Workload, Fatigue and Performance in the Rail Industry

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Abstract. Recent research has addressed the topic of workload in the rail industry. Much of this has been concerned with developing measures for use by signallers and there has been less research about the workload of passenger rail staff. The present studies addressed this issue using single item measures of workload, effort, fatigue and performance. Results from two diary studies with conductors/guards and maintenance engineers showed that high workload was associated with increased fatigue. Fatigue was associated with increased risk of incidents and slower reaction time. In the third study, results from a large scale survey showed both that high demands increased fatigue and demands were associated with perceptions of reduced performance. Overall, these results confirm the importance of workload for operational efficiency and show that the use of single item measures makes further study in real-life settings acceptable.

Keywords: Workload · Job demands · Fatigue · Performance · Rail industry

1 Introduction

The aim of the research described in this paper was to investigate workload, fatigue and performance/safety in a passenger train company in the UK. This was done using subjective reports of workload and fatigue and relating these to subjective reports of job characteristics and work outcomes. In addition, objective indicators of performance and safety were also used in some of the studies. This research was intended as a preliminary approach that will eventually be supported by studies involving objective measurement of workload and more objective outcomes (e.g. physiological measures). Although the studies were conducted using rail crew, the approach is transferable to other contexts and industries. Three studies are presented to address the initial aims. These studies are described separately as they involve different samples and differences in methodology. Brief discussions are given after each study, followed by an overall discussion of the programme of research. The next section reviews several approaches to workload that have been adopted in the UK rail industry.

There has been an increase in the importance of human factors in the rail industry [1]. In the case of workload this has led to the development of many measuring instruments and the design of standard operating procedures that will aid assessment of workload [2]. An initial aim has been to develop a function complexity index linking number of inputs to perception of workload [3]. This issue has been widely studied in

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other contexts and requires an examination of the relationship between the demand for resources imposed by the task and the ability of the individual to supply those resources [4, 5]. The aim was to develop a set of quantitative criteria and a model to define systems that provided appropriate workloads.

Workload is a multi-dimensional concept with consideration for time, mental tasks, physical tasks and stressors [6]. It could be used to plan crew sizes, allocate functions and assess effects of working practices on operator efficiency and health. Workload can be measured independently (what is imposed by the system) or by rating the workload of the individual. The term workload is used in different ways in the rail industry which has led to it being considered in a functional context (see [7] for a review). An initial starting point for earlier research was to review dimensions of workload and classify them in terms of effort (e.g. resource capacity), demand (e.g. task difficulty) or effect (e.g. performance). Workload tools used in previous studies with rail signallers were also reviewed (e.g. [8, 9]). Many of these, developed in laboratories or designed for military samples, were not suitable for real-time use or civilian populations. Interviews were also carried out with rail staff; the consensus being that the level of mental effort required to complete the work formed the major workload component. This confirms that perception of load is central to an understanding of mental workload and that the effort expended by the person to accommodate work demands is a critical dimension of mental workload [10]. Kahneman [11] specified three questions which can be applied to evaluation of demands, namely:

1. What makes an activity more or less demanding?
2. What factors control the level of capacity available?
3. What are the rules regarding allocation of resources?

Much of the literature assesses the effects of workload in terms of performance. Strategies may be adopted which are effort-conserving and standards of performance may be lowered to conserve effort. Effects of workload on wellbeing are often referred to as stress or fatigue, and it may be these states that mediate the effects of workload on performance. Tools have been developed to assess these dimensions of workload in rail signalling (see [12]). These include an Integrated Workload Scale (IWS) and an Operational Demand Checklist (ODEC). Other methods have been developed to assess the workload of train drivers (e.g. Train Driver DRAWS - Defence Research Agency Workload Scales; Acceptable Workload Evaluation; Train Driver Workload Probe; Time Line Analysis – [13]).

