Mental Workload and Other Causes of Different Types of Fatigue in Rail Staff

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Abstract. Workload and shift work have been addressed as causes of occupational fatigue in previous research. Fatigue in the workplace has usually been investigated as a single outcome. However, taking into account separate kinds of energy resources, there are different types of fatigue. The present study investigated mental workload and other causes of physical fatigue, mental fatigue, and emotional fatigue in a rail company. Overall, the results confirm the importance of mental workload for different types of work fatigue and reveal other specific causes for each type of fatigue. Prolonged work and insufficient rest resulted in physical fatigue, while poor shift patterns caused mental and emotional fatigue.

Keywords: Workload · Occupational fatigue · Rail industry · Physical fatigue · Mental fatigue · Emotional fatigue

1 Introduction

Occupational fatigue refers to extreme tiredness and reduced functional capacity experienced during and after work. Resulting in the deterioration of attention and impaired performance in the workplace, fatigue brings an increased risk of danger to rail staff, as many of their jobs are safety-critical. It also affects well-being of rail staff both at work and outside work [1]. Fatigue has generally been discussed as a single entity. However, taking into account the separate energy resources, it is clear that there are different types of fatigue, including physical fatigue, mental fatigue, and emotional fatigue. The physical fatigue resulting from the depletion of muscular energy represents physical tiredness and the incapacity to engage in physical activity, while mental fatigue resulting from the depletion of cognitive energy represents tiredness and the incapacity to engage in mental activity. Recently, in addition to these two types of fatigue, emotional fatigue has received growing amount of attention [2, 3]. This kind of fatigue results from the depletion of emotional energy and represents tiredness and the incapacity to engage in emotional activity. Frone and Tidwell [4] proposed the Three-Dimensional Work Fatigue Inventory (3D-WFI), suggesting that the measure of work fatigue should be multidimensional, with separate assessments of physical, mental, and emotional fatigue. The psychometric quality and construct of 3D-WFI was then validated in a large-scale national survey in the US [4]. In the railway industry, however, research that measures the three different types of work fatigue separately is still

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lacking, and the causes of different types of fatigue are still unclear. The Demands, Resources, and Individual Effects (DRIVE) model has been used as a framework for assessing fatigue in previous fatigue studies (e.g. [1, 5, 6]). In basic terms, this model proposes that high job demands, low job resources (support and control), and individual differences (e.g., negative personality or coping type) predict high levels of fatigue [7]. The DRIVE model was used in the present study to assess different types of fatigue.

The main goal of this study was to investigate the causes of different types of fatigue among rail staff. Toward this end, we began by reviewing the related work on risk factors of occupational fatigue. We then presented the aims, methods, and findings of present study aimed at identifying the stressors of physical, mental and emotional fatigue. It was followed by the discussion and the conclusions in the final two sections of this paper.

2 Related Work

Workload has been identified as one of the essential stressors of occupational fatigue, with high workload leading to a greater subjective feeling of fatigue [8, 9]. Workload is a multi-dimensional concept which involves time, the input load of mental and physical tasks [10], operator effort, and outcomes (i.e., performance or other results) [11]. In the domain of occupational fatigue, workload is often equated with job demands. Edwards and her colleagues [12] suggested that workload was affected by task demands variation, as well as the level of automation in the workplace. Smith and Smith [5] mentioned that in interviews, rail staff members generally believed that the level of effort required to complete work tasks was the major component of workload. These confirmed that the perception of the task load (i.e., subjective job demands) and effort are the core to understanding workload [13].

In the modern railway industry, jobs have placed more emphasis on mental workload, while the traditional physical workload has diminished due to the increasing level of automation in operating systems [14]. Mental workload is also complex and multi-dimensional which frequently is described by terms of mental effort or emotional strain [15–17]. It reflects the capacity or resources that are actually required to meet task demands [18], involving the time pressure and the effort exerted for the execution of the task [19, 20]. There has been considerable interest in mental workload [13, 20, 21] which has led to the development of models of mental workload and application to real-world problems (see [22–25]). Cain [26] reviewed the mental workload literature and claimed that it can be summarised as the total cognitive load required to accomplish a task under specific environmental and operational conditions (e.g., in a finite period of time). The majority jobs in rail transport, such as being a train driver, signaller (i.e., controller), and conductor (i.e., guard), require sustained vigilance. In addition, the engineer may be exposed to heavy time pressure which may result in heavy mental workload and increased feelings of fatigue.

