding between the number of hours at work on the test day (acute fatigue measure) and overtime per week.

Discussion

The findings support the hypothesis that overtime work results in an impaired test performance in the areas of attention and executive function and that both overtime hours and number of consecutive days worked prior to the test day affect mood. In epidemiologic studies of neurobehavioral effects, any significant deficits on a number of tests are often interpreted as evidence of impairment in central nervous system functioning. However, this is not necessarily accurate; as in this study, an evaluation of the functional areas in which those deficits are observed is required to ascertain whether the results provide evidence supporting the brain-behavior hypothesis being tested.

Due to the study protocol, it was not possible to control for specific individual circadian rhythm effects on test performance in this study (25—27). However, when time of day of testing was substituted into the model for shift worked, there were no significant changes in the regression coefficients of the model, nor was there any significant change in the regression coefficients for overtime. This result suggests that shift worked was a generally adequate surrogate for circadian rhythm effects in this study. A significant interaction effect between circadian rhythm and level of fatigue is considered important in the assessment of test performance because the circadian rhythm of arousal can be expected to oppose the acute fatigue effects of time at work during the day, but intensify the acute fatigue effects from time at work during the night (8). However, in this study, no significant interaction between shift worked and length of time at work was observed on any of the test performances, perhaps because the study analyses did not include workers from the third shift. Excluding persons from the third shift also reduced the possible confounding role of personality type on performance, as studies have indicated that different personality types tend to work different shift schedules and that different circadian performance curves have been observed between individuals categorized as introverts and extroverts (4, 28, 29).

Overall, the test battery was selected to encompass a range of functional domains and to include multiple performance modalities (ie, oral and written, as well as computer-oriented tasks) (30, 31). Due to the level of motivation required to perform computerized tests, it was predicted that increased overtime would be associated with impaired performance on these tasks. Some support for this hypothesis was observed in that evidence of a longer response time was observed on the Symbol-digit Substitution Test and a reduced number correct was observed on the vocabulary task. The Vocabulary test is usually included in test batteries as a "hold test" [eg, one that serves as a measure of general intelligence level and is often entered into models as an independent variable (20)]. In this study, the fact that it was presented on a computer in a series of 25 multiple choice questions may have affected its ability to assess general intelligence exclusively. In this performance modality, it may also represent a test of attention. Looking at the pattern of the individual responses could provide a clue to whether the decreased performance was related to impaired attention (ie, if the errors made progressively increased over the length of the task) rather than impairments in basic ability (ie, if the errors made were sporadic). However, because the data collected only recorded the total number of correct answers, it was not possible to evaluate the pattern of errors in the proposed manner.

The Wisconsin Card Sorting Test requires the subject to figure out the correct pattern of response with minimal examiner feedback. During the field testing period, examiners believed that the subjects were informing their peers about how to respond. This hypothesis was supported when one looks at the effect of the number of consecutive days worked in the full models. The number of consecutive days worked before testing was a positive predictor of both the number of sorts and the number of errors made on this test. Those that had worked more consecutive days before the testing (and thus had greater opportunity to be informed about how to respond) did significantly better. Thus the number of consecutive days worked does not appear to represent a measure of the effect of increased work load but is in fact measuring a different phenomenon. The number of consecutive days worked was also a positive predictor of performance on the Vocabulary test, a test that was perceived as frustrating by the workers. It is possible that there may have been some informing of peers on this task as well.

The most often stated theory explaining the effects of fatigue on cognitive performance is that fatigue is perceived as a stressor to the organism. Up to a certain point, demands (stressors) will increase arousal and result in an effective, optimum performance level. However, excessive demands will result in decreased performance. This hypothesized relation between arousal and performance in relation to the effects of stressors is described as the "inverted-U hypothesis" and has been referred to as the Yerkes-Dodson Law (32). Its popularity as a theory is largely due to the fact that it makes sense intuitively and the fact that there are direct physiological phenomena that relate stress to central nervous system behavior. However, the theory has not been supported conclusively in all studies of stress effects. Recently, Karasek & Theorell (16), in their two-dimensional demand-control model, have theorized that the level of control (decision latitude) over one's actions will also influence the individual's response in a stressful situation. In this study, there was some support for the concept that job type can interact with the fatigue effects of overtime on certain test performances, but the study also indicated that overtime work and job type may affect performance differently.