One of the major problems with the UK rail industry's approach to workload is that it does not address human mental workload (see [14–16]). In addition, although a number of measuring instruments have been developed for use in the rail industry, there is little evidence that they are currently being used by UK train operating companies. There are two main reasons for this; the first is that workload does not fit into any clear occupational health and safety category. It might, for example, be put under the heading of fatigue, but in this case it is often considered as secondary to factors like working hours. Indeed, job demands are included in the calculation of the HSE Fatigue and Risk Indices but they are usually set at a constant level for all staff. Workload could be put in the 'stress at work' category, however this is usually considered a HR issue rather than one of occupational health and safety, meaning that relationships with safety

outcomes may not be examined. The other problem is that of having a very simple measure that can be easily used in real-life settings. Recent research has shown that single questions can often be as useful as longer scales [17–19]. This allows one to measure a number of concepts which can lead to the testing of more sophisticated models (e.g. the Demands-Resources-Individual Effects (DRIVE model – [20]). Both the single item approach and the DRIVE model have largely been applied to stress and wellbeing but can now be applied to workload and fatigue also. Indeed, the research described in this article is one of the first studies to do this. Multi-methodologies have been used to assess workload (or demands) in rail staff. The first study described here was a diary study where conductors rated their workload and fatigue each day for a week. The second study involved similar ratings from engineers at the start and end of the first and last day of their working week. Objective measures of performance were also taken at these times. Finally, the last study involved a survey of demands, fatigue and reported performance efficiency across different sectors of a rail company. All the studies described here were carried out with the approval of the ethics committee of the School of Psychology, Cardiff University, and with the informed consent of the volunteers. They were paid a small honorarium for participating.

2 A Diary Study of Workload and Fatigue of Conductors and Guards

2.1 Methods

2.1.1 Participants

The sample consisted of 33 conductors and guards, 23 male (69.7%) and 8 female participants (24.2%) (2 participants (6.1%) did not disclose their gender). The mean age of the group was 44.9 years and the range was 27-66 years. The participants worked as conductors and guards for a passenger rail company and were on day shifts with varying start times.

2.1.2 The Diary

The diary consisted of 10 questions, five questions that were to be answered before work and five questions to be addressed after work. These questions are shown in Appendix 1. The diary was completed every day for a working week (4 days). The questions answered before work covered sleep duration and quality, time taken to travel to work, alertness before starting work and general health status. Those completed after work recorded workload, effort, fatigue, stress and breaks during the day.

2.1.3 HSE Fatigue and Risk Index Scores

In addition to the diary data, information was available on the HSE fatigue index and risk index scores [21] for 22 of the participants. These 22 participants were representative of the whole sample in that their diary data did not differ from those with no Fatigue and Risk Index scores. The Fatigue and the Risk Index are the major outcomes from the HSE fatigue and risk calculator tool. Both are calculated from three separate components of the person's working hours and the nature of their job, namely:

- *A cumulative component*. This relates to the way in which individual duty periods or shifts are put together to form a complete schedule. The cumulative component associated with a particular shift depends on the pattern of work immediately preceding that shift.
- *A component associated with duty timing*, i.e. the effect of start time, shift length and the time of day throughout the shift.
- *A job type/breaks component.* This relates to the content of the shift, in terms of the activity being undertaken and the provision of breaks during the shift.

These measures were included in the study to determine whether subjective reports of workload and fatigue were associated with the scores from these mathematical models of fatigue (the fatigue index) and risk of an incident (the risk index).

2.2 Results

Initial analyses examined whether ratings of workload changed over the working week and whether workload on successive days was correlated. Workload increased over the week (Day 1 workload mean = 5.97 s.d. = 2.79; Day 4 workload mean = 7.34 s. d. = 7.34 t = -2.59 df = 32 $p < 0.05$). The correlations between ratings of workload, effort and fatigue for individual days were significant (all p's < 0.05) and the average ratings were used for subsequent analyses. The correlations are shown in Table 1.

Table 1. Correlations between average ratings of workload, effort, fatigue, sleep duration and HSE fatigue and risk index scores

	Workload	Effort	Fatigue	Sleep duration	Fatigue index	Risk index
Workload	1					
Effort	0.66**	1				
Fatigue	0.58**	0.38*	1			
Sleep Duration	−0.01	−0.07	0.12	1		
Fatigue Index	0.08	0.32	0.00	−0.60**	1	
Risk Index	0.27	0.33	0.60**	0.18	−0.03	1

**p < 0.01, *p < 0.05

Workload ratings were significantly correlated with effort and fatigue ratings. Fatigue ratings were significantly correlated with the risk index whereas workload was not significantly correlated with it. The fatigue index was significantly correlated with sleep duration but not the ratings of workload, effort or fatigue.

2.3 Discussion

These results show that single item measures of workload, effort and fatigue show the usual pattern of correlations. Workload increased over the working week and the rating of workload was associated with fatigue which in turn was associated with higher risk of an incident as indicated by the HSE risk index. In contrast, the HSE fatigue index was predicted by sleep duration rather than workload or by the subjective report of fatigue.