Other than workload, risk factors such as shift work, sleep and rest, and individual differences have also been found to be associated with fatigue. Based on the timing to work, shift work includes day, night, and early morning (i.e., begins before 4 a.m.)

shifts. The night and early morning shifts have been found to result in fatigue [27]. Such shifts also disrupt the sleep–wake cycle and make recovery from fatigue more difficult [28]. Individual differences, such as a healthy lifestyle and positive personality, have been found to play a buffing role in increased fatigue [1]. Fan and Smith [6] systematically reviewed previous research on fatigue among rail staff, and found that workload, length of work, timing of the work (i.e., shift work), insufficient rest and sleep, poor sleep quality, job roles, and individual differences were associated with fatigue. An Australian study [29] suggested that the sleep/wake cycle, work hours and workload influenced rail staff's fatigue. Later, a large-scale fatigue survey covering all the job roles among rail staff [30] showed that train crew fatigue was predicted by heavy mental workload, low job control and support, shift work, noisy working environment, unhealthy lifestyle, and negative personality.

3 Aims

The main aim of the present study described in this paper was to investigate the causes of physical fatigue, mental fatigue, and emotional fatigue in a rail company in the UK. It separately measured the different types of fatigue, as well as types of job demands (i.e., physical demands, mental demands, and emotional demands). The study also aimed to build a more detailed picture of the relationships regarding mental workload, other risk factors, and different types of fatigue using the DRIVE model. The survey covered most of the potential risk factors of fatigue which were mentioned in previous literature, such as workload, timing to work, working hours, rest during work, sleep time and quality, and other activities that may influence fatigue. In addition, the current study aimed to determine whether an online version of such subjective measurements was as reliable as the offline one [30], and whether the online version can be used in future research (e.g., an online diary study).

4 Methods

4.1 Participants

A total of 246 participants completed an online questionnaire. Most of the participants were male (N = 173, 70.3%), with a mean age of 43.21 years (SD = 10.458, minimum 19.5yr, maximum 65.42yr). There were 66.9% of them who worked in South Wales, UK, while the rest worked in North Wales. The School of Psychology Research Ethics Committee at Cardiff University reviewed and approved this online study.

4.2 Materials

This online survey ran in the spring of 2017. The questionnaire consisted of 39 questions, the majority of which were on a 10-point scale and the rest were Yes/No answers. Data collection was performed on the Qualitrics online survey platform. The survey used single-item subjective measures which were valid and reliable [31] and have been used in previous fatigue studies (e.g., [5, 30]). It investigated the details of working hours, shift work, workload, and the potential risk factors outside work (e.g., sleep quality, other activity), and assessed the six predictors of train crew fatigue confirmed in a previous study [30]. The survey asked participants not only about the causes of their own fatigue, but also of that of their colleagues, which provided relatively objective observation data for assessing the risk factors of fatigue. Frone and Tidwell [4] claimed that the measure of work fatigue should be multidimensional with separately assessing physical, mental and emotional fatigue. Given their suggestion, in this questionnaire, work fatigue and job demands were measured alongside physical, mental, and emotional dimensions.

4.3 Analysis

Data analysis was carried out using SPSS 23. The data were analysed using descriptive analysis, exploratory factor analysis, correlation analysis, and regressions. The approach of exploratory factor analysis used here was principal components analysis (PCA) with Direct Oblimin rotation, with an oblique rotation to extract eigenvalues equalling or exceeding the threshold of 1.

5 Results

5.1 Descriptive

The primary job types participants reported were managers (21.7%), conductors (20.9%), administrators (20.9%), and train drivers (19.1%), followed by engineers (11.9%) and station workers (5.3%). There were two participants with missing job type data. There were 67.9% of participants doing shift-work. The sample generally reported personality (73.3%), efficiency (91.4%), and effort (95.5%) toward the positive end (all with threshold = 6).

