A study of fatigue in construction

For

HS2 Limited and Innovation

20th February 2025

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1.0 Executive Summary

Fatigue is widely recognised as a major risk in construction, albeit a risk the industry acknowledges is not always adequately addressed.

Tiredness and fatigue is costing governments, private clients, construction firms and construction workers each day. One estimate suggests fatigue costs £1,224 per construction worker per annum. Extrapolating this figure, the cost of fatigue to major UK infrastructure construction is £673m a year and £38m to HS2.

The problem is, it has been difficult to understand the extent of fatigue, its impact on workers and to what extent fatigue contributes to accidents and incidents.

This report presents the results of a study, undertaken across HS2, to better understand fatigue risk in major infrastructure construction projects. The aim of the study was to understand where and when fatigue risk increases and how construction-specific job characteristics impact that risk. Research conducted in 2019 on Tideway concluded that further research into fatigue was both important and achievable.

This study was conducted on behalf of HS2 Occupational Health and HS2 Innovation. By improving our understanding of fatigue as a health and safety risk we can reduce its impact, with corresponding benefits for individual construction workers, their employers, public infrastructure projects and the taxpayer. We hope some of the learnings from this study can be applied on the current project and we hope these new insights will be part of HS2's long term legacy.

We designed and created a user-friendly web application to collect data on sleepiness and the impact of fatigue on performance at multiple points during a shift from voluntary participants.

Key findings

A large percentage of respondents are not obtaining sufficient good quality sleep prior to work. In the (n. = 528) respondents who completed our (voluntary) sleep health assessment, average sleep was 6 hours 38 minutes prior to work. 49% of respondents fail to achieve seven or more hours of sleep prior to work. 83% of respondents are not meeting their sleep need over a week or shift cycle. 15% of respondents are at risk of sleep apnoea and 31% are at risk of insomnia. 57% regularly experience sleepiness at work and for 35% sleepiness interferes with daily work activities at least a few days a month.

Increasing shift duration does not always increase sleepiness and negatively impact performance at work. We saw contrasting results when we reviewed 'standard' Monday to Friday working weeks with different shift durations. In those working on site we saw a decrease in average sleepiness scores as shift duration increased, which is counter intuitive but similar to findings of a study we recently completed for National Highways in those who drive for work. The impact of fatigue on work performance remained steady as shift duration increased for those working on site but improved for office-based workers.

We found that fatigue risk rarely increases at a linear rate shift-to-shift and often fluctuates over a shift cycle. Shift patterns with a short turnaround often saw increased fatigue risk at the beginning of a shift cycle. Shorter shifts saw the peak in the relative risk of fatigue more in line with natural circadian low points (14:00 to 16:00 and 02:00 to 06:00) whereas the longer shifts tended to see relative risk of fatigue peak in the final two to three hours of a shift.

The findings from our alertness test showed that whilst efficiency rates (number of trials completed in sixty seconds) were similar on the night and day shifts, accuracy rates were 9% lower on the night shift. This is interesting for roles requiring vigilance.

Our key findings in respect of how construction-specific job characteristics impact fatigue risk include:

- Office workers experience higher levels of sleepiness versus those on site but those on site feel a greater effect of fatigue on work performance
- Those working below ground experienced higher levels of sleepiness and a greater impact of fatigue on work performance
- Those working away from home slept for less time before work, experienced significantly higher levels of sleepiness and experienced a much greater impact on performance at work
- There was a clear link between the amount of sleep workers obtained prior to work and life satisfaction scores
- Sleepiness and the impact of fatigue on work performance increase with the length of time shift workers have been working shifts, until they have been working shifts for ten or more years.

A piece of analysis we undertook on a sample of accident and incident data found that a significant percentage of accidents and incidents, where fatigue could have been a contributory factor, occurred at times when our research suggested there may be an elevated risk of fatigue. That does not mean fatigue was a factor, but it poses the question of whether fatigue may be a greater contributor to accidents and incidents than the industry is currently aware of.

Recommendations

If the industry was better able to predict fatigue risk in working patterns, including refining fatigue risk based on job characteristics, there is potential to improve health, safety and productivity.

There are potentially benefits to all stakeholders when fatigue is given greater prominence as a health and safety risk. Fatigue risk should be considered at the earliest stages of works planning, including when projects are discussing the shift patterns they are looking to implement.

Fatigue risk management plans should pay attention to times of elevated fatigue risk and direct, or at least encourage, work with higher degrees of danger or that require high levels of vigilance, concentration or physical activity to be undertaken when alertness is higher. Where safety-critical work must be undertaken during times of heightened fatigue risk it would be prudent to add interventions, such as increasing the level of supervision on a task. Weekly and daily works planning meetings should consider if work needs to be undertaken when fatigue risk is elevated and apply appropriate interventions.

It would be instructive to try to gain a greater insight into the role of fatigue in the aetiology of accidents – studying the causes. At the moment this is potentially not well understood. Asking appropriate questions could reveal that fatigue is a greater contributor to adverse health, safety and productivity outcomes. If so, this will strengthen the business case for more investment in further research and interventions.

We would encourage accident and incident investigations to look beyond the individual who is injured or undertaking an unsafe act. It would be worth reviewing the chain of events, the decisions made, and those making the decisions to get closer to the root cause of the incident. Part of this deeper review should include identifying whether decisions and actions took place when alertness may have been impaired.

In populations with more rigid start, finish and break times we often found a spike in sleepiness thirty to ninety minutes after the first break. Our discussions revealed the food choices made by workers when eating in canteens may induce to a post-prandial spike in sleepiness. Subsidising healthy food options in canteens may provide employers with a healthy return, especially if there is currently a corresponding increase in adverse safety and productivity events during this window.

Our study identified certain groups as being at particular risk of sleep disorders. These included night workers, those working shifts for two or more years, those working below ground, supervisors and senior managers. Running sleep disorder screening for these worker groups and pointing them towards suitable diagnosis and treatment pathways will be beneficial for the individual and the organisations employing them.

Third Pillar of Health will now work with our existing stakeholders and use the data collected in this study to develop a new tool, to help identify times of heightened fatigue risk based on shift patterns and job characteristics, as well as an app to better understand the potential contribution of fatigue in accidents and incidents. If you would like to be kept abreast of developments, please contact us using the details on the first page of this report or visit www.alert-risk.com.

2.0 Introduction

This study has been commissioned by HS2 Limited and HS2 Innovation. This study sought to better understand fatigue risk in different working patterns worked in infrastructure construction projects and how job characteristics impact fatigue risk.

Secondary aims of the study were to understand whether the Fatigue and Risk Index – the biomathematical model most commonly used to forecast fatigue risk in working patterns and previously supported by the HSE – was suitable and reliable for the type of work undertaken in construction.

Globally, it is estimated that there are 6,000 worker deaths due to construction accidents annually (1); with a major proportion (80%) reported due to individual attributes (2-4). According to the HSE 51 workers were killed in work-related accidents in construction in 2023/4. Occupational accidents result in devastating socioeconomic consequences because, in addition to causing physical and mental disability, fatal accidents have significant personal, societal, and financial costs (5).

Our research and report are specifically focused on fatigue. Whilst there is no single definition of fatigue, according to the HSE's 'Managing shiftwork' guidance, it is generally thought to be the decline in mental and / or physical performance that results from prolonged mental or physical exertion, lack of quality sleep or disruption of the internal body clock.

We hope the results of our research will help better inform those working on HS2 and other infrastructure projects of times of elevated fatigue risk and how different job characteristics and demographics influence fatigue risk. We also hope this study will form part of the legacy HS2 leaves the construction industry.

We believe our study across HS2 is the largest study ever conducted on fatigue risk in construction when factoring in the number of participants, the total number of days of participation, the length of the study and the number of data points gathered.

Our research set out to understand some key questions, including:

- Do longer shifts result in higher levels of sleepiness; do longer shifts have a greater impact on performance at work?
- Is sleepiness greater if working in the office, on site or both; is the impact on performance greater if working in the office, on site or both?
- Does shift working result in higher levels of sleepiness; does shift working have a greater impact on performance at work?
- Does how long workers have worked shifts result in higher levels of sleepiness; does how long workers have worked shifts have a greater impact on performance at work?
- Is sleepiness greater if working above ground, below ground or both; is the impact on performance greater if working above ground, below ground or both?
- Do jobs requiring mental activity, physical activity or both increase sleepiness; do jobs requiring mental activity, physical activity or both have a greater impact on performance at work?
- Does the percentage of a shift fully focused on work activities result in higher levels of sleepiness; does the percentage of a shift fully focused on work activities have a greater impact on performance at work?
- Do those working away from home experience higher levels of sleepiness; do those working away from home see a greater impact on performance at work?
- Does the level of seniority have any effect on sleepiness; does the level of seniority have an impact on performance at work?
- Does age have any effect on sleepiness; does age have an impact on performance at work?

- Does (biological) sex have any effect on sleepiness; does (biological) sex have an impact on performance at work?

Existing knowledge and literature review

Fatigue can be exacerbated by the work environment, including dim lighting, high temperatures, high noise and high comfort; by the type of work being undertaken including complex, boring or monotonous work; or by shift design including long periods or work, insufficient breaks and extended workdays.

According to the Canadian Standard Association the effects of fatigue can be mental, physical or subjective. The effects of fatigue include reduced mental capacity, inattention, indecisiveness, physiological weakness, physical exhaustion, tiredness, drowsiness, weariness, sleepiness and lethargy. Additional effects of fatigue include poor communication, irritability, reduced reaction time, increased risk-taking, errors in judgement, lack of motivation and forgetfulness. It is easy to understand how the effects of fatigue can impair performance but also in interactions with clients, colleagues and the general public.

According to the National Safety Council's 'Employee Cost Calculator for fatigue' in construction the annual cost of fatigue per worker is £1,224. This breaks down as £237 for absenteeism, £552 for decreased productivity and £435 for healthcare. The annual costs of fatigue for UK infrastructure workers is £673m (2.2m total UK construction workers x 25% being infrastructure's share of UK construction spending = 550k workers x £1,224). This breaks down as £130m for absenteeism, £304m for decreased productivity and £239m for healthcare – which for the most part is a cost to the NHS in the UK. Based on 31,000 workers across HS2, the annual cost of fatigue to the project is estimated to be £38m. This breaks down as £7.4m for absenteeism, £17.1m for decreased productivity and £13.5m for healthcare.

Numerous studies done across multiple industries have shown the adverse impact on physical and cognitive performance in fatigued workers. Research on Tideway in 2019 (6) and by Transport for London on Crossrail and other TfL sites in 2014 (7) concluded that the industry tolerates high fatigue risk, including long hours awake, especially when commutes are factored in.

The problem with the industry's tolerance of high fatigue risk are the consequences. A 2010 study looking at worker fatigue in highways construction noted the effects of fatigue on performance included "a reduction in quality, reduction in productivity, increased severity of injuries, increased frequency of injuries, decreased teamwork, physical weakness and a lack of motivation" (8).

There appear to be two clear barriers to tackling fatigue in infrastructure construction projects. The first is client expectations, including 24/7 working and low margin contracts. The second is worker earnings. This was highlighted in the Tideway tunnelling research where a shift pattern of 7 nights on, 4 days off, 7 days on, 3 days off, working twelve hour shifts suited the skilled workforce that frequently commuted long distances to and from work during the four days off and who want to maximise earnings, with as little time to fill between shifts.

Interviews with managers and workers on Tideway highlighted key contributors to fatigue as being insufficient sleep, physical work, monotonous work, excessive commuting, long shifts and rotating shifts. So, it is easy to see how the barriers alluded to above create conditions that lead to worker fatigue.

Another common problem is how workers perceive fatigue affects their work. One finding from the Tideway research was that workers generally felt they could work through fatigue. However, a study undertaken on a Vancouver construction project in 2010 noted that, inadequate sleep has been associated with numerous major work-related accidents, but a common problem is that individuals do not either understand their state of fatigue or its consequences or both". (9)

A 2015 study exploring the impact of fatigue during a simulated manual handling task (the short distance manual transport of heavy materials) suggested workers cannot simply work through fatigue. The study showed that as fatigue increased, workers were less able to process hazard information and reached a point where even if they identified a hazard, they were physically unable to respond to avoid the hazard. (10)

In October 2018 the National Safety Council looked at 'Fatigue in Safety Critical Industries'. One hundred percent of construction workers had at least one risk factor for on-the-job fatigue, which can cause hazardous jobsite conditions. The authors noted that; "the role of fatigue in the aetiology of accidents may be twofold: first, fatigue may decrease the ability to process information about a hazardous situation; and second, it may decrease the ability to respond".

A study looking at fatigue in oil and gas construction in China asked three hundred and twenty stakeholders from four construction projects to rank risks and evaluate their contributions to accidents. This was the first study where "fatigue has been identified as the leading accident risk in the construction industry". (11) This fed into our hypothesis that fatigue is a contributory factor in more accidents and incidents than the industry is aware of.

The authors of the oil and gas study assert that fatigue is four times more likely to contribute to workplace accidents than drugs or alcohol. Another interesting point raised by the authors is that single risk items in themselves are "unlikely to influence the occurrence of events". It is instead the confluence of associated risk items (distraction, incorrect use of equipment, failure to use PPE etc.) that occur at the same time that is likely to lead to accidents, often with fatigue as the trigger risk item.

3.0 Methodology

Participants volunteered to take part in the study. No participant's data were excluded from analysis. The data was quantitative and for the most part, other than the results of the alertness and cognition test, subjective in nature.

Previous studies have also sought to obtain objective data using wearable technology. Whilst there are concerns over the accuracy of wearables the consensus is that they can tell when users are awake and asleep. It was decided not to use wearable technology as it limits the potential number of participants due to device cost. Our approach was designed to collect data from hundreds of workers.

A great deal of time was spent at the design stage trying to reduce the amount of time it would take for volunteers to participate, both at registration and ongoing on a daily basis. Through extensive testing and being present for the first few launches we were able to observe how the app was being used and make adjustments accordingly. Overall, feedback on use of the app was positive on its ease of use and simplicity.

The study collected subjective assessments of sleepiness data at multiple points during shifts from voluntary participants across the HS2 programme, working a variety of shift patterns and job roles.