These results suggest that a very short audit of workload, effort and fatigue can demonstrate the expected relationships between these variables. Furthermore, the rating of fatigue was correlated with the risk of having an incident (as calculated by the HSE Risk Indicator) which indicates the potential of using these short subjective reports in combination with mathematical models of risk. It is now important to determine whether these measures are of use for other jobs in the rail company. The next study aimed to replicate these findings with volunteers doing a different job (maintenance engineers) and working both night and day shifts. The HSE fatigue and risk calculations were not available for this group and an objective measure of performance (a variable fore-period simple reaction time task, often known as a psychomotor vigilance task [PVT]) was submitted along with the recording of the subjective reports of workload, effort and fatigue.

3 Study 2: Before and After Work Assessment of Rail Engineers

This study used a technique (the After-Effect method) that has been used for examining fatigue [22, 23] and workload [24]. It is very similar to the diary method from the previous study but it only involved the first and last day of the working week.

3.1 Methods

Testing occurred immediately before starting work and immediately after finishing work on each of those days. The diary questions were the same as those of the conductor study. A simple reaction time task was also given at these times.

3.1.1 Participants

Thirty six volunteers (all maintenance engineers) took part in the study (all male; mean age = 44.9 years, range 21–64 years).

3.1.2 Simple Reaction Time Task

In this task a box was displayed in the centre of the screen and at varying intervals (from 1-8 s) a target square appeared in the box. As soon as they detected the square participants were required to press a response key using the forefinger of their dominant hand only. Reaction times were measured to the nearest millisecond. This task lasted for 3 min. The measure of interest here was the mean reaction time (test-re-test reliability: $r = 0.65$). The mean reaction time from the before work session was subtracted from the after work mean reaction time to obtain an indication of the effects of the working day.

3.2 Results

Results from the first and last day of the working week were averaged. Table 2 shows the correlations between variables. The results were almost identical to the conductors study. Workload, effort and fatigue were correlated. Fatigue was significantly correlated with the before-after difference in reaction time but workload and effort were not.

Table 2. Correlations between workload, effort, fatigue and RT difference

	Workload	Effort	Fatigue	RT difference
Workload	1			
Effort	0.66**	1		
Fatigue	0.65**	0.46*	1	
RT differences	0.11	0.24	0.55**	1

**$p < 0.01$, *$p < 0.05$

3.3 Discussion

This study with rail maintenance engineers working a range of shifts has confirmed that the single item measures of workload and effort are correlated with a single item measure of fatigue. Fatigue is then correlated with performance impairment due to working, as measured using the simple reaction time task before and after work.

These first two studies have been small scale and focused on specific time periods. It is now important to determine whether similar results are obtained in a wider range of different jobs and locations, and whether these effects occur generally. The next study aimed to extend these findings using a survey methodology and a much larger sample covering a wide variety of jobs in a rail company. The goal was to see which outcomes are associated with job demands, and to try to replicate the results obtained in the diary studies. A different measure of performance was used in this study, namely a single question regarding performance efficiency.

4 Study 3: A Survey of Demands, Fatigue and Performance in Rail Staff

A detailed account of this survey is given in another paper [25]. The main features of the study are briefly summarised here. This, plus details of the actual questionnaire, should provide enough methodological detail. The questionnaire used was based on the Smith Wellbeing Questionnaire (SWELL, [19]). It was designed to provide a detailed profile of the wellbeing of the organisation. It also allows consideration of specific issues and the one of interest here was the association between job demands, fatigue and performance.

4.1 Methods

4.1.1 Sample

1067 employees of a train company completed the questionnaire (Mean age: 44.25 years). This represented a response rate of approximately 50%. The main job types were train drivers, conductors, engineers, station staff, administrators, managers and catering stewards. Participants were entered into a prize draw.

4.1.2 Questionnaire

This is given in Appendix 2.

4.2 Results

Job demands, the current measure of workload, were significantly correlated with fatigue ($r = 0.43$ $p < 0.001$). Demands were also associated with reduced efficiency at work ($r = -0.11$ $p < 0.01$). Fatigue was also associated with reduced performance ($r = -0.14$ $p < 0.01$).

Demands were not the only predictors of fatigue; it was also predicted by lifestyle, control/support at work, noise and shift work. A multiple regression put all of these predictors of fatigue, along with fatigue itself, into an analysis to predict performance. The results of this are shown in Table 3.

High job demands, an unhealthy lifestyle, shift work, and low control/support ($p <$ were all predictors of poor performance. Fatigue was no longer a significant predictor of performance when these variables were included.