The impaired performances on the attention and executive function tests suggest that the cumulative fatigue effects of overtime can affect workers' motivation to complete tasks, as well as the ability to process information in complex tasks in order to respond efficiently. Overall, the accuracy of responses did not appear to be significantly affected by overtime, whereas the response times were longer (eg, Trails A and B). These findings suggest that the cumulative fatigue effects of overtime hours worked result in a specific strategic change in test performance: slower response time in order to maintain accuracy, as has been indicated in some studies of workplace fatigue (7). On the contrary, persons working machine-paced jobs performed significantly faster and with more errors than those working nonmachine paced jobs (on Trails B) representing a different type of strategic change: faster response time with more errors. Whether this strategic change carries over to job performance needs to be examined in further studies.

There is some discussion in the literature that the stressor effect of overtime operates according to a sleeper effect model (33) based on studies that have demonstrated observed effects of overtime only after an extended period of overtime is over. The assumption is that recovery time after a period of overtime work is necessary in order to recuperate from stressful work (34, 35). Not accounted for in the sleeper effect model, however, is the impact that the intensity of the stressor factor may have on time course (ie, possible threshold effects) nor the concept that a stressor effect in the workplace is often influenced by other moderating or mediating factors. In the automotive plant under study, overtime work varied throughout the year depending on production demands and other factors [eg, peak highs in overtime work were calculated and found to occur in March 1988, June 1988, November-December 1988, and February 1989 (14)]. Thus testing the effect of overtime on test performance longitudinally (by examining the difference in overtime hours worked on the difference in neurobehavioral test performance) at a one-year time interval probably would not be the most appropriate. In this plant, repeat testing at three- to four-month intervals with the same test battery would perhaps permit a better opportunity to evaluate the extent of the cumulative fatigue effect of overtime on test performance.

In conclusion, the findings support the hypothesis that overtime work affects cognitive function as measured by neuropsychological testing, with impairments observed in tasks requiring attention and executive function skills. Regarding mood changes, it appears that both the number of consecutive days worked and the number of overtime hours worked in the seven days prior to the test day were predictive of increased feelings of depression, fatigue and confusion. These cross-sectional findings are consistent with those of previous studies of the functional state of cumulative fatigue. Recognition that increased overtime affects cognitive function in certain functional areas and, by extension, may affect worker performance, has important implications for the health and safety of workers, as well as for the economic management of the workplace. Results from this investigation suggest that performance on certain types of job tasks, such as those in which minimal time to complete somewhat complex, interactive job tasks is important (eg, production or manufacturing jobs), may be affected by increased overtime. However, future study is required before performance on neurobehavioral tests can be translated into the performance of job-specific tasks.

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Appendix

Multiple linear regression models for selected neuropsychological test outcomes

Table 1. Multiple linear regression model for time to complete Trails A.[a]

Variable[b]	Regression coefficient	95% confidence interval
Alcohol abuse history	−2.68	−12.4—7.0
Repeated grade	0.97	−3.4—5.4
Acute exposure [mg · (h · m⁻³)]	0.005	0.001—0.009
Number of consecutive days worked	−0.21	−0.74—0.32
Age (years)	0.33	0.11—0.55
Female	−4.06	−7.8—−0.32
Years of education	−1.88	−3.3—−0.45
Shift 2	0.43	−3.3—4.13
Hours at work on test day	−0.45	−1.3—0.37
Machine-paced job	3.09	−2.01—8.2
Overtime (hours)	0.31	0.04—0.58
(Constant)	41.96	20.8—63.2
model r^2 = 0.16		

[a] A low score indicates a faster performance.
[b] See the text for a description of the variables.