We gathered data from participants using questions, questionnaires and objective tests including:

- Sleepiness levels via the Karolinska Sleepiness Scale ("KSS"). The Karolinska Sleepiness Scale (KSS) defines sleepiness subjectively, using a 9-point scale where 1 represents "extremely alert" and 9 signifies "very sleepy, great effort to keep awake, fighting sleep" (13).
- The extent to which fatigue impacts performance at work, via a single question
- Objective individual performance on our bespoke alertness and cognition test
- Prior period sleep duration, sleep quality, bedtime, wake time, start work and finish work times
- Sleepiness levels and the impact on performance based on the hours of continual wakefulness
- Demographic and job characteristic data (see Appendix 1 – registration questionnaire)
- The Third Pillar of Health sleep health self-assessment, which included more in-depth questions about sleep quality, sleep duration, sleep need, workday sleep debt, daytime sleepiness, lifestyle habits and life satisfaction. This was open to all study participants.

To collect the data, we designed and built a brand new web application which could be accessed via computer, tablet or smartphone with Wi-Fi or mobile data connection. We required users to register, create a login and answer fourteen to seventeen questions about where they worked, their job roles, basic demographics, job characteristics and whether there were any reasons preventing them from sleeping well.

We offered three levels of participation.

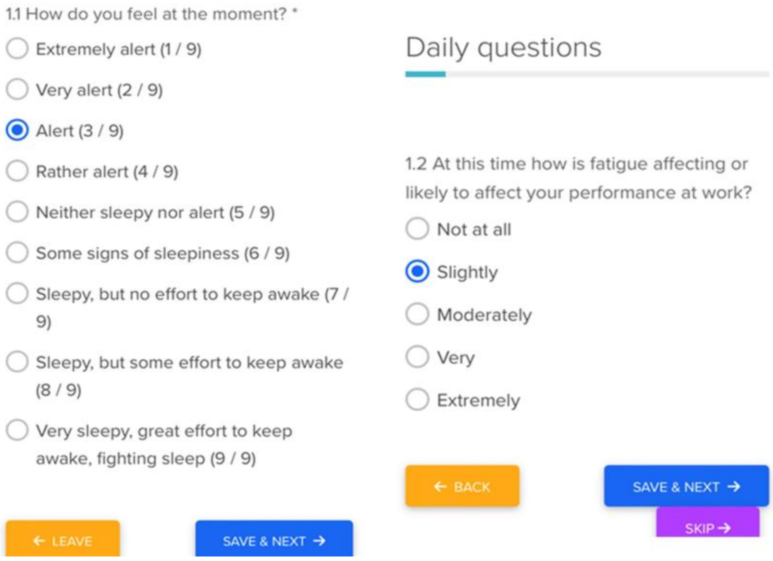
Table 1 – Daily requirements for each level of participation

Information provided	Basic	Silver	Gold
Sleepiness scores three time a shift	Yes	Yes	Yes
Impact of fatigue on performance (3x / shift)	Yes	Yes	Yes
Undertake alertness and cognition test	No	Yes	Yes
Answer questions on sleep and work	No	No	Yes

1. Basic, where all users answered two questions on their sleepiness level three times a shift - somewhere near the beginning, the middle and near the end of their shift. (see question 1.1 below – figure 1) and how fatigue is affecting performance at work (see question 1.2 below – figure 1). Users

had an option to set SMS text and / or email reminders to add data in the middle (4 or 6 hours after their first data entry) and end of their shift (8 or 12 hours after their first data entry).

Figure 1 – the two questions wee asked three times a shift



2. Silver users undertook a 60-second alertness and cognition test at the beginning of their shift (only). The test asked users to accurately confirm the colour of the word in the top box. The results are based on the percentage accuracy (the number of correct trials / the total number of trials) and efficiency (the number of trials in the 60 seconds). It would be insightful to run the alertness test three times a shift but we were concerned about asking too much of a time commitment from participants.

3. Gold users in addition to the above in basic and gold answered six questions on their sleep, wake and work times at the beginning of their shift (only):

1. Excluding time awake how long did you sleep for in your most recent main sleep period?
2. What time did you wake up prior to work?
3. How would you rate the quality of your most recent sleep period?
4. What time did you turn the lights out to go to bed?
5. What time did you start or are you expecting to start work?
6. What time are you expecting to finish work?

As a result, we obtained well over one hundred thousand data points that were specific to fatigue.

A data cleanse was carried out to delete duplicate data – i.e. when the same results for sleepiness and the extent to which fatigue is likely to affect performance at work were exactly the same just minutes (or seconds) apart.

Excel was then used to undertake the analysis of how the data breaks down for each sleepiness and performance score for all the different groups. To understand how sleepiness, fatigue and performance changed across time on shift, we used descriptive statistics to compute the average scores of these four measures across time on shift using a statistical analyses package (SAS 9.4, SAS Analytics software). We specifically looked at the mean and standard error of the mean at each time point. These data were then plotted using Sigmaplot 15.0, to visualise the results.

A finer grained analysis was done by looking at the data at hourly intervals (based on clock time), separately, for the beginning, middle and end of a shift. This allowed us to look at the impact of interaction between the sleep drive and circadian drive on sleepiness, fatigue and performance. To note, two measures of performance were used, namely, accuracy (percentage of correct responses) and efficiency (percent of correct responses per unit time).

Finally, to see how sleepiness changes across different shift patterns we performed a cumulative frequency analysis and then did a curve fit to the analysed data. This allowed us to visualise the how the increase in sleepiness varied between the different groups. This latter analysis was done using (Sigmaplot 15.0 software).

The greatest benefit of our approach was obtaining data from a large cohort of workers in real working environments. From a sleep and circadian science perspective our results were in line with what we would expect to find. This is in part due to the voluntary nature of the study. The interesting aspect is the nuances within the data which is explained further in the results section.

Limitations of the study

Not all workers were comfortable using smartphones and a web application. So, we missed a few workers that might have participated if we had used paper-based entry. However, when we looked at that as an option it would have been difficult to add the time and date stamp in the system and time consuming entering the data manually.

One conclusion from studies on Crossrail and other Transport for London sites (7) was a caution over using subjective measures within the tunnelling and construction industry. Our two main questions – asking how you feel and the extent to which fatigue is likely to affect performance at work are both subjective. We know the construction industry still has elements of ‘macho’ culture and workers may not always be willing to admit they are tired and that fatigue will affect their work. We saw some evidence of that in our results. However, having gone through each line of data multiple times we feel the vast majority of our data is accurate. We further mitigate this issue by looking at the relative fatigue risk in the ‘heatmaps’ in appendix 2 of this report. Additional mitigation comes from the number of participants, meaning workers who provided false data were a very small percentage of the overall data set.

As we have explained above, we chose not to use wearable technology in this study. It may have been worthwhile having some participants use wearables to compare to the subjective data we collected.

Challenges

The main challenges were to firstly promote the study to get participants to sign up and complete registration and secondly to get participants to enter data daily.

To overcome these challenges, we promoted the study by advertising it through a variety of channels to get voluntary sign up. We frequently attended safety, health, wellbeing and leadership team meetings to explain the study and obtain senior level buy-in. Supervisor briefings were used to tell the workers about the study and to encourage participation. Screens in communal areas were used to advertise the study including a video with subtitles. Emails were sent to office-based staff. A number of informative webinars were held to gain participants.

We provided posters for communal areas. We provided QR code stickers with the login URL which could be added to hard hats, put on desks, added to entry pass lanyards, placed in the cabs of vehicles etc. We encouraged computer users to add an outlook invite reminder at the beginning of their shift. We provided a slide that could be used in pre-shift briefings for site operatives to act as a reminder to participate at the beginning of a shift. Senior leaders frequently engaged the supervisors and foremen to ensure the study was being promoted to the workforce.

We created SMS text and / or email reminders near the middle and end of shifts. These reminders were triggered once the user had added data at the beginning of their shift. A limitation was not being able to set a reminder to provide data at the beginning of the shift given many of our participants were working rotating shifts and doing different shift patterns.

4.0 The results

4.1 About the results – participation

The study ran from October 2002 to December 2024.

Across HS2, 754 workers completed registration and 642 provided data that could be analysed with over 270 job roles recorded. After a significant data cleanse, we received 9,763 separate KSS sleepiness responses and 9,605 responses to the question on fatigue affecting performance. These responses came from over 5,000 separate working days.

We are grateful to all workers across the project who helped us achieve this level of engagement and participation.

4.2.1 Alertness and performance

One of the most pleasing aspects of this research is that broadly speaking we found what we would expect to find, from a sleep and circadian science perspective, which is when sleep need is high (such as during a night shift, or at the end of a long working shift) alertness, performance accuracy and efficiency are impaired. Also, during the circadian nadir of alertness, such as on a night shift, performance accuracy and efficiency are impaired. Below is a table of the responses we received to our two main questions. These were:

- How do you feel at the moment?
- At this time how is fatigue affecting or likely to affect your performance at work?

Table 2 – Alertness and performance data

KSS responses	KSS responses				Performance responses			
	KSS score	# responses	% of responses		Answer	# responses	% of responses	
Extremely Alert	1	1192	12%		Not at all	4312	45%	
Very alert	2	2205	23%	63%	Slightly	3462	36%	
Alert	3	2757	28%		Moderately	1441	15%	
Rather alert	4	1244	13%		Very	305	3%	4%
Neither sleepy or alert	5	853	9%		Extremely	85	1%	
Some signs of sleepiness	6	917	9%			9605	100%	
Sleepy, but no effort to keep awake	7	320	3%					
Sleepy, but some effort to keep awake	8	207	2%	6%				
Very sleepy, great effort to keep awake	9	68	1%					
		9763	100%					

The study found:

- 63% of responses were in the top three ‘alert’ responses. 6% of responses were in the bottom three options (scores of 7, 8 or 9) indicating high levels of sleepiness. The fatigue index (previously supported by the HSE), which is used extensively in construction to try to predict fatigue risk in working patterns, is based on the percentage chance of the KSS response being 7 or greater over the course of a whole shift. In our research, we have where possible tried to break this down into hourly intervals for the different shift patterns operated across HS2.

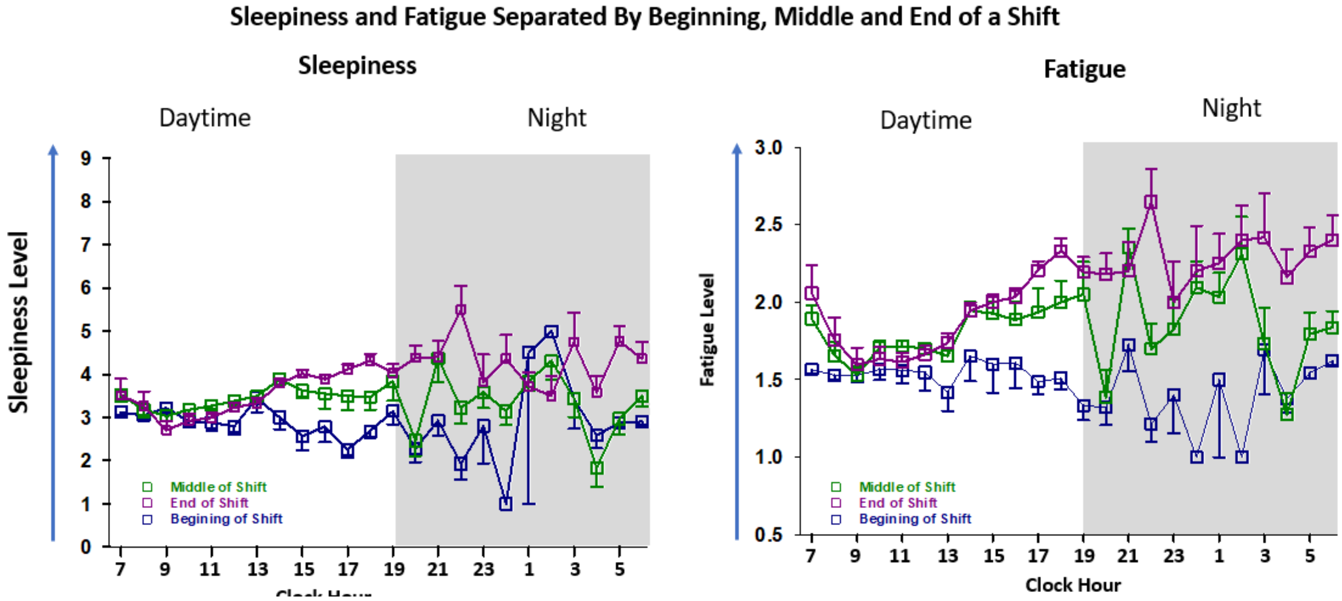
- 45% of responses indicated that fatigue was not at all likely to affect performance at work.

- 19% of responses indicated at least a moderate effect on work performance due to fatigue.

- 4% of responses indicated that work performance is likely to be 'very' or 'extremely' affected by fatigue. Given it is well documented that we tend to be bad judges of how our sleepiness impacts our performance it is not a surprise to see this figure lower than those who indicated high levels of sleepiness.

Our research partner, Northumbria University did some detailed research looking at how KSS sleepiness scores and fatigue impairment differed depending on the time of day and if workers were at the beginning, middle or end of a shift. In the left hand graph, the y axis indicates increases in the KSS sleepiness score. In the right hand graph, the y axis indicates an increase in the impact of fatigue on performance from not at all ("1") to Extremely ("5"). On a shift that occurs during the night (grey box) Sleepiness (left hand graph) and Impairment due to fatigue (right hand graph) increase at a greater rate as the shift progress from middle to end. In contrast, on a shift that occurs during the daytime hours, sleepiness and fatigue are lower than during a shift at night and critically, remain level throughout the shift. Furthermore, during the night variability in sleepiness and fatigue increase, note the increase in standard error between 19:00 – 6:00 am. It indicates that increasing instability or inconsistency in performance, a well-known impact of working at an adverse circadian time, such as the night.

Graph 1 – Sleepiness by time of day & Graph 2 – Impact of fatigue on performance by time of day



The subjective responses match the results from the alertness and cognition test results (below), which 'silver' and 'gold' users do at the beginning of a shift. Because not everyone logs on at the very beginning of their shift, we get the benefit of results from across a range of times of day.

4.2.2 Results from the alertness test

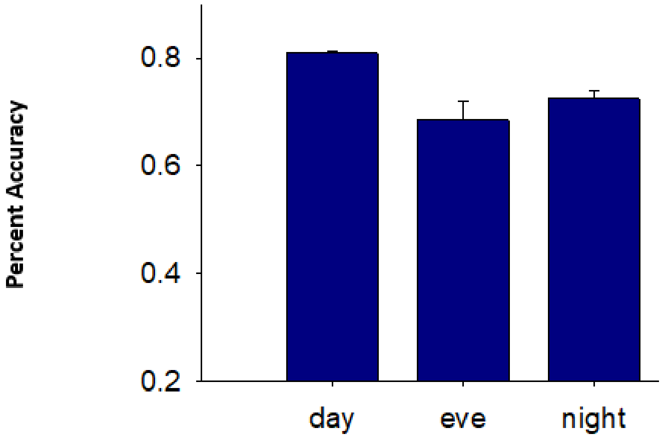
The results of our alertness and cognition test (similar to the validated Stroop test)are based on the percentage accuracy (the number of correct trials / the total number of trials) and efficiency (the number of trials in the 60 seconds). We had a total of 379 users (335 Gold and 44 Silver) who completed at least one alertness test.