Table 3. Regression predicting performance efficiency

Variable	Unstandardised coefficients beta	Unstandardised coefficients std error	Standardised coefficients beta	t	sig
Lifestyle	0.111	0.020	0.156	5.41	0.001
Noise	0.022	0.013	0.050	1.63	0.103
Shiftwork	0.289	0.091	0.096	3.20	0.001
Control/Support	0.227	0.019	0.346	11.79	0.000
Demands	−0.047	0.020	−0.075	−2.38	0.017
Fatigue	−0.019	0.020	−0.031	−0.95	0.344

4.3 Discussion

The present results confirm that high workload is associated with greater fatigue. At a univariate level, both workload and fatigue were associated with perceptions of reduced performance efficiency. However, the survey showed that there were other predictors of fatigue and impaired performance (unhealthy lifestyle; shift work; low control/support). When these were included in the analyses the effects of fatigue on performance were no longer significant. However, workload (job demands) remained a significant predictor of performance in these multi-variate analyses.

The results obtained in the survey show a different pattern of results to those obtained in the diary studies. There could be a number of different interpretations of these discrepancies. The first could be that the measures of workload and fatigue used in the survey were different from those used in the diary studies. However, job demands were correlated with fatigue in the survey which is similar to the observed relationship between workload and fatigue in the diary studies. What may be more important are the different measures of safety/performance used in the three studies. The first study used a mathematical calculation of the risk of being involved in an incident. The second study used an objective measure of reaction as the indicator of effects of the working day. The third study used a subjective assessment of performance efficiency which may not be correlated with the objective indicators of performance or safety.

5 Overall Discussion

The research described in this article has confirmed that workload is an important factor to consider in the operations of railways. Previous research on workload in the railways has largely focused on signallers. The present research has shown that it is highly relevant to the staff of passenger rail companies. The first two studies focused on safety critical staff, namely conductors/guards and engineers. The results from this research showed that workload increased fatigue, which in turn was associated with a greater risk of incidents and slower reaction times. Workload itself did not appear to have a direct influence on safety and performance outcomes. These findings are important for policy and practice. One of the problems faced by railway companies is where to place workload in terms of health and safety practice. The demonstrated strong link between workload and fatigue indicates that workload should come under the agenda of "fatigue". The company involved in the present research have a fatigue policy, and are also developing a scheme of fatigue awareness training. At the moment, fatigue is conceptualised in terms of working hours, and the HSE fatigue index is used as a tool to monitor and prevent fatigue. This suggests that future research should develop appropriate methods for assessing the workload of rail staff. One approach would be to develop the assessments of subjective workload used here. This needs to be supported by objective measurement of workload. Fundamental research is required to compare subjective and objective workload and also to distinguish between physical workload, mental workload and emotional workload. Approaches to these issues have already been developed in fatigue research. The link between workload and fatigue means that templates are already in place to help gain a better understanding of the area and make advances in policy and practice.

The last study used a survey methodology to collect data from a greater range of occupations. High job demands were one of the predictors of fatigue, and both of these were associated with perceptions of reduced performance. Multi-variate analyses showed that high workload remained a significant predictor of performance whereas the effects of fatigue could be accounted for by other factors. These discrepant results in the studies could reflect differences in the jobs represented or in the measures of performance used.

Further analyses are required to determine whether the overall results obtained are consistent when specific jobs are analysed. Again, a practical issue for the rail companies is where the workload should be addressed. The first two studies described here suggest that workload can affect levels of fatigue and as such should be treated as a safety issue. The areas covered by the survey in the third study fall more within the remit of the HR department. This is not to say that performance efficiency is not an issue, rather that different underlying mechanisms may be involved due to both outcomes and predictors being based on subjective perceptions. Validation of the results of the survey using objective measures is an important next step. This could be achieved for both the predictor variables (e.g. objective measurement of job demands) and the outcomes (objective measurement of performance). The results of the survey justify these future studies and suggest further fundamental research to inform practice and policy.

In conclusion, the results reported here show that workload influences the performance of rail staff, either directly or through its association with fatigue. An important

feature of the research has been the use of single item measures of workload, fatigue and performance. These short measures were acceptable and could be administered in real-life contexts.

Appendix 1. Diary Questions

Before work diary:

a. How many hours sleep did you get last night?

b. How was the quality of your sleep?

Not at all good								Very good	
1	2	3	4	5	6	7	8	9	10

c. How long did it take you to travel to work? _____ minutes

d. How well are you feeling?