5.2 Factor Analysis

Principal components analysis (PCA) with the Direct Oblimin rotation was conducted, and the factor scores (i.e., component scores) were created using the regression method. The components and factor loadings are described in Table 1.

In total, there were 11 components, including 10 independent factors and one outcome. Independent factors included negative work characteristics, positive work and individual characteristics, job demands, length of shift, overtime work, timing of shift, mental workload, effort, positive sleep factor, and other activities. The outcome component was three-dimensional fatigue (3D-fatigue). It should be noted that, based on factor loading, the contribution of physical demands on three-dimensional work demands (3D-demands, originally component 7) was found to be much smaller than that of either mental or emotional demands; thus, component 7 was renamed as mental workload.

Table 1. Summary of the factor loading of PCA with Oblimin rotation.

	Factor loading	Initial eigenvalue	Cumulative variance (%)
Predictors		1.657	68.1
Component 1: negative work characteristics			
Shift work	.882		
Exposure to noise and vibration	.859		
Component 2: positive work and individual characteristics			
Positive personality	.811		
Healthy behaviours	.667		
Job control and support *Component 3: job demands*	.580		
Job demands	.934		
Causes of fatigue		3.058	68.4
Component 4: length of shift			
Length of shift (colleagues)	.808		
Length of shift (self)	.805		
Component 5: overtime work			
Overtime	.829		
Number of shifts before rest day (colleagues)	.695		
Overtime (colleagues)	.613		
Number of shifts before rest day (self)	.544		
Component 6: timing of shift			
Timing of shift (self)	.828		
Timing of shift (colleagues)	.822		
Workload		2.109	63.5
Component 7: mental workload			
Hurried or rushed	.845		
Frustrating	.782		
Mental demands	.750		
Physical demands	.462		
Component 8: effort			
Effort	.960		
Activity outside work		1.585	72.4
Component 9: positive sleep factor			
Sleep length (hours)	.874		
Quality of sleep	.870		
Component 10: other activities			
Activities outside work (colleagues)	.826		
Activities outside work (self)	.816		
Outcome		2.021	67.4
Component 11: 3D-fatigue			
Emotional fatigue	.876		
Mental fatigue	.859		
Physical fatigue	.717		

5.3 Bivariate Analysis

Associations Between Fatigue, Efficiency, and Working Hours. The associations between the three different types of fatigue, efficiency, and six working hours-related variables were investigated using a Pearson correlation (shown in Table 2). The three dimensions of fatigue were significantly correlated with each other ($p < .01$). Physical fatigue showed a significant positive correlation with shift length and the frequency of rest and breaks during work (r from .26 to .27, $p < .01$). Mental fatigue showed a significant correlation with the start time of shift work (r (222) = −.20, $p < .01$), with higher levels of mental fatigue associated with earlier shift work start times (i.e., early morning shift work). Mental fatigue, emotional fatigue, and efficiency were significantly correlated with the numbers of shifts taken before a rest day, with correlation coefficients between .13 and .15, both $p < .05$. In addition, higher efficiency was found to be significantly associated with longer break length, (r (219) = .17, $p < .05$).

Table 2. Correlations between three different types of fatigue, efficiency, and working hour-related independent variables (IV).

Variables	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)
Physical fatigue (1)	1									
Mental fatigue (2)	.40**	1								
Emotional fatigue (3)	.44**	.67**	1							
Efficiency (4)	−.02	−.09	−.12	1						
Shift length (5)	.26**	.11	.09	−.12	1					
Number of shifts before rest day (6)	.02	.13*	.15*	.15*	−.31**	1				
Start time of shift (7)	−.10	−.20**	−.08	−.11	.18**	−.27**	1			
Overtime work (8)	.11	.03	.07	.13	−.09	.15*	−.13	1		
Frequency of break during work (9)	.27**	.02	.03	.06	.18*	−.09	−.10	−.05	1	
Break length (10)	−.06	−.08	−.10	.17*	.09	.01	.03	.04	−.02	1