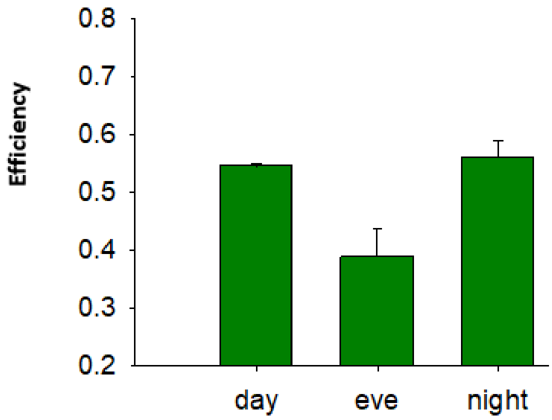
In the graphs below the day shift typically started at 06:00 or 07:00 for those on site, with those in office-based roles typically starting a little later – often on a staggered basis.

Those working the evening or 'back' shift typically start work between 12:00 and 16:00 and finished between 22:00 and 02:00.

The night shift tended to start at 18:00 or 19:00 and run through to 06:00 or 07:00.

Graph 3 – Alertness test accuracy by shift & Graph 4 – Alertness test efficiency by shift





Our results, illustrated in the charts above, show that accuracy and efficiency are lowest on the evening / 'back' shift. It may be that this is a difficult time to start a shift. We also found that whilst efficiency was similar on the day shift and night shift accuracy was 9% lower on the night shift. This is an interesting finding, especially where jobs require high levels of vigilance.

Also note the higher variability (higher standard error) on the evening and night shifts. This indicates that on day shifts all participants were stable and similar to each other in performance, whereas on the evening and night shifts variability between participants was higher. This is a well-known indication of individual differences in susceptibility to adverse effects of sleep pressure and adverse circadian time. To get a better understanding of individual differences, we have analysed the data separately for different shift patterns, between males and females, and across different age-groups.

4.2.3 Alertness and performance by joint venture

Below we look at the results by each joint venture. The three columns for each JV indicate the number of responses corresponding to the KSS sleepiness response (1 to 9), the percentage of all responses received from that JV and then the combined percentage of the top three alert responses and bottom three low alertness responses.

Table 3 – Alertness and performance results by joint venture

KSS responses		All HS2			JV1			JV2			JV3			JV4			JV5			JV6		
		n. = 643			n. = 215			n. = 249			n. = 27			n. = 36			n. = 44			n. = 43		
Extremely Alert	1	1192	12%		453	17%		597	11%		11	5%		123	17%		100	18%		41	6%	
Very alert	2	2205	23%	63%	682	26%	66%	1203	21%	64%	54	23%	53%	231	32%	79%	70	13%	43%	101	16%	48%
Alert	3	2757	28%		628	24%		1811	32%		60	25%		216	30%		72	13%		164	26%	
Rather alert	4	1244	13%		277	10%		781	14%		32	14%		66	9%		77	14%		75	12%	
Neither sleepy or alert	5	853	9%		230	9%		394	7%		23	10%		49	7%		105	19%		76	12%	
Some signs of sleepiness	6	917	9%		205	8%		504	9%		32	14%		24	3%		95	17%		115	18%	
Sleepy, but no effort to keep awake	7	320	3%		106	4%		143	3%		16	7%		5	1%		22	4%		36	6%	
Sleepy, but some effort to keep awake	8	207	2%	6.1%	56	2%	6.8%	130	2%	5.8%	8	3%	10.5%	5	1%	1.4%	12	2%	7.2%	23	4%	10.1%
Very sleepy, great effort to keep awake	9	68	1%		18	1%		53	1%		1	0%		0	0%		6	1%		5	1%	
		9763	100%		2655	100%		5616	100%		237	100%		719	100%		559	100%		636	100%	
Performance responses					JV1			JV2			JV3			JV4			JV5			JV6		
Not at all	1	4312	45%		1363	52%		2232	40%		81	35%		436	61%		275	50%		219	35%	
Slightly	2	3462	36%		819	31%		2205	40%		91	40%		209	29%		118	21%		285	45%	
Moderately	3	1441	15%		322	12%		842	15%		52	23%		52	7%		132	24%		93	15%	
Very	4	305	3%	4.1%	83	3%	3.9%	186	3%	4.6%	4	2%	2.2%	12	2%	1.7%	20	4%	4.9%	29	5%	5.4%
Extremely	5	85	1%		19	1%		70	1%		1	0%		0	0%		7	1%		5	1%	
		9605	100%		2606	100%		5535	100%		229	100%		709	100%		552	100%		631	100%	

6% of all KSS sleepiness responses from all our participants indicated high levels of sleepiness. 4% of all responses indicated that fatigue was very or extremely likely to affect performance at work. Whilst the number of participants varied by JV it was interesting to see how the responses varied.

The two organisations with comfortably the greatest risk of high levels of sleepiness – JV3 and JV6 – had significantly higher proportions of office-based respondents. JV4 compared favourably on the percentage of responses indicating high levels of sleepiness.

When we asked the extent to which fatigue affects performance at work, we saw a similar trend across JV1, JV2 and JV5. JV4 continued to compare well. JV6 personnel slightly underperformed the HS2 average. Despite high levels of sleepiness respondents at JV3 did not feel as though fatigue was very or extremely likely to affect performance at work.

4.3 Comparing alertness across shift patterns worked

In this section we wanted to understand differences in the experience of sleepiness and the impact of fatigue on work performance based the different shift patterns worked across HS2. The shift patterns we could identify included:

- 5 days on 2 days off (for less than 10 hour, 10 to 11 hour and 12+ hour shifts) for site and office workers
- 7 nights on 4 days off, 7 days on 3 days off (all 12 hour shifts)
- 6 days on 1 day off (for less than 12 hour shifts and 12+ hour shifts)
- 12 days on 2 days off (all 12 hour shifts).

In appendix 2 a more detailed hour-by-hour look at fatigue risk in each of the different working patterns is available.

We have separated out the data based on day shifts and night shifts, where we had enough data to get an insight into how these shifts compare.

Table 4 – Comparting key alertness & performance impact metrics across different shift patterns

Shift pattern (DAYS)	HS2 All	5_2 < 10	5_2 10-11	5_2 12+	Office < 10	Office 10-11	Office 12+	7473 12+	6_1 < 12	6_1 12+	12_2 12 +
% of Alert scores (KSS scores 1 to 3)	64%	63%	70%	70%	57%	52%	86%	39%	89%	81%	41%
% High sleepiness (KSS scores 7 to 9)	5.5%	6.1%	3.6%	3.7%	7.3%	4.0%	5.9%	14.5%	1.4%	4.1%	12.5%
No impact of fatigue on performance	46%	54%	55%	55%	38%	51%	52%	42%	59%	41%	4%
High impact of fatigue on performance	3.8%	3.0%	3.1%	4.0%	4.4%	1.2%	0.8%	7.6%	0.8%	4.6%	12.6%
80th percentile KSS score	N/A	4.0	3.5	3.5	4.2	4.4	3.0	6.0	3.0	3.7	5.1
Average KSS score	3.4	3.4	3.1	2.9	3.7	3.7	2.7	4.3	2.4	2.9	4.4
Impact of fatigue on performance (1 to 5)	1.79	1.62	1.63	1.69	1.89	1.64	1.55	2.02	1.49	1.79	2.55
Number of KSS data points	9071	1419	1611	1078	2547	350	119	338	366	540	176
Number of participants working that pattern	605	66	163	133	118	27	7	55	9	8	6
Day shift rank (/ 10)	N/A	5	3	4	8	7	2	9	1	6	10
Shift pattern (NIGHTS)	**HS2 All**	**5_2 < 10**	**5_2 10-11**	**5_2 12+**	**Office < 10**	**Office 10-11**	**Office 12+**	**7473 12+**	**6_1 < 12**	**6_1 12+**	**12_2 12 +**
% of Alert scores (KSS scores 1 to 3)	57%			65%				33%		48%	44%
% High sleepiness (KSS scores 7 to 9)	11.6%			10.8%				20.6%		2.5%	6.0%
No impact of fatigue on performance	41%			44%				41%		8%	6%
High impact of fatigue on performance	7.1%			5.9%				10.1%		7.7%	6.1%
80th percentile KSS score	N/A			5.0				6.3		4	5
Average KSS score	3.6			3.3				4.9		3.5	3.8
Impact of fatigue on performance (1 to 5)	2.0			1.91				2.04		2.41	2.47
Number of KSS data points	882			296				233		40	50
Number of participants working that pattern	77			24				26		2	3
Night shift rank (/ 4)	N/A			1				4		2	3

5 days on 2 days off patterns generally compare well or in line with HS2 average results, which represents a combination of results from all shift patterns. The exception is those working across site and office working less than ten hour shifts where there is an increased risk of high levels of sleepiness. In terms of office workers there was a slight trend to key metrics improving as the shift duration increased, however, this is something that needs to be tested further. Office workers working eight or nine hour shifts compared poorly to the overall average on many metrics.

The 7473 pattern compares poorly against most of the other shift patterns. In this pattern we see lower likelihood of alert scores, a much higher likelihood of high levels of sleepiness and a significant increase in the chances of fatigue affecting performance at work for the day shift. The eightieth percentile average KSS sleepiness score is the comfortably the highest of all shifts on both the day and night shifts. This score indicates the KSS score at which the highest 20% bracket of the relative risk of fatigue begins.

Those working **6 days on 1 off** compare favourably on key metrics, no matter the length of the shift on the day shift. Where we had data from the 6 days on 1 off 12+ hour pattern on the night shift we tended to see a lower percentage of high alertness (KSS) scores and a greater chance fatigue being very or extremely likely to impact performance at work. This is an area that requires further research as we had a high proportion of data from a few individuals whose responses may have skewed the data positively.

Those working 12 days on 2 off compared poorly on all key metrics on the day shift. It appears there are some favourable comparisons on key metrics on the night shift, albeit we received a limited amount of data.

Key takeaways from appendix 2

For those on site working **5 days on 2 days off** patterns we frequently saw the peak in average KSS score on a Tuesday or Wednesday shift followed by a decline or flattening of the curve. This was normally mirrored by the impact of fatigue on performance at work. That said we did see incidences of the chances of experiencing high levels of sleepiness or the impact of fatigue on performance increasing with consecutive shifts to a Friday peak. For those working in the office we also tended to see peaks in the middle of the week.

For patterns with longer periods of work followed by relatively short periods of days off **(such as 6 days on 1 day off)** we saw the peaks in average KSS score and the impact of fatigue on work performance on the first shift, suggesting that one day off may not be enough time to recover from a period of six consecutive shifts.

In terms of the time of day for peak relative risk of fatigue, we saw a pattern emerge whereby for shift durations (less than 10 hours) we tended to see the peak in the relative risk of fatigue in the natural circadian dip from 14:00 to 17:00.

When shift lengths increased to **10 or 11 hours** the relative risk of fatigue tended to increase during the circadian dip but peak in the last one to two hours of the shift.

Where shifts were **12 hours or more**, we again saw an increase in average KSS scores in the circadian dip but the peak in the last two to three hours of the shift.

4.4 Alertness and performance for worker sub-groups

4.4.1 Differences between office and site-based workers

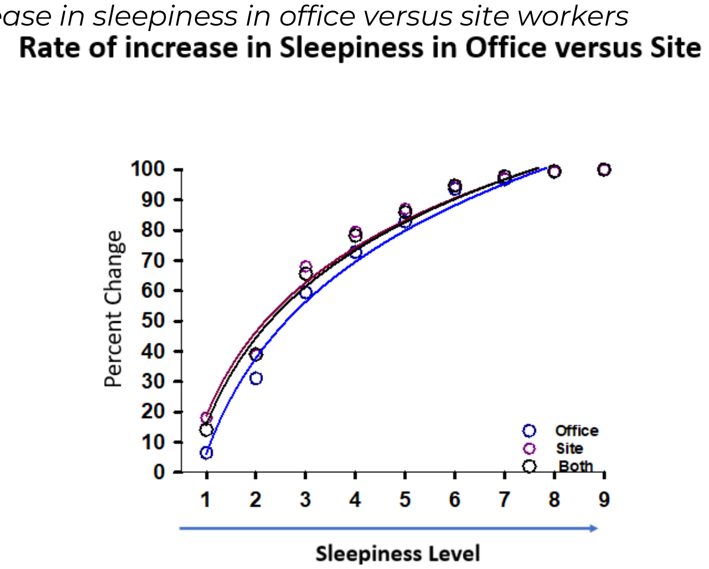
The three columns for each worker group indicate the number of responses corresponding to the KSS sleepiness response (1 to 9), the percentage of all responses received from that group and then the combined percentage of the top 3 alert responses and low alertness responses.

Table 5 – Alertness and performance by office or site-based workers

KSS responses		Overall			Office-based			Site-based			Both		
		n. = 643			n. = 154			n. = 296			n. = 193		
Extremely Alert	1	1192	12%	63%	187	6%	58%	558	16%	65%	447	14%	65%
Very alert	2	2205	23%		705	23%		688	19%		812	26%	
Alert	3	2757	28%		853	28%		1106	31%		798	25%	
Rather alert	4	1244	13%		414	14%		446	12%		384	12%	
Neither sleepy or alert	5	853	9%		305	10%		297	8%		251	8%	
Some signs of sleepiness	6	917	9%		344	11%		290	8%		283	9%	
Sleepy, but no effort to keep awake	7	320	3%	6.1%	106	4%	6.9%	113	3%	6.0%	101	3%	5.5%
Sleepy, but some effort to keep awake	8	207	2%		79	3%		71	2%		57	2%	
Very sleepy, great effort to keep awake	9	68	1%		23	1%		31	1%		14	0%	
		9763	100%		3016	100%		3600	100%		3147	100%	
Performance responses		**Overall**			**Office-based**			**Site-based**			**Both**		
Not at all	1	4312	45%		1176	40%		1452	41%		1684	54%	
Slightly	2	3462	36%		1199	41%		1304	37%		959	31%	
Moderately	3	1441	15%		466	16%		589	17%		386	12%	
Very	4	305	3%	4.1%	98	3%	3.9%	138	4%	5.4%	69	2%	2.7%
Extremely	5	85	1%		18	1%		53	1%		14	0%	
		9605	100%		2957	100%		3536	100%		3112	100%	

Office respondents had a lower percentage of KSS sleepiness responses in the top 3 alertness scores and were more likely than the average to have responses indicating high levels of sleepiness. When reviewing responses to the voluntary sleep health self-assessment **office-based respondents compared poorly on all key sleep health metrics (See appendix 3)**. Office respondents were in line with responses on the likelihood of fatigue being very or extremely likely to affect performance at work. Site-based respondents were in line with the percentage of scores in the highest sleepiness brackets but were significantly more likely to say that fatigue affects performance at work. Those working across site and site compared well on both key sleepiness and performance impact metrics. This is perhaps no surprise as varying tasks can reduce fatigue.