Table 2. Multiple linear regression model for time to complete Trails B.[a]

Variable[b]	Regression coefficient	95% confidence interval
Alcohol abuse history	−25.3	−58.6—8.0
Repeated grade	8.1	−7.0—23.2
Acute exposure [mg · (h · m⁻³)]	0.01	−0.006—0.03
Number of consecutive days worked	−0.98	−2.8—0.82
Age (years)	0.75	0.0—1.5
Female	−12.6	−25.5—0.34
Years of education	−9.6	−14.5—−4.7
Shift 2	1.1	−11.6—13.8
Hours at work on test day	−0.5	−3.2—2.2
Machine-paced job	−12.8	−30.2—4.6
Overtime (hours)	1.6	0.66—2.5
(Constant)	165.0	92.5—237.5
model r^2 = 0.16		

[a] A low score indicates a faster performance.
[b] See the text for a description of the variables.

Table 3. Multiple linear regression model for the number of successful sorts on the Wisconsin Card Sorting Test.[a]

Variable[b]	Regression coefficient	95% confidence interval
Alcohol abuse history	−0.23	−1.3—0.85
Repeated grade	−0.26	−0.75—0.23
Acute exposure [mg · (h · m⁻³)]	0.00008	−0.0005—0.0007
Number of consecutive days worked	0.06	0.001—0.12
Age (years)	−0.01	−0.03—0.01
Female	−0.01	−0.42—0.40
Years of education	0.03	−0.13—0.19
Shift 2	0.22	0.19—0.63
Hours at work on test day	0.05	−0.05—0.15
Machine-paced job	0.14	−0.43—0.71
Overtime (hours)	−0.036	−0.07—−0.005
(Constant)	3.0	0.65—5.4
model r^2 = 0.16		

[a] A high score indicates a faster performance.
[b] See the text for a description of the variables.

Table 4. Multiple linear regression model for number of errors on the Wisconsin Card Sorting Test.[a]

Variable[b]	Regression coefficient	95% confidence interval
Alcohol abuse history	1.8	−7.0—10.6
Repeated grade	1.4	−2.5—5.3
Acute exposure [mg · (h · m⁻³)]	0.0006	−0.003—0.005
Number of consecutive days worked	−0.41	−0.88—0.06
Age (years)	0.11	−0.09—0.31
Female	0.24	−3.1—3.6
Years of education	−0.21	−1.5—1.1
Shift 2	−1.2	−4.5—2.1
Hours at work on test day	−0.45	−1.2—0.3
Machine-paced job	−3.2	−7.9—1.5
Overtime (hours)	0.28	0.03—0.53
(Constant)	13.2	−6.0—32.4
model r^2 = 0.06		

[a] A low score indicates a faster performance.
[b] See the text for a description of the variables.

Table 5. Multiple linear regression model for percent correct on the computerized Vocabulary Test.[a]

Variable[b]	Regression coefficient	95% confidence interval
Familiarity with video	0.60	−3.3—4.5
Alcohol abuse history	12.5	2.3—22.7
Repeated grade	−4.1	−8.6—0.41
Acute exposure [mg · (h · m⁻³)]	0.008	0.002—0.01
Number of consecutive days worked	0.51	−0.04—1.1
Age (years)	0.42	0.19—0.66
Female	0.43	−3.3—4.2
Years of education	3.4	1.9—4.9
Shift 2	−2.9	−6.8—1.0
Hours at work on test day	−0.99	−1.9—−0.13
Machine-paced job	−7.7	−13.0—−2.4
Overtime (hours)	−0.55	−0.84—−0.26
(Constant)	19.0	−4.1—42.1
model r^2 = 0.28		

[a] A high score indicates a faster performance.
[b] See the text for a description of the variables.

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