Not at all well								Very well	
1	2	3	4	5	6	7	8	9	10

e. How alert do you feel now?

Very tired								Very alert
1	2	3	4	5	6	7	8	9	10

After work diary:

f. How was your workload today?

Very low								Very high	
1	2	3	4	5	6	7	8	9	10

g. How much effort did you have to put into your job today?

Very little								A great deal	
1	2	3	4	5	6	7	8	9	10

h. How fatigued do you feel now?

Not at all fatigued								Very fatigued	
1	2	3	4	5	6	7	8	9	10

i. How stressed do you feel now?

Not at all stressed							Very stressed		
1	2	3	4	5	6	7	8	9	10

j. What was the total length of your breaks today?

_____ minutes

Appendix 2: Questionnaire to Assess Wellbeing of Rail Staff (SWELL, [19])

1. *Age (years):*
2. *Gender: M/F*
3. *Job description:*
4. *Health-related behaviours*

A healthy lifestyle involves taking exercise, eating a balanced diet, not smoking, not drinking excessive amounts of alcohol, and not being overweight. To what extent do you have a healthy life style?

Not at all									Very much so
1	2	3	4	5	6	7	8	9	10

5. *Personality*

People often describe themselves as being positive ("seeing" the glass as half full) or negative ("seeing the glass as half empty"). How would you describe yourself?

Very negative									Very positive
1	2	3	4	5	6	7	8	9	10

Thinking about the last 6 months:

6. *Life satisfaction*

How satisfied are you with life in general?

Not at all									Very much so
1	2	3	4	5	6	7	8	9	10

7. *Life stress*

How much stress have you had in your life in general?

Very little									A great deal
1	2	3	4	5	6	7	8	9	10

8. *Happiness*

Would you say you are generally happy?

Not at all									Very much so
1	2	3	4	5	6	7	8	9	10

9. *Anxious/Depressed*

Would you say that you generally feel anxious or depressed?

Not at all									Very much so
1	2	3	4	5	6	7	8	9	10

10. *Musculo-skeletal problems*

Do you suffer from musculo-skeletal disorders (e.g. arthritis; back pain; sciatica; repetitive strain injury)?

Not at all									Very much so
1	2	3	4	5	6	7	8	9	10

11. *Noise and vibration*

Are you exposed to noise or vibration at work?

Not at all									Very much so
1	2	3	4	5	6	7	8	9	10

12. *Shift work/Night work*
Do you work shifts or work at night? Yes/No

13. *Fumes*
Are you exposed to fumes, dust or solvents at work?

Not at all									Very much so
1	2	3	4	5	6	7	8	9	10

14. *Job demands*
How demanding do you find your job (e.g. do you have constant pressure, have to work fast, have to put in great effort)?

Not at all demanding							Very demanding		
1	2	3	4	5	6	7	8	9	10

15. *Job control and support*
Do you feel you have control over your job and support from fellow workers?

Not at all									Very much so
1	2	3	4	5	6	7	8	9	10

16. *Perceived stress at work*
How much stress do you have at work?

Very little									A great deal
1	2	3	4	5	6	7	8	9	10

17. *Job satisfaction*
Are you satisfied with your job?

Not at all									Very much so
1	2	3	4	5	6	7	8	9	10

18. *Physical and mental fatigue*
How physically or mentally tired do you get at work?

Not at all tired									Very tired
1	2	3	4	5	6	7	8	9	10

19. *Illness caused or made worse by work*
Have you had an illness (either physical or mental) caused or made worse by work? Yes/No

20. *Presenteeism*
Do you ever come to work when you are feeling ill and knowing you can't do your job as well as you would like to?
Yes/No

21. *Efficiency at work*
How efficiently do you carry out your work?

Not very efficiently									Very efficiently
1	2	3	4	5	6	7	8	9	10

22. *Work-life balance*
Do you find your job interferes with your life outside work or your life outside of work interferes with your job?

Never									Very often
1	2	3	4	5	6	7	8	9	10

23. *Happy at Work*
Are you happy at work?
Never Very often
1 2 3 4 5 6 7 8 9 10
24. *Anxious/Depressed because of work*
Are you anxious or depressed because of work?
Never Very often
1 2 3 4 5 6 7 8 9 10
25. *Absenteeism*
Approximately how many days sick leave have you had in the last 12 months? _____
26. *Accidents at work*
How many accidents requiring medical attention have you had in the last 12 months? _____

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