Graph 5 – Rate of increase in sleepiness in office versus site workers



These graphs illustrate the percentage increase to maximum sleepiness. The key is in comparing the curves for the different groups. The curves show two key things. Firstly, the maximum sleepiness score reached for that group – corresponding to the KSS values from 1 (low) to 9 (high) on the X-axis. Secondly the steepness of the curve indicates how quickly that group reaches their maximum sleepiness level. A steeper curve indicates that group reaches maximum sleepiness quicker.

Analysis by Northumbria University showed trends for those working in the office versus those working on site. These data show the accumulation in sleepiness in office, site and those working across office and site. Note the trajectory for the three curves, which indicates site personnel tire quicker than those working across office and site. This would be understandable where site personnel have little variety in their work. Office staff begin the shift less sleepy than site-based staff. However, the office personnel reach the same level of higher sleepiness as the other two groups.

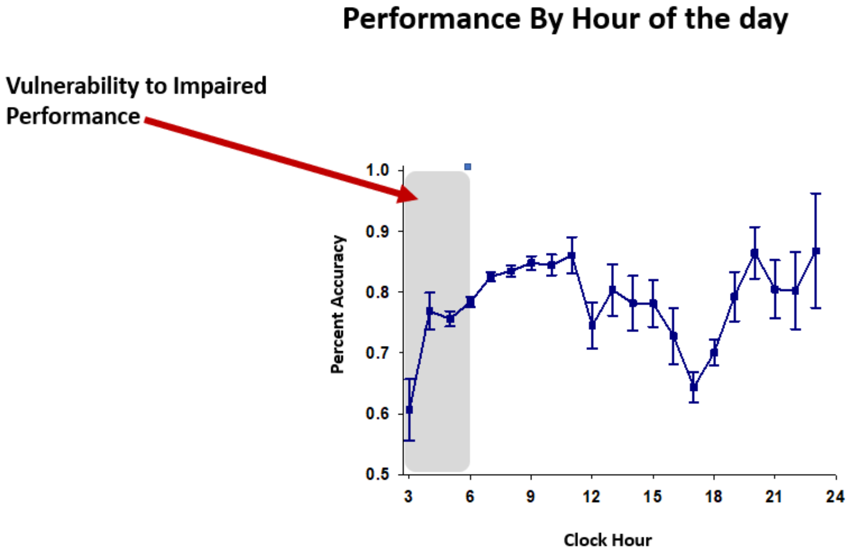
4.4.2 Differences between day and shift workers

Table 6 – Alertness and performance by shifts worked

KSS responses		Overall			Day shift			Night shift			Mixed shift		
		n. = 643			n. = 440			n. = 7			n. = 196		
Extremely Alert	1	1192	12%		745	10%		9	20%		438	20%	
Very alert	2	2205	23%	63%	1772	24%	64%	16	36%	67%	417	19%	59%
Alert	3	2757	28%		2303	31%		5	11%		449	20%	
Rather alert	4	1244	13%		951	13%		1	2%		292	13%	
Neither sleepy or alert	5	853	9%		654	9%		6	13%		193	9%	
Some signs of sleepiness	6	917	9%		697	9%		4	9%		216	10%	
Sleepy, but no effort to keep awake	7	320	3%		206	3%		2	4%		112	5%	
Sleepy, but some effort to keep awake	8	207	2%	6.1%	139	2%	5.1%	1	2%	8.9%	67	3%	9.4%
Very sleepy, great effort to keep awake	9	68	1%		39	1%		1	2%		28	1%	
		9763	100%		7506	100%		45	100%		2212	100%	
Performance responses		Overall			Day shift			Night shift			Mixed shift		
Not at all	1	4312	45%		3339	45%		17	38%		956	44%	
Slightly	2	3462	36%		2825	38%		14	31%		623	29%	
Moderately	3	1441	15%		985	13%		10	22%		446	21%	
Very	4	305	3%	4.1%	195	3%	3.3%	3	7%	8.9%	107	5%	6.6%
Extremely	5	85	1%		49	1%		1	2%		35	2%	
		9605	100%		7393	100%		45	100%		2167	100%	

Day workers compared favourably on the chances of experiencing high levels of sleepiness and fatigue being very or extremely likely to impact performance at work versus shift workers, which is in line with what we would expect to find.

Graph 6 – Performance in the alertness test by hour of the day



When you look more closely at performance every hour on the alertness and cognition test, you can see that accuracy is especially low between 3 am and 6 am. This region is considered a zone of vulnerability because this is a time when alertness is at its lowest and sleepiness at its highest. We also see reductions around 12:00, which may be a post-prandial effect and again in the late afternoon, which is likely to coincide with the end of a shift.

4.4.3 Differences based on how many years shift workers had been working shifts

In shift workers we wanted to find out if the length of time they had worked shifts had any impact on some of the key sleepiness and performance impact metrics.

Table 7 – *Alertness and performance by number of years shift workers have been working shifts*

KSS responses		All shift workers			Less 6 months			6m to 2 years			2y to 5 years			5y to 10 years			10+ years		
		n. = 203			n. = 38			n. = 95			n. = 29			n. = 15			n. = 26		
Extremely Alert	1	447	20%		67	12%		215	20%		55	23%		7	11%		103	32%	
Very alert	2	433	19%	59%	110	20%	58%	241	22%	62%	37	16%	55%	7	11%	39%	38	12%	58%
Alert	3	454	20%		144	26%		219	20%		37	16%		11	17%		43	14%	
Rather alert	4	293	13%		153	28%		92	8%		20	8%		5	8%		23	7%	
Neither sleepy or alert	5	199	9%		25	5%		125	11%		20	8%		5	8%		24	8%	
Some signs of sleepiness	6	220	10%		31	6%		91	8%		33	14%		9	14%		56	18%	
Sleepy, but no effort to keep awake	7	114	5%		13	2%		58	5%		19	8%		6	9%		18	6%	
Sleepy, but some effort to keep awake	8	68	3%	9%	4	1%	4%	34	3%	10%	13	6%	14%	8	13%	31%	9	3%	10%
Very sleepy, great effort to keep awake	9	29	1%		5	1%		12	1%		2	1%		6	9%		4	1%	
		2257	100%		552	100%		1087	100%		236	100%		64	100%		318	100%	
Performance responses		All shift workers			Less 6 months			6m to 2 years			2y to 5 years			5y to 10 years			10+ years		
Not at all	1	973	44%		244	45%		472	44%		81	35%		27	45%		149	48%	
Slightly	2	637	29%		165	30%		360	34%		64	28%		8	13%		40	13%	
Moderately	3	456	21%		117	21%		165	16%		61	26%		15	25%		98	32%	
Very	4	110	5%	7%	16	3%	4%	47	4%	6%	21	9%	11%	6	10%	17%	20	6%	7%
Extremely	5	36	2%		5	1%		19	2%		5	2%		4	7%		3	1%	
		2212	100%		547	100%		1063	100%		232	100%		60	100%		310	100%	

Those who are newest to shift working are less likely to experience high levels of sleepiness and are less likely to say that fatigue is very or extremely likely to impact performance at work. **There is a clear trend for the chances of high levels of sleepiness and a greater impact on performance as the number of years working shifts increases up to 10 years.** This is perhaps no surprise as key sleep metrics from the voluntary sleep health assessment show declines as the number of years working shifts increases. Those who have worked shifts for 10 or more years are broadly in line with the overall average for shift workers in both key sleepiness and performance impact metrics.

4.4.4 Differences based on day, evening and night shift results

Our final piece of analysis in respect of shift working was to understand the differences in results for the day shift, the night shift and the back / evening shift.

Table 8 – *Alertness and performance by type of shift being worked*

KSS responses		Overall			Day shift			Back shift			Night shift		
Extremely Alert	1	1192	12%		1091	12%		438	20%		155	18%	
Very alert	2	2205	23%	63%	2106	23%	64%	417	19%	59%	146	17%	57%
Alert	3	2757	28%		2593	29%		449	20%		202	23%	
Rather alert	4	1244	13%		1138	13%		292	13%		125	14%	
Neither sleepy or alert	5	853	9%		791	9%		193	9%		69	8%	
Some signs of sleepiness	6	917	9%		852	9%		216	10%		83	9%	
Sleepy, but no effort to keep awake	7	320	3%		273	3%		112	5%		56	6%	
Sleepy, but some effort to keep awake	8	207	2%	6.1%	176	2%	5.5%	67	3%	9.4%	31	4%	11.6%
Very sleepy, great effort to keep awake	9	68	1%		51	1%		28	1%		15	2%	
		9763	100%		9071	100%		2212	100%		882	100%	

Performance responses		Overall			Day shift			Back shift			Night shift		
Not at all	1	4312	45%		4076	46%		956	44%		351	41%	
Slightly	2	3462	36%		3241	36%		623	29%		266	31%	
Moderately	3	1441	15%		1279	14%		446	21%		181	21%	
Very	4	305	3%	4.1%	267	3%	3.8%	107	5%	6.6%	45	5%	7.1%
Extremely	5	85	1%		69	1%		35	2%		16	2%	
		9605	100%		8932	100%		2167	100%		859	100%	

In this instance the results follow the trend we would perhaps expect to see, based on results from over 10,000 participants in our sleep health self-assessment. The day shift sees less chance of high levels of sleepiness and an impact on performance. The back / evening shift sees an increase in both metrics and the night shift sees a further increase in the key sleepiness and performance impact metrics.

4.4.5 Differences between those working above ground, below ground and about the same (above and below)

Table 9 – Alertness and performance by those working above or below ground

KSS responses		Overall			Above ground			Below ground			Same		
		643			n. = 446			n. = 81			n. = 116		
Extremely Alert	1	1192	12%		715	10%		141	28%		336	19%	
Very alert	2	2205	23%	63%	1775	24%	64%	112	22%	68%	318	18%	56%
Alert	3	2757	28%		2332	31%		89	18%		336	19%	
Rather alert	4	1244	13%		910	12%		47	9%		287	16%	
Neither sleepy or alert	5	853	9%		671	9%		35	7%		147	8%	
Some signs of sleepiness	6	917	9%		682	9%		37	7%		198	11%	
Sleepy, but no effort to keep awake	7	320	3%		225	3%		13	3%		82	5%	
Sleepy, but some effort to keep awake	8	207	2%	6.1%	138	2%	5.4%	18	4%	8.3%	51	3%	8.4%
Very sleepy, great effort to keep awake	9	68	1%		42	1%		11	2%		15	1%	
		9763	100%		7490	100%		503	100%		1770	100%	
Performance responses		Overall			Above ground			Below ground			Same		
Not at all	1	4312	45%		3407	46%		222	46%		683	39%	
Slightly	2	3462	36%		2798	38%		154	32%		510	29%	
Moderately	3	1441	15%		958	13%		60	12%		423	24%	
Very	4	305	3%	4.1%	167	2%	2.8%	22	5%	10.3%	116	7%	7.8%
Extremely	5	85	1%		36	0%		28	6%		21	1%	
		9605	100%		7366	100%		486	100%		1753	100%	

Those working above ground compared favourably to those working below ground on the chances of experiencing high levels of sleepiness and the impact of fatigue on performance at work. **Those working above and below ground were more likely to experience high levels of sleepiness and for fatigue to be very or extremely likely to affect performance at work. This was the case for those working below ground albeit the impact on performance was even more pronounced. <u>Those working below ground were at higher risk of insomnia and sleep apnoea.</u>**

4.4.6 Differences between those who consider their work to be mentally or physically demanding

Table 10 – Alertness and performance by based on mentally or physically demanding job roles

KSS responses		Overall			Physically			Mentally			Both			Not demanding		
		n. = 643			n. = 41			n. = 237			n. = 295			n. = 70		
Extremely Alert	1	1192	12%		33	8%		305	8%		710	17%		144	13%	
Very alert	2	2205	23%	63%	50	12%	50%	962	24%	61%	863	21%	66%	330	29%	66%
Alert	3	2757	28%		119	30%		1189	29%		1172	28%		277	24%	
Rather alert	4	1244	13%		47	12%		515	13%		541	13%		141	12%	
Neither sleepy or alert	5	853	9%		77	19%		391	10%		280	7%		105	9%	
Some signs of sleepiness	6	917	9%		41	10%		411	10%		351	8%		114	10%	
Sleepy, but no effort to keep awake	7	320	3%		26	6%		155	4%		113	3%		26	2%	
Sleepy, but some effort to keep awake	8	207	2%	6.1%	7	2%	8.5%	99	2%	7.0%	97	2%	5.9%	4	0%	3.0%
Very sleepy, great effort to keep awake	9	68	1%		1	0%		28	1%		35	1%		4	0%	
		9763	100%		401	100%		4055	100%		4162	100%		1145	100%	
Performance responses		**Overall**			**Physically**			**Mentally**			**Both**			**Not demanding**		
Not at all	1	4312	45%		3407	46%		1712	43%		1836	45%		604	53%	
Slightly	2	3462	36%		2798	38%		1504	38%		1472	36%		351	31%	
Moderately	3	1441	15%		958	13%		628	16%		574	14%		167	15%	
Very	4	305	3%	4.1%	167	2%	2.8%	117	3%	3.5%	159	4%	5.2%	13	1%	1.2%
Extremely	5	85	1%		36	0%		22	1%		56	1%		1	0%	
		9605	100%		7366	100%		3983	100%		4097	100%		1136	100%	

Those with physically demanding jobs have the highest chance of experiencing high levels of sleepiness. Those with roles they do consider as demanding compared favourably. The picture changes when we look at whether fatigue is likely to impact performance at work. As with sleepiness those with jobs that are not demanding are least likely to experience an impact on performance at work. Those with physically demanding and those with mentally demanding roles are also less likely to feel the impact of performance at work. It is those with both physically and mentally demanding roles that see an increased risk of fatigue affecting performance at work.

4.4.7 Impact of transient work

A significant section of the workforce in construction generally works away from home.