*$p < 0.05$, **$p < 0.001$

Associations Between 3D-Fatigue and Independent Factors. The associations between 3D-fatigue and 10 independent components were analysed using their factor scores. The results are summarised in Table 3. As the components of fatigue predictors, job demands and negative work characteristics showed a significant positive correlation with 3D-fatigue, while positive work and individual characteristics showed significant negative correlations with fatigue (all $p < 0.01$). 3D-fatigue positively correlated with length of shift, overtime work, and timing of shift (r from .20 to .32, $p < .01$). Considering the components of the factor mental workload, 3D-fatigue showed a significant positive correlation with emotional and mental demands, r (217) = .66, $p < .01$, with a higher level of fatigue associated with a higher level of emotional and mental demands. Meanwhile, fatigue showed a negative correlation with effort, indicating that poorer effort was associated with a higher level of fatigue. In terms of the activities outside of work, fatigue showed a significant correlation with the sleep factor, r (195) = −.260, $p < 0.01$, with a higher level of fatigue associated with a poorer sleep experience. There was no significant association between fatigue and other activities.

Table 3. Correlation between 3D-fatigue and factor IVs.

Factor	3D-fatigue
Negative work characteristics	.35**
Positive work and individual characteristics	−.24**
Job demands	.47**
Length of shift	.32**
Overtime work	.31**
Timing of shift	.20**
Mental workload	.66**
Effort	−.17*
Sleep factor	−.26**
Other activity	.02

*$p < 0.05$, **$p < 0.001$

5.4 Regression

Regression analyses were carried out to investigate the associations of multiple independent variables with fatigue. First, a linear regression was run using the factor scores of the independent components and 3D-fatigue. As shown in Table 4, mental work, positive work and individual characteristics, and job demands were the strongest predictors of 3D-fatigue by beta weight, followed by overtime work. The regressions account for 51.3% of the variance in 3D-fatigue.

Table 4. Regression predicting 3D-fatigue.

Variables	B	S. E	β	t	Sig.
Negative work characteristics	.099	.071	.100	1.384	0.168
Positive work and individual characteristics	−.172	.064	−.173	−2.680	<0.01
Job demands	.178	.080	.171	2.231	<0.05
Length of shift	.048	.066	.050	.727	0.468
Overtime work	.123	.058	.123	2.109	<0.05
Timing of shift	.079	.065	.080	1.216	0.226
Mental workload	.425	.084	.418	5.042	<0.001
Effort	−.047	.067	−.045	−.700	0.485
Sleep factor	−.081	.058	−.083	−1.408	0.161
Other activities	.040	.057	.041	.702	0.484

However, given that the risk factors for different dimensions of fatigue can be different, separate analyses of the physical, mental, and emotional fatigue variables were needed. Therefore, binary logistics regression analyses (using enter method) were run, using the original fatigue variables as the outcomes, and dichotomised factors as the predictors. The dependent variables used here were physical fatigue, mental fatigue, and emotional fatigue, which were dichotomised into high/low groups using median splits ($M_{Physical\ Fatigue} = 6$, $M_{Mental\ Fatigue} = 7$, $M_{Emotional}$ Fatigue = 6). The independent variables were the 10 independent factors, which were dichotomised though median splitting the factor scores. The results are presented in Tables 5, 6 and 7.

Analysing Predictors of Physical Fatigue. In the regression analysis, negative work characteristics, long length of shifts, and overtime work were found to be associated with physical fatigue at a significant level ($p < .05$). The strongest predictor of reporting a physical fatigue problem in this model was the length of shift work, recording an odds ratio (OR) of 4.5, indicating that participants working long shifts were 4.5 times more likely to report physical fatigue problems ($p < 0.001$) than those with shorter shifts. This was followed by overtime work, recording an OR of 3.1, and negative work characteristics, recording an OR of 2.6. High mental workload and high job demands showed a trend toward significance in predicting physical fatigue ($p_{Mental\ workload} = 0.069$, $p_{Job\ Demands} = 0.084$, both OR = 2.1). There was no significant association between other factors and physical fatigue in this model. The account of explanatory power of this model was 39.5% of the variance, and the classification accuracy was 75.0%. The full model containing all predictors, was statistically significant, X^2 (1, N = 172) = 59.972, $p < 0.001$, indicating that the model was able to distinguish between participants who reported and those who did not report a physical fatigue problem.