Table 11 – Alertness and performance by those working close to or away from home

KSS responses		Overall			Not transient			Transient		
		n. = 643			n. = 509			n. = 134		
Extremely Alert	1	1192	12%		911	11%		275	17%	
Very alert	2	2205	23%	63%	1902	24%	65%	266	16%	53%
Alert	3	2757	28%		2420	30%		327	20%	
Rather alert	4	1244	13%		1055	13%		188	12%	
Neither sleepy or alert	5	853	9%		706	9%		147	9%	
Some signs of sleepiness	6	917	9%		694	9%		222	14%	
Sleepy, but no effort to keep awake	7	320	3%		223	3%		97	6%	
Sleepy, but some effort to keep awake	8	207	2%	6.1%	132	2%	4.9%	75	5%	12.2%
Very sleepy, great effort to keep awake	9	68	1%		42	1%		26	2%	
		9763	100%		8085	100%		1623	100%	
Performance responses		**Overall**			**Not transient**			**Transient**		
Not at all	1	4312	45%		3646	46%		622	39%	
Slightly	2	3462	36%		3004	38%		448	28%	
Moderately	3	1441	15%		1093	14%		348	22%	
Very	4	305	3%	4.1%	157	2%	2.6%	148	9%	11.3%
Extremely	5	85	1%		52	1%		33	2%	
		9605	100%		7952	100%		1599	100%	

Transient workers were twice as likely to experience high levels of sleepiness versus the HS2 overall average and were well over twice as likely to say that fatigue is very or extremely likely to affect performance at work. Results from the sleep health self-assessment showed transient workers obtain less sleep prior to work.

4.4.8 Differences based on job seniority

Table 12 – Alertness and performance by seniority of workers

KSS responses		Overall			Operative			Supervisor			Manager			Professional			Senior manager		
		643			n. = 304			n. = 81			n. = 171			n. = 36			n. = 48		
Extremely Alert	1	1192	12%		487	12%		240	22%		380	11%		14	4%		71	8%	
Very alert	2	2205	23%	63%	660	17%	54%	406	36%	74%	871	25%	71%	85	23%	51%	182	21%	64%
Alert	3	2757	28%		957	24%		182	16%		1231	35%		87	24%		297	35%	
Rather alert	4	1244	13%		609	16%		74	7%		381	11%		49	13%		129	15%	
Neither sleepy or alert	5	853	9%		431	11%		72	6%		197	6%		69	19%		82	10%	
Some signs of sleepiness	6	917	9%		474	12%		86	8%		249	7%		37	10%		70	8%	
Sleepy, but no effort to keep awake	7	320	3%		160	4%		30	3%		100	3%		14	4%		14	2%	
Sleepy, but some effort to keep awake	8	207	2%	6.1%	114	3%	7.9%	16	1%	4.8%	58	2%	5.2%	8	2%	6.1%	11	1%	3.1%
Very sleepy, great effort to keep awake	9	68	1%		36	1%		7	1%		23	1%		0	0%		2	0%	
		9763	100%		3928	100%		1113	100%		3490	100%		363	100%		858	100%	
Performance responses		Overall			Operative			Supervisor			Manager			Professional			Senior manager		
Not at all	1	4312	45%		1611	42%		693	64%		1361	40%		216	61%		425	50%	
Slightly	2	3462	36%		1368	35%		235	22%		1467	43%		84	24%		303	36%	
Moderately	3	1441	15%		655	17%		134	12%		498	15%		44	12%		110	13%	
Very	4	305	3%	4.1%	178	5%	6.1%	21	2%	2.6%	87	3%	3.1%	13	4%	3.6%	6	1%	1.1%
Extremely	5	85	1%		57	1%		7	1%		18	1%		0	0%		3	0%	
		9605	100%		3869	100%		1090	100%		3431	100%		357	100%		847	100%	

There was a broad trend towards the chances of experiencing high levels of sleepiness declining as seniority increased. This was not quite as simple for the impact of fatigue on performance. Operatives were also more likely to say that fatigue is very or extremely likely to affect performance at work. Senior managers were least likely to say fatigue is very or extremely likely to impact performance at work. Supervisors compared well on both key sleepiness and performance impact metrics versus the overall average despite unfavourable comparisons in sleep health metrics.

4.4.9 Differences based on age

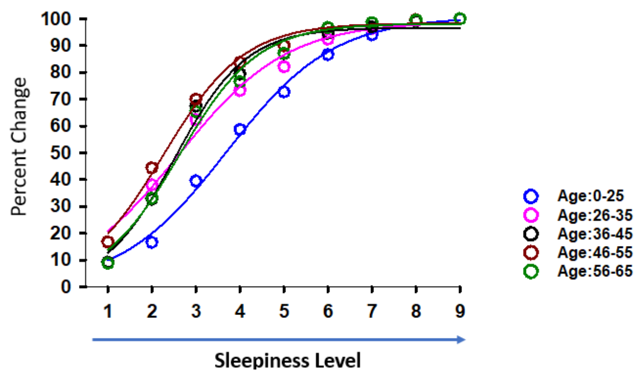
Table 13 – Alertness and performance by age bracket

KSS responses		Overall			0 to 25			26 to 35			36 to 45			46 to 55			56 to 65		
		n. = 643			n. = 81			n. = 211			n. = 180			n. = 131			n. = 81		
Extremely Alert	1	1192	12%		49	9%		493	17%		207	8%		354	14%		85	8%	
Very alert	2	2205	23%	63%	41	8%	41%	651	22%	63%	557	22%	66%	663	27%	66%	252	23%	60%
Alert	3	2757	28%		125	24%		705	24%		929	36%		639	26%		323	30%	
Rather alert	4	1244	13%		98	19%		307	10%		286	11%		397	16%		136	12%	
Neither sleepy or alert	5	853	9%		71	13%		252	9%		220	9%		176	7%		121	11%	
Some signs of sleepiness	6	917	9%		75	14%		287	10%		216	8%		191	8%		127	12%	
Sleepy, but no effort to keep awake	7	320	3%		39	7%		128	4%		71	3%		47	2%		31	3%	
Sleepy, but some effort to keep awake	8	207	2%	6.1%	26	5%	13.2%	84	3%	8.2%	56	2%	5.7%	23	1%	3.2%	12	1%	4.5%
Very sleepy, great effort to keep awake	9	68	1%		5	1%		28	1%		19	1%		10	0%		6	1%	
		9763	100%		529	100%		2935	100%		2561	100%		2500	100%		1093	100%	
Performance responses		Overall			0 to 25			26 to 35			36 to 45			46 to 55			56 to 65		
Not at all	1	4312	45%		251	48%		1332	46%		962	38%		1247	51%		463	43%	
Slightly	2	3462	36%		150	29%		949	33%		1093	43%		841	34%		394	37%	
Moderately	3	1441	15%		81	16%		447	16%		356	14%		328	13%		193	18%	
Very	4	305	3%	4.1%	20	4%	7.3%	117	4%	5.3%	101	4%	4.7%	32	1%	1.6%	22	2%	2.6%
Extremely	5	85	1%		18	3%		36	1%		17	1%		8	0%		6	1%	
		9605	100%		520	100%		2881	100%		2529	100%		2456	100%		1078	100%	

As we often find, the youngest age groups have the highest levels of sleepiness (despite sleeping the longest) and the oldest group the lowest levels. This trend was also replicated in the impact of fatigue on performance. Those 46 to 55 had the highest percentage of alert scores, the lowest chances of experiencing high levels of sleepiness, were most likely to indicate that fatigue is 'not at all' likely to affect performance at work and had the lowest chance of fatigue being very or extremely likely to impact performance at work.

Graph 6 – Rate of increase in sleepiness by age bracket

Rate of increase in Sleepiness in the different age groups



Analysis by Northumbria University showed trends by age group. These data show the accumulation in sleepiness in age groups. Note the trajectory shows the acceleration to sleepiness in different age groups. The under 25 age group shows a particularly slower increase to sleepiness and their maximum sleepiness is far lower than other groups.

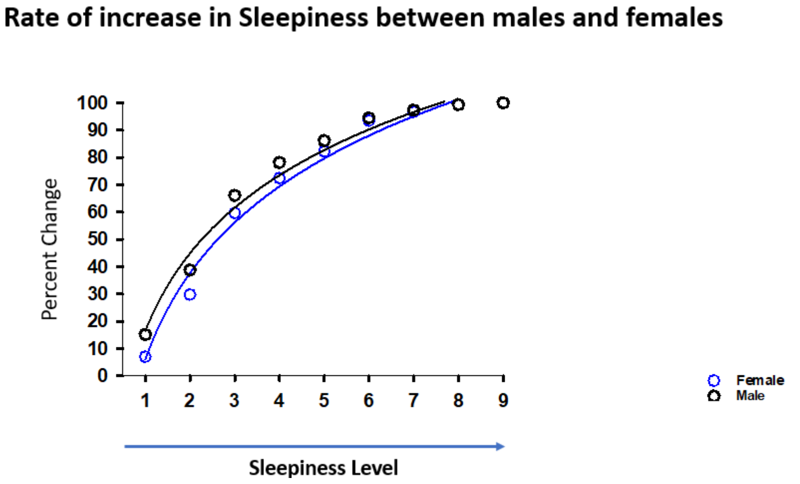
4.4.10 Differences based on biological sex

Table 14 – Alertness and performance by biological sex

KSS responses		Overall			Male			Female		
		n. = 643			n. = 525			n. = 113		
Extremely Alert	1	1192	12%		1043	14%		141	7%	
Very alert	2	2205	23%	63%	1722	23%	65%	477	22%	58%
Alert	3	2757	28%		2074	28%		630	29%	
Rather alert	4	1244	13%		923	12%		284	13%	
Neither sleepy or alert	5	853	9%		640	9%		205	10%	
Some signs of sleepiness	6	917	9%		640	9%		270	13%	
Sleepy, but no effort to keep awake	7	320	3%		239	3%		77	4%	
Sleepy, but some effort to keep awake	8	207	2%	6.1%	155	2%	6.0%	52	2%	6.7%
Very sleepy, great effort to keep awake	9	68	1%		54	1%		14	1%	
Performance responses		Overall			Male			Female		
Not at all	1	4312	45%		3263	44%		973	46%	
Slightly	2	3462	36%		2642	36%		777	37%	
Moderately	3	1441	15%		1146	16%		293	14%	
Very	4	305	3%	4.1%	245	3%	4.3%	60	3%	3.4%
Extremely	5	85	1%		74	1%		11	1%	
		9605	100%		7370	100%		2114	100%	

Female workers had a lower percentage of alert responses and a higher percentage of responses indicating high levels of sleepiness, which is perhaps no surprise given our sleep health self-assessment showed unfavourable comparisons in sleep duration, sleep quality and daytime sleepiness. However, they compared favourably to male workers in terms of the impact of fatigue on performance at work. They had a higher percentage of responses saying fatigue is ‘not at all’ likely to affect performance at work and a lower percentage of scores indicating fatigue being very or extremely likely to impact performance at work. This is less surprising when 64% of female respondent worked in the office versus 14% of male respondents.

Graph 7 – Rate of increase in sleepiness by biological sex



Analysis by Northumbria University show the accumulation in sleepiness in the different sexes, as reported. Note that trajectory indicates that the acceleration to sleepiness is the similar between males and females.

4.5 Learnings from the voluntary Third Pillar of Health sleep health self-assessment

As part of the study, we are offered all participants the chance to do the Third Pillar of Health sleep health self-assessment, which we were able to benchmark against. You can see a full comparison, breakdown and commentary of the results in appendix 3.

Once workers complete thirty working days of data, we provided them with a personalised report of their sleep health and highlighted areas where they can make, often small, changes to improve their sleep and personal energy. They have an option to download up to ten factsheets which explain how certain factors impact sleep – mainly lifestyle factors. We know from working with organisations on multiple rounds of the assessment that workers who do the assessment and receive their report significantly improve all key sleep health metrics: sleep duration, sleep quality, daytime sleepiness and lifestyle factors on a long-term basis.

Table 15 – Key sleep health metrics by JV

Voluntary questionnaire - key metrics	All HS2	JV1	JV2	JV3	JV4	JV5	JV6
	n. = 528	n. = 173	n. = 206	n. = 20	n. = 31	n. = 38	n. = 38
Average workday sleep	6.63	6.74	6.48	6.93	6.89	6.44	6.72
The percent sleeping < 7 hours before work	49%	47%	52%	40%	42%	55%	45%
The percent carrying a sleep debt	83%	84%	86%	90%	63%	79%	84%
The percent at risk of sleep apnoea	15%	17%	14%	15%	10%	11%	21%
The percent at risk of insomnia	31%	30%	29%	40%	19%	37%	53%
Sleepiness at work (few times / month +)	57%	51%	59%	60%	45%	58%	87%
Sleepiness interfere with work (F/M+)	35%	31%	38%	35%	16%	37%	58%
Life satisfaction (score out of 10)	6.86	7.14	6.61	7.25	6.84	6.66	6.74

Across HS2 average sleep duration prior to work is 6 hours 38 minutes, slightly below the recommended 7 to 9 hours. 49% of respondents fail to achieve seven or more hours of sleep a night. 83% of all respondents are carrying a sleep debt – meaning they are not meeting their sleep need over the course of a shift cycle or work week. 15% of respondents are at risk of sleep apnoea and 31% are at risk of insomnia. 57% experience sleepiness at work at least a few times a week and for 35% sleepiness interferes with daily work activities at least a few days a month. The average life satisfaction score was 6.86 out of 10, compared to the UK average life satisfaction score of 7.45 in the year ending March 2023.

These results clearly demonstrate that many workers are not obtaining sufficient good quality sleep prior to work. This is leading to sleepiness at work, which is frequently interfering with daily work activities.

JV4 compared well on almost all key sleep health metrics. JV6 compared unfavourably on the percentage at risk of insomnia and sleep apnoea, experiencing sleepiness at work, sleepiness interfering with work and life satisfaction. JV1 results were broadly positive. JV2 compared poorly on sleep duration prior to work and on life satisfaction. JV3 was a mixed set of results as was JV5.

4.6 How do respondents compare on lifestyle factors that can inhibit good sleep and against equivalent benchmark data, based on responses to the voluntary sleep health self-assessment

Those who chose to undertake the (voluntary) sleep health self-assessment also answered a number of questions on their lifestyle habits. In their report they were given ‘traffic light’ coloured feedback. Each lifestyle factor was accompanied by a factsheet participants could download to understand how that factor can impact sleep, as well as tips on how to reduce the impact of that lifestyle habit on their sleep.

We have split the workers for each section into day and shift workers to compare how results for lifestyle factors that can inhibit our ability to obtain sufficient good quality sleep. We have then compared the results to Third Pillar of Health benchmark data from 3,757 day workers and 6,319 shift workers from a wide variety of companies and industries.

Table 16 – Lifestyle habits by JV and by day or shift worker

Voluntary questionnaire - responses to lifestyle questions	Day workers								Shift workers			
	TPoH Bench.	JV1	JV2	JV3	JV4	JV5	JV6		TPoH Bench.	JV1	JV2	JV5
Use alcohol as a sleep aid	9%	3%	4%	5%	3%	0%	10%		10%	4%	3%	15%
5+ caffeinated drinks a day	23%	11%	17%	5%	13%	0%	26%		36%	12%	20%	15%
Last caffeine 6+ hours before bed	44%	35%	67%	35%	72%	25%	58%		20%	33%	40%	50%
Last caffeine within 2 hours of bed	13%	20%	8%	15%	22%	8%	32%		20%	25%	23%	19%
Smoke tobacco	10%	20%	14%	25%	19%	0%	13%		10%	15%	20%	19%
Use any form of nicotine	N/A	30%	19%	25%	26%	8%	19%		N/A	21%	31%	31%
< 150 minutes of exercise a week	48%	56%	53%	60%	71%	75%	45%		42%	64%	60%	42%
Make healthy food choices	82%	77%	83%	80%	65%	50%	90%		75%	79%	86%	96%
Use gadgets before bed	93%	80%	90%	100%	87%	92%	97%		90%	88%	74%	92%
Use gadgets in bed	65%	61%	73%	75%	58%	67%	84%		69%	75%	69%	69%
Life satisfaction	6.53	7.51	6.70	7.25	6.84	7.17	6.81		6.34	6.65	6.29	6.42
Overweight or obese	58%	67%	62%	50%	81%	92%	58%		66%	58%	80%	73%

Key highlights from lifestyle questions asked in the voluntary assessment

- HS2 workers generally compare well on the percentage of respondents using alcohol as a sleep aid
- They also compare well on the percentage drinking five or more caffeinated beverages a day
- Shift workers compare well on drinking caffeine too close to bed
- Almost all HS2 worker groups compare poorly on the percentage who smoke tobacco and against the national average of 11.2% and 15% for those who smoke or use nicotine replacement.
- Almost all HS2 worker groups compare poorly on the percentage who exercise for > 150 minutes a week and poorly against the national average 63% (37% who exercise < 150 minutes)
- The majority of workers make healthy food choices. JV4 and JV5 day workers are a slight exception

- There are mixed results for using gadgets before bed and using gadgets in bed
- Shift worker life satisfaction scores are below those of day workers. Both groups compared poorly to UK average life satisfaction scores of 7.45.
- Overall, more worker groups compare unfavourably than favourably to their relevant benchmark data on the percentage of respondents either overweight or obese and against the national average of 64%.

4.7 Reasons stopping respondents from obtaining sufficient sleep

As part of registration, we asked all participants: Other than work reasons are there any other reasons stopping you from getting good sleep? We received 739 responses. 337 (46%) indicated there were no reasons. 202 (27%) indicated one reason. 200 (27%) of the 266 responses indicated more than one reason prevents them from getting good sleep.

Table 17 – Reasons stopping respondents from obtaining sufficient sleep

Reasons for not sleeping enough	% of those indicating a problem	% of all responses
	n. = 402	n. = 739
Pain condition	11%	6%
I don't sleep well	33%	18%
Children or partner	32%	18%
Noise disturbance	17%	9%
Light disturbance	13%	7%
Stress (any form)	44%	24%
Medications	3%	2%
Frequent need to use bathroom	9%	5%
Other	11%	6%

4.8 The connection between sleep and mental health

There has been a great deal of research into the interaction between sleep and mental health. There is a well-proven bi-directional link between sleep and mental health. An interesting piece of analysis in this group was how life satisfaction scores compared to average sleep duration prior to work.

In the voluntary sleep health assessment, all participants had a chance to complete we asked a question on the amount of sleep a worker usually obtains prior to work. We asked another question to grade their life satisfaction from 0 to 10. In this analysis we have looked at the average life satisfaction scores based on the number of hours sleep they typically obtain prior to work. **There is a clear link between sleep duration and life satisfaction, with those getting the recommended 7–9 hours being the happiest.**

Table 18 – Average life satisfaction scores by average sleep duration prior to work

Workday sleep	Life satisfaction
All	6.86
< 5 hours	4.36
5 to 5.9 hours	5.78
6 to 6.9 hours	6.60
7 to 9 hours	7.48
9+ hours	7.00

4.9 The difference in commuting durations between those working days, nights or rotating shifts

Commuting before and after a shift, especially if driving, can be amongst the most dangerous times of days for workers. During registration, we asked, 'On average how many minutes do you spend commuting in total to AND from work on a daily basis?'. Below we break down the results by type of shift worked.

Table 19 – Commuting durations by shifts worked

Commuting duration (mins)	<=30		31 to 60		61 to 120		121 to 180		181 to 240		>= 240	
Permanent day	76	*15%*	150	*29%*	173	*34%*	75	*15%*	32	*6%*	10	*2%*
Permanent nights	6	*60%*	2	*20%*	1	*10%*	0	*0%*	0	*0%*	0	*0%*
Mixed day and nights	83	*36%*	61	*27%*	55	*24%*	19	*8%*	9	*4%*	1	*0%*

Total commutes for shift workers tend to be lower than those for day workers, especially those working permanent nights. However, for 21% (49 of 228) of those working rotating shifts average commuting time is at least 2 hours a day, 9% (20) over 3 hours and for 3% (6) it is over 4 hours. **Adding long commutes to long shifts potentially puts workers at risk of road traffic collisions**, which can have serious repercussions.

5.0 Discussion and recommendations

At the start of this research project, we set out to try to gain a greater insight in to fatigue in major infrastructure construction projects. We now have some answers to the questions we posed at the beginning of our research.

Answering our key questions

1. Do longer shifts result in higher levels of sleepiness; do longer shifts have a greater impact on performance at work?

The evidence on whether longer shifts increase sleepiness is inconclusive. When we looked at those working 5 on 2 off patterns on site and in the office, we saw a decrease in average sleepiness scores as shift duration increased in those working on site and across office and site, which is counter intuitive, but similar to findings of a study we recently completed for National Highways in those who drive for work. However, we saw the opposite trend in office-based workers where sleepiness did increase with shift duration.

For those working on site the impact of fatigue on work performance remained steady as shift duration increased. For office-based workers work performance improved as shift duration increased.

2. Is sleepiness greater if working in the office, on site or both; is the impact on performance greater if working in the office, on site or both?

Inconclusive. Office-based respondents had a higher percentage of responses indicating high levels of sleepiness when compared to site-based workers and those working across site and office. This is not a surprise as they compared poorly on key sleep health metrics from the Third Pillar of Health (voluntary) sleep health assessment. Those working across office and site compared well on the chances of high levels of sleepiness.

However, site-based workers were more likely to indicate fatigue being very or extremely likely to affect performance at work. It may be easier for site workers to link sleepiness to performance. Those working across office and site compared well on the impact on performance. This aligns with the idea that changing tasks can be positive for maintaining alertness.

3. Does shift working result in higher levels of sleepiness; does shift working have a greater impact on performance at work?

Shift workers compared poorly on the chances of experiencing high levels of sleepiness and the impact of fatigue on performance at work, which was the case for both the 'back' / 'evening' shift and the night shift. Shift workers also experienced shorter sleep duration prior to work. These findings are common in many populations we assess.

4. Does how long workers have worked shifts result in higher levels of sleepiness; does how long workers have worked shifts have a greater impact on performance at work?

The chances of experiencing high levels of sleepiness increased as the number of years working shifts increased. However, once workers had worked shifts for ten or more years the chances of experiencing high levels of sleepiness returned in line with results for those who had been working shifts for six months to two years. We also saw an increase in the risk of insomnia after shift workers have been working shifts for over two years and an increase in the risk of sleep apnoea after five years working shifts (albeit we had fewer participants who had worked shifts for 5 to 10 years).

The impact of fatigue affecting performance at work increased as the number of years working shifts increased. However, once workers had worked shifts for ten or more years the chances of fatigue affecting performance at work returned in line with results for those who had been working shifts for six months to two years. This mirrored trends in sleepiness.

5. Is sleepiness greater if working above ground, below ground or both; is the impact on performance greater if working above ground, below ground or both?

Those working above ground were less likely to experience high levels of sleepiness. Those working below ground and those working both above and below ground were significantly more likely to experience high levels of sleepiness. Those working below ground were also at higher risk of sleep apnoea and insomnia.

Those working above ground were less likely to see an impact of fatigue on performance. Those working below ground and those working both above and below ground were significantly more likely to see an impact on performance. The impact on performance was even more pronounced than the chances of experiencing high levels of sleepiness.

6. Do jobs requiring mental activity, physical activity or both increase sleepiness; do jobs requiring mental activity, physical activity or both have a greater impact on performance at work?

Inconclusive. We asked participants if they considered their jobs to be mentally or physically demanding. Respondents also had the option to say they considered their job to be both mentally and physically demanding or that they considered their job not demanding.

Those with roles they considered to be only mentally demanding or only physically demanding were more likely to experience high levels of sleepiness. Those with roles they did not consider as demanding compared well on sleepiness.

However, those with roles they considered to be only mentally demanding or only physically demanding were less likely to say that fatigue is very or extremely likely to impact performance at work. Those with roles they did not consider as demanding compared well on the impact on performance. Those with both roles they considered to be both mentally and physically demanding were easily the most likely to indicate that fatigue impacted performance at work.

7. Does the percentage of a shift fully focused on work activities result in higher levels of sleepiness; does the percentage of a shift fully focused on work activities have a greater impact on performance at work?

We saw improvements in sleepiness as the percentage of a shift spent focused on work activities increased. Inactivity can lead to boredom, which can unmask the symptoms of sleepiness. Interestingly life satisfaction scores (from the voluntary assessment) fell as time on task at work fell.

Similarly, we saw improvements in the impact on performance as the percentage of a shift spent focused on work activities increased.

8. Do those working away from home experience higher levels of sleepiness; do those working away from home see a greater impact on performance at work?

The transient workforce – those working away from home – were much more likely to experience high levels of sleepiness versus the population average. The transient workforce obtains less sleep prior to work and we saw lower life satisfaction scores compared to the rest of the study participants. There was little difference in total commute duration between the transient and non-transient workforce.

Those working away from home were well over twice as likely to say that fatigue is very or extremely likely to affect performance at work.

9. Does the level of seniority have any effect on sleepiness; does the level of seniority have an impact on performance at work?

Operatives were more likely to experience high levels of sleepiness. Senior Managers were less likely to experience high levels of sleepiness' despite being the group with the highest risk of sleep apnoea. Supervisors were less likely to experience high levels of sleepiness than most groups despite comparing poorly on insomnia and sleep apnoea risk.

Operatives were also more likely to say that fatigue is very or extremely likely to impact performance at work

10. Does age have any effect on sleepiness; does age have an impact on performance at work?

As we often find in populations we assess, the youngest age groups have the highest levels of sleepiness and the oldest groups the least. This finding was replicated in the impact of fatigue on performance at work. This is all despite sleep duration falling as age increased.

11. Does (biological) sex have any effect on sleepiness; does (biological) sex have an impact on performance at work?

Our study was inconclusive. Male and female workers were broadly in line in terms of the chances of experiencing high levels of sleepiness.

Female workers were less likely to say that fatigue is very or extremely likely to affect performance at work. This is perhaps unexpected given the results from the (voluntary) sleep assessment, which found female workers obtained less sleep, were at greater risk of insomnia, regularly experienced bouts of sleep at work and that sleepiness regularly interfered with work activities. However, a greater proportion of female respondents worked in office-based roles.

Other discussion points

An important secondary aim of this study was to understand whether the Fatigue and Risk Index ("FRI") is suitable and reliable for the type of work undertaken in major infrastructure construction. The findings of our study potentially challenge a number of assumptions underpinning existing biomathematical models such as fatigue risk increases with each consecutive shift and fatigue risk increasing with longer shifts.

As we outline in appendix four and five, the average time from waking to starting work was 2 hours 18 minutes on the day shift, 6 hours 45 minutes on the back shift and 6 hours 21 minutes on the night shift. This is interesting in discussions on shift length. Somone working a twelve hour shift will start work roughly 6.5 hours after waking. According to our study results, after 13 hours of wakefulness (6.5 hours into a shift), they will start to feel more tired and there will be an increased impact of fatigue on performance at work. After 17 hours of wakefulness (10.5 hours into a shift) performance will be equivalent to a BAC (blood alcohol concentration) impairment of 0.05% - the drink drive limit in Scotland (12). They will still have 1.5 hours more of their shift and their commute home still to navigate. In our study average commute duration was 43 minutes each way. This means those on a 12 hour night shift are likely to have been awake for over 19 hours by the time they get home.

Whilst most workers (80%) made healthy food choices this was not always the case. In our study in a number of populations who worked schedules with rigid start, finish and break times we often observed a spike in sleepiness around 60 to 90 minutes after the first main break. We understood this is when the main meal is often eaten and anecdotally, we understand the food option taken was not always 'healthy' and may include foods that are high in carbohydrates. These foods make us feel full and we believe provide the energy needed to 'power' through the next period of work so it is an understandable choice. These foods can also be more economically viable for caterers to provide. Subsidising healthy food options that allow for a slow release of energy, rather than a spike followed by a dip, might yield organisations savings in terms of productivity, quality, accidents and incidents.

When we reviewed lifestyle habits of day and shift workers – based on responses to the Third Pillar of Health (voluntary) sleep health assessment – against their respective (TPoH) benchmarks, HS2 respondents compared well on the percentage using alcohol as a sleep aid, drinking 5 or more caffeinated beverages a day and drinking caffeine within 6 hours of bed. However, they compared poorly on the percentage who smoked tobacco or exercised for over 150 minutes a week, which are both lifestyle habits that can impact our ability to obtain sufficient good quality sleep.

A number of worker groups across the project compared poorly on the percentage of respondents who are overweight or obese. We are aware of the limitations of BMI (body mass index), especially for those who have higher muscle mass, as might be the case for those with more physically demanding jobs. However, it can offer a useful snapshot of healthy living. According to the Sleep Foundation being overweight causes sleep issues – not least an increased risk of sleep apnoea, which can, in turn, worsen biological processes that contribute to weight gain.

Another interesting finding that is consistent in all populations we assess is a clear link between sleep duration prior to work and life satisfaction. Those obtaining (the recommended) 7 to 9 hours of sleep prior to work have the highest average life satisfaction scores. Life satisfaction scores decline as sleep duration declines.