Table 5. Odds ratio of each IV on physical fatigue.

Variables	Odds ratio	95% CI for odds ratio
Negative work characteristics (high)	2.630*	[1.189, 5.820]
Positive work and individual characteristics (low)	2.080	[0.907, 4.771]
Job demands (high)	1.888	[0.856, 4.165]
Length of shift (long)	4.468**	[1.929, 10.347]
Overtime work	3.122*	[1.433, 6.804]
Timing of shift (poor)	0.909	[0.420, 1.969]
Mental workload (high)	2.105	[0.943, 4.702]
Effort (high)	1.239	[0.563, 2.729]
Sleep factor (negative)	1.489	[0.682, 3.250]
Other activities	1.769	[0.808, 3.874]

*$p < 0.05$, **$p < 0.001$

Analysing Predictors of Mental Fatigue. Job demands, mental workload, and overtime work were found to influence mental fatigue significantly ($p < .01$). The strongest predictor of mental fatigue was job demands, recording an OR of 5.4, indicating that participants working with high job demands were 5.4 times more likely to report a mental fatigue problem ($p < 0.001$) than those with low job demands. This was followed by mental workload (OR = 3.0) and overtime work (OR = 2.9). No significant association between other factors and mental fatigue was found in this model. The model of mental fatigue accounted for 40.0% of the variance and correctly classified 75.7% of cases. The full model containing all predictors, was statistically significant (X^2 (1, N = 173) = 61.131, $p < 0.001$), indicating that the model was able to distinguish between participants who reported and those who did not report a mental fatigue problem.

Table 6. Odds ratio of each IV on mental fatigue.

Variable	Odds ratio	95% CI for odds ratio
Negative work characteristics (high)	1.658	[0.728, 3.777]
Positive work and individual characteristics (low)	1.253	[0.549, 2.857]
Job demands (high)	5.403**	[2.465, 11.840]
Length of shift (long)	0.807	[0.337, 1.932]
Overtime work	2.899*	[1.324, 6.345]
Timing of shift (poor)	1.066	[0.478, 2.378]
Mental workload (high)	2.959*	[1.311, 6.679]
Effort (high)	1.788	[0.808, 3.954]
Sleep factor (negative)	1.819	[0.817, 4.051]
Other activities	0.951	[0.440, 2.058]

* $p < 0.05$, ** $p < 0.001$

Analysing Predictors of Emotional Fatigue. Emotional fatigue was significantly predicted by positive work and individual characteristics, job demands, length of shift, overtime work, timing of shift, and mental workload. Overtime work was the strongest predictor of reporting emotional fatigue, recording an OR of 4.2, $p < 0.001$. This was followed by length of shift (OR = 3.9, $p < .01$), low scores for positive work and individual characteristics (OR = 3.8, $p < .01$), and high job demands (OR = 3.6, $p < .01$). Mental workload and the timing of shift were also the important predictors of emotional fatigue, both recording ORs of 2.7, $p < .05$. The model of emotional fatigue accounted for 42.1% of the variance and correctly classified 76.3% of cases. The full model containing all predictors, was statistically significant (X^2 (1, N = 173) = 65.407, $p < 0.001$), indicating that the model was able to distinguish between participants who reported and those who did not report an emotional fatigue problem.

Table 7. Odds ratio of each IV on emotional fatigue.