We undertook a subjective review of three months of accident and incident data from one joint venture. Based on the short description of the incident we determined whether fatigue may have been contributory factor. In those incidents where fatigue may have been contributory factor 69% occurred at times – based on shift pattern heatmaps (see appendix 2) – when fatigue risk was elevated. This does not mean fatigue was a factor and in the incident investigations fatigue was not identified as a factor in any of the incidents, but it poses the question whether fatigue may be a greater contributor to accidents and incidents than the industry is currently aware of.

Recommendations

1. Ensure fatigue is more properly considered during accident and incident investigations

We would encourage the industry to explore fatigue as a contributory factor in all accidents and incidents and to further explore the chain of events and decisions leading to the incident and not just the individual involved / injured. Incorporating fatigue metrics into such analyses can uncover patterns and triggers, informing better preventative measures. This enhanced understanding ensures that historical data contributes to evolving safety protocols and workforce protection.

The shift pattern 'heatmaps' in appendix 2 offer an excellent starting point to understand periods of elevated fatigue risk in common shift patterns worked in major infrastructure construction. Additionally, on the back of this research we will also shortly be launching a standardised set of questions that can be used for accident and incident investigations. If through greater exploration of fatigue in investigations, fatigue is discovered to be a 'hidden' contributor to incidents, there will be a stronger business case to tackle fatigue, with more research and piloting of fatigue-related interventions.

2. Regularly review fatigue as a risk factor during works planning

Reducing the instances of dangerous, monotonous or safety-critical work being undertaken at times of lower alertness / higher sleepiness, will almost certainly improve safety and productivity outcomes. The challenge is to bring fatigue risk into daily conversations. Being able to better predict fatigue risk in working patterns, would be invaluable in work scheduling. Certain work could be planned in advance to avoid periods of elevated risk, or where this work must go ahead, interventions could be as simple as increasing supervision. Additionally, fostering a culture of awareness and proactive interventions ensures that fatigue is treated as a critical safety and productivity factor, rather than an inevitable side effect of construction work.

3. Explore whether subsidising healthy food in canteens can lead to improved safety and productivity

It would be interesting to further explore productivity, quality and incident data in the 30 to 90 minutes after the main break, especially if taken in an on-site canteen facility. Subsidising healthy food options in canteens may well improve productivity and safety outcomes in the period after the main break if workers choose to eat better on a regular basis. Education on the healthy foods that help us feel full for longer and give us the energy to navigate the next session of work would also be beneficial. Healthier eating will also have the added benefit of improving overall health.

4. Undertake sleep disorder screening for high risk groups

In our study we identified certain groups as being at particular risk of sleep disorders. These included night workers, those working shifts for two or more years, those working below ground, supervisors and senior managers. Running sleep disorder screening for shift workers who have been working shifts for two plus years and pointing those workers deemed to be at risk of a sleep disorder towards the next step on the diagnosis and treatment pathway could be an extremely valuable intervention at both individual, team and organisational level. Treating undiagnosed sleep disorders will reflect well in key productivity, safety and absence metrics. Sleep disorder screening questions could be added to night worker assessments and / or to safety-critical worker medicals. As we understand it there are currently no or few questions asked on sleep despite the crucial link sleep has to physical and mental health as well as performance and safety.

5. Provide education on the importance of sleep to health, wellbeing, productivity and safety

Providing education on the importance of sleep and ensuring workers have a sufficient window to achieve the sleep they need will likely have beneficial effects in terms mental health, physical health, wellbeing, productivity and safety. Education is a core element of effective fatigue management, which supports the dual goals of productivity and worker health. By proactively addressing fatigue, construction projects can maintain consistent performance levels while safeguarding the physical and mental wellbeing of workers. This alignment fosters a more sustainable work environment that benefits firms and employees alike.

6. Provide quality accommodation on site

We saw the popularity of the accommodation provided on site at Align. Providing good quality accommodation reduces commute times and can decrease the time from waking up to finishing work, which in turn will reduce the effects of fatigue at the end of a shift, which was frequently when relative risk of fatigue was at its highest on longer shifts. Accommodation needs to be clean, well maintained, block out noise, have the ability to fully block out light as well as provide quality bedding and even pay attention to the colour schemes to ensure a calming and inviting space for sleep.

7. Explore the benefits of providing safe and comfortable facilities to take controlled rest breaks (naps)

Many of the workforce are not obtaining sufficient good quality sleep, sometimes for reasons beyond their control – such as light and noise disturbance (especially when sleeping during the day) or disturbance by partners or young children. Short periods of rest are both healthy and productive. Providing clean, secure, comfortable and ergonomic facilities to take a controlled rest break on site could offer workers an alertness boost to last them through their shift and during their commute home. Workers could access the facilities during breaks and / or if directed to take a short, controlled rest break by a manager or supervisor. Workers can already be seen catching sleep, often slouched over tables in canteens or trying to lie on benches in changing rooms. This should not be encouraged given the issues with musculoskeletal issues in construction workforces.

8. Undertake more research into fatigue in major infrastructure construction

Whilst we hope this research advances the industry's knowledge of fatigue, we feel there is scope to continue to build on the body of research already undertaken in this sector. An emerging consensus in sleep and fatigue fields is that there are individual differences in vulnerability to factors that contribute to fatigue risk and its impact on performance. It is, therefore, important to explore factors that contribute to individual differences. Some well-known factors are biological sex, age and different work patterns or work environment. Exploring all factors will allow the industry to develop a more precise fatigue risk index and countermeasures for it.

Furthermore, it would be interesting to gather more data in different populations on the shift patterns we have explored as well as other shift patterns worked in construction. It could be highly instructive to monitor the effects of different shift patterns in groups of workers undertaking the same type of work on the same project to see if it is possible to identify the best shift patterns for the most common types of work / projects. This would allow for a better assessment of individual differences therein and more effective countermeasures for performance impairment.

6.0 Conclusion

Fatigue is a significant and often misunderstood issue in the construction industry. Its impacts on safety, productivity, and workforce health necessitate a more adaptive and insightful approach to management. By embracing tools and technologies that provide greater awareness of fatigue risks and opportunities for mitigation, the industry can achieve substantial returns in safety and productivity. Proactive fatigue management is not merely a commercial advantage – it is a moral imperative that places the well-being of construction workers at the forefront of industry priorities.

It is clear from our research that fatigue is an issue in major infrastructure construction. A significant part of the reason for that is the high proportion of workers who are not obtaining sufficient good quality sleep prior to work. This is resulting in sleepiness at work, which is frequently interfering with work activities.

As we explored in the introduction tiredness and fatigue has negative outcomes for safety and productivity in construction. As we also explored, there are significant productivity and health costs associated with tiredness and fatigue. It logically follows that anything the industry can do to reduce the impact of fatigue will be beneficial to the industry, construction firms and of course, construction workers.

We feel the industry would benefit from paying more attention to fatigue as a safety risk in fatigue risk management plans. This should include when discussing the shift patterns a project will implement and in the longer term, doing more to understand the patterns that maximise safety and productivity.

Daily, weekly and monthly works planning should pay attention to times of elevated fatigue risk and direct, or at least encourage, work with higher degrees of danger or that require high levels of vigilance, concentration or physical activity to be undertaken when alertness is higher.

We acknowledge that some works must be carried out at times when fatigue risk is elevated. If supervisors, managers and health and safety professionals can identify when safety-critical work will be carried out during times of reduced alertness they could allocate resource to increase supervision of tasks. Considering fatigue in weekly and daily works planning meetings is likely to yield improved safety and productivity outcomes.

The industry often places the focus of accident and incident investigation on the individual who was injured or undertaking unsafe acts. We would encourage accident and incident investigation to look beyond the individual and to review the chain of events, the decisions made, and those making the decisions to get closer to the root cause of the incident. Part of this deeper review should include identifying if decisions and actions took place when alertness may have been impaired – both at individual level and at times when we can expect elevated fatigue risk.

Third Pillar of Health has made a start on developing a tool, using the data collected in this study, which will enable identification of fatigue 'hotspots' based on shift patterns and job characteristics that will include accident and incident investigation. If you would like to find out more, our contact details are on the first page of the report or register your interest at www.alert-risk.com.

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8.0 Acknowledgements

We are grateful to those who enabled the study to go ahead and who have supported the roll out of the study across the project.

We are grateful to Fiona King (Head of Occupational Health and Wellbeing, HS2) for her vision and invaluable support in obtaining the necessary approvals to undertake the study and for part funding the study. We also thank Fiona for her effort to promote the study to HS2 Head Office staff. We also thank HS2 Innovation for their approval for the study and for their part funding of the study. Thanks go to Robert Cairns and Nick Podevyn from HS2 Innovation for their support during the application process and in encouraging the joint ventures to participate.

On C1 Align, our launch partner, we thank Ralph Ashwood for his support in the approval process and for launching the study. Neil Hancox, Kevin Long and Phil Key from the Align health and safety team also provided invaluable support to the study. Our thanks go to David Andrews, Gary Russon and Marcos Roman Pina from the Align Segment Precast Factory for their support in being the first section across HS2 to launch the study. Laura Roberts provided invaluable assistance in leading the communications across Align. We thank Didier Jacques for his support in rolling out the study to the tunnel. We thank Eric Ball from Park Health for his support, especially in the early stages when we were deciding what questions to ask about job characteristics, but also in reviewing the results from Align and looking at incident data.

Our thanks go to Align subcontractors and staff including Marian O'Donnell, Gordon Kerins and Michael Tiffoney from Kilnbridge for their support in rolling out the study to their staff – primarily on the viaduct section. Similarly, thanks to Andy Taylor from KVJV enabling us to obtain data from those working in the tunnel. Thanks also to Darren Thorowgood from Socotec and Sarah Byrne from Volker Laser for enlisting staff to participate in the study.

A special mention and thanks go to Demetrios 'Jimmy' Tandis who became the first participant to (diligently) complete 30 working days of data. We thank all workers across C1 Align who participated and provided data.

Image 1 – Voucher handover to the first participant to complete 30 days of data

At JV5S we would like to thank Philippe Galley, Anuj Amin and Andy Bourne for their efforts to try to promote the study. Thanks also go to Ian Pegrum of London Concrete for his efforts with his staff.

At SCS we would like to thank Sandra Winters and Nancy Smith for their tireless efforts to get the study off the ground. Following an encounter at an online tunnelling forum event Andy Levett was instrumental in helping to progress the study on SCS. Robert Dubber and Fiona Power helped promote the study in their sections. We also thank Des Roy, Will Christie, Musa Bah, Annie Scott and Laura Tarpey for their support. We also thank Emma Shannon for her help with the communications. We also thank Erato Mygdaliou for helping to enlist a sizeable participation from the Jospeh Gallagher workers working on SCS.

Our thanks go to Mark Harrington at EKFB for his support and understanding of fatigue as a risk factor in groundwork operations and for helping to enlist his sub-contractors into the study. Thanks go to Mark Bamford at Walters Group and Dale Wilson at Blackwells Earthmoving for helping to promote the study to their workers on EKFB. Our thanks also go to John Phillips and Alex Cox for their support in rolling out the study on the T2G section.

At JV5 we are grateful to Mark Groombridge for driving the study forward, despite being relatively newly in post heading up the Health, Safety and Wellbeing function. Phil Harris was instrumental in helping to roll out the study across JV5. We also thank Roger Bridge, who we also met at an online tunnelling forum event, for his strenuous efforts to promote the study in the tunnels and shafts. Without his support it would have been difficult to continue the dialogue with JV5. Our thanks go to Jules Arlaud and his team and John O’Hara for their support in rolling out the study to the tunnel.

Appendix 1 – Essential question asked at registration

The following questions were asked of all participants in the study. We wanted to understand how demographic and construction-specific job characteristics influenced fatigue risk.

Table 20 – Questions asked of participants at registration

SECTION 1 – JOB TYPE	☐ Please tick one box unless asked to tick all that apply.
1.1 Which part of HS2 do you work on?	☐ Align [Also 1.1 ai] ☐ Atalian Servest ☐ JV5 [Also 1.1 di] ☐ JV5S – Old Oak Common [Also 1.1 ci] ☐ EKFB [Also 1.1 fi] ☐ HS2 office – Snowhill, Podium, Albany House, Other [Also 1.1 ei] ☐ MDJV ☐ SCS [Also 1.1 bi]
1.1 ai Do you work for a major contractor or which part of Align do you work on?	☐ Align - Office team ☐ Earthworks ☐ Segment factory ☐ Shaft sites ☐ Tunnel ☐ Viaduct ☐ Viaduct factory
1.1 bi Which part of SCS do you work on?	☐ Euston delivery unit ☐ West delivery unit ☐ Tunnels and shafts – TBM tunnelling ☐ Tunnels and shafts – SCL tunnelling / Cross passages ☐ Tunnels and shafts – Tunnelling surface support / conveyor ☐ Tunnels and shafts – Shafts ☐ Tunnels and shafts – Routeway ☐ Tunnels and shafts – Office staff

	☐ Logistics ☐ Enabling functions
1.1 ci Did you had to have a medical to work on JV5S?	☐ Yes ☐ No
1.1 di Which part of JV5 do you work on?	☐ Avonmouth segment factory ☐ Bromford tunnel ☐ Curzon street / Delta ☐ 2A and 2B earthworks ☐ Intermediate shaft ☐ Long Itchington Wood Tunnel ☐ Office ☐ PSV factory
1.1 ei Which directorate do you work in?	☐ HS2 – CFO ☐ HS2 – HR ☐ HS2 – Technical services ☐ HS2 – Stations & systems ☐ HS2 – CCO ☐ HS2 – Communications & stakeholder engagement ☐ HS2 – Phase 2 ☐ HS2 – Civils
1.1 fi What is your role or what type of machine do you operate?	☐ Non-plant – e.g. labourer, maintenance, supervisor ☐ Dozer ☐ Dump truck ☐ Excavator ☐ Grader ☐ Roller ☐ Tractor ☐ Other
1.2 What level do you work at?	☐ Operative ☐ Supervisor – Black hat