Variable	Odds ratio	95% CI for odds ratio
Negative work characteristics (high)	1.478	[0.636, 3.434]
Positive work and individual characteristics (low)	3.809*	[1.635, 8.875]
Job demands (high)	3.603*	[1.604, 8.093]
Length of shift (long)	3.883*	[1.591, 9.473]
Overtime work	4.180**	[1.851, 9.436]
Timing of shift (poor)	2.804*	[1.197, 6.568]
Mental workload (high)	2.809*	[1.248, 6.323]
Effort (high)	1.541	[0.703, 3.381]
Sleep factor (negative)	1.378	[0.630, 3.014]
Other activities	1.776	[0.799, 3.948]

*$p < 0.05$, **$p < 0.001$

6 Discussion

The present study confirmed that mental workload is an essential cause of fatigue among rail staff. Although other risk factors were also found to be associated with fatigue, only positive work and individual characteristics, job demands, overtime work, and mental workload predicted fatigue as a single outcome, which is consistent with previous studies [6, 30]. The findings provided more specific information on mental workload and other causes of different types of fatigue. When different types of fatigue were analysed separately, mental workload, job demands, and overtime work were still found to predict fatigue in all its three dimensions. Physical fatigue was also associated with longer length of shift work, negative work characteristics, and less frequent breaks during work. Moreover, the findings provide evidence that poor shift patterns result in mental and emotional fatigue. Both mental and emotional fatigue were associated with poor timing of shifts and a greater number of shifts taken before a day of rest. Emotional fatigue was also predicted by positive work and individual characteristics, which means that high job supports and control, healthy lifestyle, and positive personality helped to reduce emotional fatigue. Although the effects of positive work and individual characteristics were in line with a previous large-scale study [1] that showed they play a buffering role in fatigue, they only influenced emotional fatigue, not mental fatigue. These findings support the idea that the jobs of rail staff place greater emphasis on the mental workload. In the factor analysis, the contribution of physical job demands to 3D-demands was much smaller than that of mental and emotional demands. This supported the view from previous research [14] that currently, work in the railway industry imposes more cognitive demands than physical demands. Moreover, the predictive ability of job demands was consistent with those of mental workload. It predicted all three different types of fatigue, as well as fatigue as a whole, while the effect of effort was not found to be significant. It was the mental workload and overtime work that resulted in all different types of fatigue among train crew. “More work over longer times from fewer people” is a dangerous strategy which can make the train staff more fatigued. Currently, fatigue is conceptualised in terms of working hours in rail transport. This suggests that future fatigue study of the railway staff should develop an appropriate mental workload measurement. Subjective measure of the mental workload will be sufficient [16, 26], despite the fundamental research required to compare subjective and objective workload in the industry. Based on data gathered through an online survey, the results of the current study are in line with those of previous studies (e.g., [5, 6, 30]). Furthermore, the results showed a bias towards having a positive personality, efficiency, and effort, which also appeared in the offline survey [30]. These suggests that the online survey was as reliable as the offline version, and in the future, online studies can be carried out.

In future research, measuring different types of fatigue separately will be useful to better understand job role differences. Although the high mental workload and overtime work cannot be avoided in many industries, a better understanding of the causes of different types of fatigue among workers will help with fatigue management in the workplace. It is suggested that sufficient opportunities to take breaks during work should be provided to control physical fatigue, and that shift patterns should be well arranged to reduce the risk of mental and emotional fatigue.

7 Conclusion

Fatigue has usually been investigated as a single outcome, but there are different types of fatigue taking into account separate kinds of energy resources. This study explored the causes of physical, mental, and emotional fatigue among rail staff. The finding indicated that mental workload and overtime work were the essential causes of all these types of fatigue among rail staff. Alongside these two causes, these three dimensions of fatigue were influenced by different factors. Physical fatigue resulted from prolonged shift work, insufficient rest during work, and negative work characteristics, while mental and emotional fatigue resulted from poorly arranged shift patterns, including poor timing of shifts and working more shifts before taking a regular rest day. Positive work and individual characteristics played a buffering role only for emotional fatigue, but not for mental fatigue. This suggested that to recovery from physical and mental fatigue, appropriate rests and breaks and better arranged shift patterns were needed. In future research, measuring different types of fatigue separately will be useful to better understand job role differences and benefit fatigue management.

References

1. Fan, J., Smith, A.P.: The mediating effect of fatigue on work-life balance positive well-being in railway staff. Open J. Soc. Sci. **6**, 1–10 (2018). https://doi.org/10.4236/jss.2018.66001
2. Shirom, A., Melamed, S.: A comparison of the construct validity of two burnout measures in two groups of professionals. Int. J. Stress Manag. **13**(2), 176–200 (2006). https://doi.org/10.1037/1072-5245.13.2.176

3. Australian Safety and Compensation Council. Work-related fatigue: summary of recent indicative research. https://www.safeworkaustralia.gov.au/doc/work-related-fatigue-summary-recent-indicative-research-archived
4. Frone, M.R., Tidwell, M.C.O.: The meaning and measurement of work fatigue: development and evaluation of the three-dimensional work fatigue inventory (3D-WFI). J. Occup. Health Psychol. **20**(3), 273–288 (2015). https://doi.org/10.1037/a0038700
5. Smith, A.P., Smith, H.N.: Workload, fatigue and performance in the rail industry. In: Longo, L., Leva, M.C. (eds.) H-WORKLOAD 2017. CCIS, vol. 726, pp. 251–263. Springer, Cham (2017). https://doi.org/10.1007/978-3-319-61061-0_17
6. Fan, J., Smith, A.P.: A preliminary review of fatigue among rail staff. Front. Psychol. **9**, 634 (2018). https://doi.org/10.3389/fpsyg.2018.00634
7. Mark, G.M., Smith, A.P.: Stress models: a review and suggested new direction. In: Houdmont, J., Leka, S. (eds.) Occupational Health Psychology: European Perspectives on Research, Education and Practice, pp. 111–144. Nottingham University Press, Nortingham (2008)
8. Robert, G., Hockey, J., Wiethoff, M.: Assessing patterns of adjustment to the demands of work. In: Puglisi-Allegra, S., Oliverio, A. (eds.) The Psychobiology of Stress, vol. 54, pp. 231–240. Springer, Dordrecht (1990). https://doi.org/10.1007/978-94-009-1990-7_21
9. Dorrian, J., Baulk, S.D., Dawson, D.: Work hours, workload, sleep and fatigue in australian rail industry employees. Appl. Ergon. **42**(2), 202–209 (2011). https://doi.org/10.1016/j.apergo.2010.06.009
10. Wickens, C.D.: Engineering Psychology and Human Performance, 2nd edn. HarperCollins Publishers Inc., New York (1992). https://doi.org/10.1146/annurev.ps.27.020176.001513
11. Jahns, D.W.: A concept of operator workload in manual vehicle operations. Research Institute Anthropotechnology, Meckenheim (1973)
12. Edwards, T., Martin, L., Bienert, N., Mercer, J.: The relationship between workload and performance in air traffic control: exploring the influence of levels of automation and variation in task demand. In: Longo, L., Leva, M.C. (eds.) H-WORKLOAD 2017. CCIS, vol. 726, pp. 120–139. Springer, Cham (2017). https://doi.org/10.1007/978-3-319-61061-0_8
13. Hancock, P.A., Caird, J.K.: Experimental evaluation of a model of mental workload. Hum. Factors **35**, 413–429 (1993). https://doi.org/10.1177/001872089303500303
14. Young, M.S., Brookhuis, K.A., Wickens, C.D., Hancock, P.A.: State of science: mental workload in ergonomics. Ergonomics **58**(1), 1–17 (2015). https://doi.org/10.1080/00140139.2014.956151
15. Longo, L.: Formalising human mental workload as a defeasible computational concept. Ph.D. thesis, Trinity College Dublin (2014)
16. Longo, L.: A defeasible reasoning framework for human mental workload representation and assessment. Behav. Inf. Technol. **34**(8), 758–786 (2015). https://doi.org/10.1080/0144929X.2015.1015166
17. Reid, G.B., Nygren, T.E.: The subjective workload assessment technique: a scaling procedure for measuring mental workload, vol. 52. North-Holland (1988). https://doi.org/10.1016/s0166-4115(08)62387-0
18. Eggemeier, F.T., Wilson, G.F., Kramer, A.F., Damos, D.L.: Workload assessment in multi-task environments. In: Damos, D.L. (ed.) Multiple Task Performance, pp. 207–216. Taylor & Francis, London (1991)
19. Hancock, P.A., Chignell, M.H.: Mental workload dynamics in adaptive interface design. IEEE Trans. Syst. Man Cybern. **18**(4), 647–658 (1988). https://doi.org/10.1109/21.17382

20. Wickens, C.D.: Mental workload: assessment, prediction and consequences. In: Longo, L., Leva, M.C. (eds.) H-WORKLOAD 2017. CCIS, vol. 726, pp. 18–29. Springer, Cham (2017). https://doi.org/10.1007/978-3-319-61061-0_2
21. Hancock, P.A.: Whither workload? Mapping a path for its future development. In: Longo, L., Leva, M.Chiara (eds.) H-WORKLOAD 2017. CCIS, vol. 726, pp. 3–17. Springer, Cham (2017). https://doi.org/10.1007/978-3-319-61061-0_1
22. Rizzo, L., Dondio, P., Delany, S.J., Longo, L.: Modeling mental workload via rule-based expert system: a comparison with NASA-TLX and workload profile. In: Iliadis, L., Maglogiannis, I. (eds.) AIAI 2016. IAICT, vol. 475, pp. 215–229. Springer, Cham (2016). https://doi.org/10.1007/978-3-319-44944-9_19
23. Longo, L.: Mental workload in medicine: foundations, applications, open problems, challenges and future perspectives. In: 2016 IEEE 29th International Symposium on Computer-Based Medical Systems (CBMS), pp. 106–111. IEEE (2016). https://doi.org/10.1109/cbms.2016.36
24. Byrne, A.: Mental workload as an outcome in medical education. In: Longo, L., Leva, M.C. (eds.) H-WORKLOAD 2017. CCIS, vol. 726, pp. 187–197. Springer, Cham (2017). https://doi.org/10.1007/978-3-319-61061-0_12
25. Guastello, S.J., Marra, D.E., Correro, A.N., Michels, M., Schimmel, H.: Elasticity and rigidity constructs and ratings of subjective workload for individuals and groups. In: Longo, L., Leva, M.C. (eds.) H-WORKLOAD 2017. CCIS, vol. 726, pp. 51–76. Springer, Cham (2017). https://doi.org/10.1007/978-3-319-61061-0_4
26. Cain, B.: A review of the mental workload literature. RTO-TR-HFM-121-Part II, NATO report, pp. 4-1–4-34. Defence Research and Development, Toronto, Canada (2007)
27. Dorrian, J., Baulk, S.D., Dawson, D.: Work hours, workload, sleep and fatigue in Australian Rail Industry employees. Appl. Ergon. **42**, 202–209 (2011). https://doi.org/10.1016/j.apergo.2010.06.009
28. Ferguson, S.A., Lamond, N., Kandelaars, K., Jay, S.M., Dawson, D.: The impact of short, irregular sleep opportunities at sea on the alertness of marine pilots working extended hours. Chronobiol. Int. **25**(2–3), 399–411 (2008). https://doi.org/10.1080/07420520802106819
29. Dorrian, J., Baulk, S.D., Dawson, D.: Work hours, workload, sleep and fatigue in Australian Rail Industry employees. Appl. Ergon. **42**(2), 20–209 (2011). https://doi.org/10.1016/j.apergo.2010.06.009
30. Fan, J., Smith, A.P.: The impact of workload and fatigue on performance. In: Longo, L., Leva, M.C. (eds.) H-WORKLOAD 2017. CCIS, vol. 726, pp. 90–105. Springer, Cham (2017). https://doi.org/10.1007/978-3-319-61061-0_6
31. Williams, J., Smith, A.P.: Stress, job satisfaction and mental health of NHS nurses. In: Contemporary Ergonomics and Human Factors 2013: Proceedings of the International Conference on Ergonomics and Human Factors 2013, Cambridge, UK, 15–18 April 2013, p. 95. Taylor & Francis, London (2013). https://doi.org/10.1201/b13826-22