	☐ Manages and/or supervises a team ☐ Senior Manager ☐ Board Director
1.3 What is your job role?	[Free text box]
1.4 Is your role mainly office or site based?	☐ Office ☐ Site ☐ Both
1.5 Do you work mainly above ground or below ground?	☐ Above ground ☐ Below ground ☐ About the same
1.6 Do you consider your work to be physically or mentally demanding?	☐ Physically ☐ Mentally ☐ Both physically and mentally ☐ Not demanding
1.7 What percentage of your shift are you fully focused on work-related tasks? Excluding breaks. **Note**: this is not a question designed to judge your work ethic as we know everyone has downtime from time to time perhaps waiting for another job to finish.	☐ 0 to 20% ☐ 21 to 40% ☐ 41 to 60% ☐ 61 to 80% ☐ 81 to 100%
SECTION 2 – DEMOGRAPHICS	Please tick one box unless asked to tick all that apply.
2.1 Please tell us your age.	Years [Drop down box starting at 16].
2.2 Please tell us the sex assigned to you at birth. The sex assigned to us at birth influences our circadian rhythm and how we respond to sleep deprivation. This is why we have not listed more options for gender.	☐ Female ☐ Male ☐ Prefer not to say

SECTION 3 – WORK PATTERN	☐ Please tick one box unless asked to tick all that apply.
3.1 What shifts do you work?	☐ Permanent night [Also 3.1a] ☐ Permanent day [Go to 3.2] ☐ Mixed night and day [Also 3.1a & 3.1b]
3.1a How long have you been working shifts?	☐ Less than 6 months ☐ 6 months to 2 years ☐ 2 years to 5 years ☐ 5 years to 10 years ☐ 10 year or more
3.1b Normally how many consecutive day or night shifts do you work before you rotate?	☐ 1 to 2 ☐ 3 to 4 ☐ 5 to 6 ☐ 7 to 8 ☐ 9 or more
3.2 On average how long is your workday / shift?	Hours:____________? Minutes:____________?
SECTION 4 – COMMUTING	☐ Please tick one box unless asked to tick all that apply.
4.1 On average how many minutes do you spend commuting in total to <u>AND</u> from work on a daily basis?	Minutes:____________? [To nearest 15 minutes]
4.2 Are you a transient worker, where you often commute over 3 hours to / from home at the beginning and end of a shift pattern?	☐ Yes ☐ No
SECTION 5 – HOME CONDITIONS	☐ Please tick as many boxes that apply. If the list doesn't include your

	issue, then please complete the free text box
5.1 Other than work reasons are there any other reasons that stop you from getting good sleep?	☐ Not applicable, I sleep quite well ☐ Pain condition ☐ I don't sleep well ☐ Child / children or partner ☐ Noise disturbances ☐ Light disturbances ☐ Stress ☐ Medications ☐ Frequent need to use the bathroom ☐ Other (please state) [Free text box appears

Appendix 2 – High resolution insight into the relative risk of fatigue based on different working patterns

The heatmaps below are based on the relative risk of fatigue. When we looked at the average scores (from 1 to 9 for sleepiness and 1 to 5 for the impact of fatigue on performance) for each hour of each shift we grouped the results in ascending order in 20% groups from low to very high. The figure in the middle blue box under each day is the ranking of the shift from 1 being the most difficult upwards, based on average scores for each shift in a pattern.

Low	Slight	Moderate - Mod	High	Very high - V high

5252 – five days on, 2 days off. Shift lengths less than 10 hours. Site and both office and site

This shift pattern tends to stick to a Monday to Friday schedule with working hours between 06:00 and 19:00.

Table 21 – 5252 less than 10 hour shifts, site staff, sleepiness heatmap

Chance of being very tired (KSS >=7), Relative risk based on average KSS scores (1 to 9), # Data points																		
Time	Monday			Tuesday			Wednesday			Thursday			Friday			Overall		
6	0%	Low	12	18%	V high	11	0%	High	8	0%	Low	4	0%	Low	6	5%	Slight	41
7	0%	Low	15	0%	Low	29	0%	Slight	18	0%	Low	19	8%	Mod	26	2%	Low	107
8	3%	Slight	38	3%	Mod	31	4%	Low	25	5%	Slight	37	3%	Low	33	4%	Slight	164
9	0%	Slight	10	15%	Mod	13	5%	Low	20	5%	Mod	21	0%	Low	22	5%	Slight	86
10	4%	Low	23	0%	Slight	29	3%	Slight	29	5%	Slight	37	4%	Slight	23	4%	Slight	141
11	3%	Mod	29	6%	Slight	31	4%	Mod	27	0%	Slight	27	4%	High	24	4%	Mod	138
12	5%	Slight	21	3%	Low	36	7%	Slight	28	11%	High	38	8%	Mod	25	7%	Mod	148
13	8%	V high	24	10%	High	21	5%	Mod	22	0%	Mod	30	9%	High	35	6%	High	132
14	0%	Slight	34	3%	High	29	10%	V high	41	13%	High	23	28%	V high	29	10%	High	156
15	12%	Mod	26	10%	High	29	12%	V high	26	9%	V high	34	17%	V high	29	12%	V high	144
16	0%	V high	8	5%	V high	21	15%	V high	20	18%	V high	22	0%	High	9	10%	V high	80
17	0%	Mod	9	0%	Low	13	0%	Mod	7	8%	V high	13	25%	V high	8	6%	Mod	50
18	0%	Mod	4	0%	Slight	7	0%	High	5	0%	V high	7	0%	High	5	0%	High	28
19	0%	Slight	2	0%	Slight	1				0%	High	1				0%	Slight	4
FRI	3.5%	5	1.0	5.0%	4	1.7	6.2%	1	2.5	6.4%	2	3.5	9.1%	3	4.4	6.1%		1419

The figure in the off-blue box is the value the Fatigue index gives based on a 9-hour working day with two breaks (once every 3 hours) totalling an hour. We assume the workload is moderately demanding with little spare capacity and that the job requires continuous attention most of the time. Our results also assume a commute of 50 minutes each way – in line with the answers given to us by respondents during registration.

We see and increase in the average sleepiness score to Wednesday, which then flattens. The percentage chance of high levels of sleepiness increases throughout the week and is consistently above the value predicted by the Fatigue and Risk Index ("FRI"). The peak relative risk of fatigue occurs during the natural circadian dip – in this instance from 15:00 to 17:00. The eightieth percentile score is 4.0.

How is fatigue affecting or likely to affect your performance at work?

Table 22 – 5252 less than 10 hour shifts, site staff, performance impact heatmap

Time	Monday	Tuesday	Wednesda	Thursday	Friday	Data point	Overall	Fatigue interfere with work
6	Slight	Very high	Moderate	Low	Moderate	41	Moderate	Low
7	Low	Low	Low	Low	High	107	Slight	Slight
8	Low	Low	Low	Low	Low	164	Low	Moderate
9	Low	Slight	Slight	Slight	Moderate	86	Slight	High
10	Slight	Slight	Moderate	Moderate	Slight	141	Slight	Very high
11	Slight	Moderate	Moderate	Moderate	Moderate	138	Moderate	
12	Moderate	Slight	Moderate	High	Slight	143	Moderate	Shift rank
13	Slight	Slight	Slight	High	Moderate	131	Moderate	1 = Most difficult
14	Slight	High	Moderate	High	Very high	154	High	5 = Easiest
15	High	Moderate	High	Very high	Very high	140	High	
16	Very high	Moderate	Very high	Very high	Very high	79	Very high	
17	Moderate	Moderate	High	High	Very high	49	High	
18	High	Moderate	Very high	Moderate	High	28	High	
19	Slight	Very high		Very high		4	High	
Rank	5	4	3	2	1	1405		

When we look at the responses to the likelihood of fatigue affecting work performance the trends broadly follow those of the KSS sleepiness scores. There is a clear trend to the effect on performance increasing as the week progresses, with the peak impact on a Friday, and particularly Friday afternoon.

5252 – five days on, 2 days off. Shift lengths 10 to 11 hours. Site and both office and site

This shift pattern tends to stick to a Monday to Friday schedule with working hours between 06:00 and 19:00.

Table 23 – 5252 10-11 hour shifts, site staff, sleepiness heatmap

Chance of being very tired (KSS >=7), Relative risk based on average KSS scores (1 to 9), # Data points																		
Time	Monday			Tuesday			Wednesday			Thursday			Friday			Overall		
6	0%	Low	14	8%	Slight	12	0%	Low	17	5%	Low	19	5%	Mod	21	4%	Low	83
7	3%	Low	38	9%	High	47	0%	Slight	46	0%	Low	49	2%	Low	54	3%	Slight	234
8	7%	Slight	15	4%	High	24	0%	Low	19	0%	Slight	21	0%	Slight	22	2%	Slight	101
9	10%	Mod	21	0%	Low	16	0%	Mod	21	4%	Low	28	0%	Low	15	3%	Low	101
10	0%	Low	10	8%	Mod	24	13%	Slight	16	6%	Slight	18	4%	High	23	7%	Mod	91
11	3%	Slight	33	3%	Mod	29	0%	High	32	0%	Mod	31	0%	Low	28	1%	Slight	153
12	4%	Mod	24	3%	Mod	32	5%	V high	20	0%	Slight	35	0%	Low	28	2%	Mod	139
13	4%	Mod	27	5%	Slight	20	0%	Slight	29	0%	High	31	4%	Mod	26	2%	Mod	133
14	0%	Low	19	4%	V high	23	4%	High	24	8%	V high	39	11%	V high	28	6%	High	133
15	9%	High	22	4%	High	27	5%	V high	37	0%	High	27	5%	Slight	21	4%	High	134
16	5%	High	19	3%	V high	29	16%	V high	31	0%	High	23	0%	Mod	21	6%	High	123
17	0%	High	12	0%	V high	13	0%	High	12	4%	Slight	26	0%	Mod	15	1%	Mod	78
18	14%	V high	7	0%	High	5	0%	V high	11	0%	Mod	10	14%	V high	7	5%	V high	40
19	0%	V high	6	0%	V high	2	0%	Mod	2	17%	V high	6	0%	V high	1	6%	V high	17
FRI	4.1%	5	1.9	4.6%	1	3.6	3.5%	2	6.1	2.2%	4	8.8	2.9%	3	11.3	3.5%		1560

The figure in the off-blue box is the value the Fatigue index gives based on an 11-hour working day with two breaks (once every 3.5 hours) totalling an hour. We assume the workload is moderately demanding with little spare capacity and that the job requires continuous attention most of the time. Our results also assume a commute of 50 minutes each way – in line with the answers given to us by respondents during registration.

We see an increase in the average sleepiness score on Tuesday before a slight decline as the week progresses. The percentage chance of high levels of sleepiness decreases through the week and consistently falls below the value predicted by the Fatigue and Risk Index ("FRI") from Wednesday. We see an increase in the relative risk of fatigue during the natural circadian dip – in this instance from 14:00 to 17:00, but the highest relative risk of fatigue occurs in the last hour / two hours of the shift. The eightieth percentile score is 3.5.

How is fatigue affecting or likely to affect your performance at work?

Table 24 – 5252 10-11 hour shifts, site staff, performance impact heatmap

Time	Monday	Tuesday	Wednesda	Thursday	Friday		Data poin	Overall
6	High	High	Very high	Moderate	Very high		82	High
7	Moderate	High	Low	Low	Low		232	Slight
8	Moderate	Low	Moderate	Low	Low		101	Slight
9	Slight	Low	Low	Low	Slight		98	Low
10	High	Slight	Low	Moderate	Moderate		91	Moderate
11	Slight	Moderate	Moderate	Slight	Slight		152	Slight
12	Slight	Moderate	Very high	Moderate	Slight		138	Moderate
13	Slight	Low	Slight	Slight	Moderate		131	Slight
14	Low	Very high	Moderate	High	Moderate		130	Moderate
15	Very high	High	Moderate	High	Moderate		131	High
16	High	Very high	High	Moderate	High		120	High
17	High	High	High	Moderate	Very high		78	High
18	Very high	Very high	Very high	High	Very high		38	Very high
19	Very high	Very high	Low	Very high	Low		16	Moderate
	2	1	3	3	5		1538	

Fatigue interfere with work
Low
Slight
Moderate
High
Very high
Shift rank
1 = Most difficult
5 = Easiest

When we look at the responses to the likelihood of fatigue affecting work performance the trends broadly follow those of the KSS sleepiness scores. There is a peak in the effect on performance on Tuesday before a steady decline as the week progresses.

5252 – five days on, 2 days off. Shift lengths 12+ hours. Site and both office and site (day shift)

This shift pattern tends to stick to a Monday to Friday schedule with working between 06:00 and 19:00.

Table 25 – 5252 12+ hour shifts day shift, site staff, sleepiness heatmap

Chance of being very tired (KSS >=7), Relative risk based on average KSS scores (1 to 9), # Data points																		
Time	Monday			Tuesday			Wednesday			Thursday			Friday			Overall		
6	0%	Low	25	5%	Low	20	8%	Mod	50	6%	Low	32	12%	Mod	41	7%	Slight	168
7	0%	High	19	0%	Slight	27	0%	Mod	23	6%	High	34	0%	Mod	29	2%	Mod	132
8	7%	Low	14	0%	Slight	13	0%	Slight	10	0%	Slight	5	10%	Mod	10	4%	Slight	52
9	0%	Low	8	0%	Low	5	0%	Slight	3	0%	V high	8	0%	Low	3	0%	Slight	27
10	8%	High	13	0%	High	8	0%	Low	5	8%	High	13	0%	High	4	5%	High	43
11	0%	Low	9	0%	High	18	0%	Mod	9	0%	Low	17	8%	V high	12	2%	Mod	65
12	0%	Mod	12	0%	Slight	12	0%	Slight	18	4%	Mod	55	0%	Slight	15	2%	Slight	112
13	0%	Mod	18	0%	Mod	52	0%	Low	18	0%	Slight	30	6%	High	16	1%	Mod	134
14	0%	Mod	15	0%	Slight	12	7%	V high	14	0%	Mod	7	8%	V high	12	3%	High	60
15	8%	Mod	13	0%	Slight	13	0%	High	22	17%	V high	12	9%	V high	11	6%	High	71
16	0%	Mod	7	0%	V high	6	8%	High	13	0%	V high	13	0%	Mod	5	2%	High	44
17	6%	V high	16	0%	V high	14	0%	High	16	0%	Mod	10	7%	V high	14	3%	High	70
18	0%	High	14	0%	V high	10	18%	V high	11	0%	Low	17	40%	V high	5	7%	V high	57
19				33%	V high	3	0%	Slight	4	0%	Low	1	0%	Mod	1	11%	Mod	9
FRI	2.2%	5	2.1	0.9%	2	3.8	3.7%	4	6.7	3.5%	3	9.7	7.3%	1	12	3.4%		1044

The figure in the off-blue box is the value the Fatigue index gives based on a 12-hour working day with two breaks (once every 4 hours) totalling an hour. We assume the workload is moderately demanding with little spare capacity and that the job requires continuous attention most of the time. Our results also assume a commute of 50 minutes each way – in line with the answers given to us by respondents during registration.

We see an increase in the average sleepiness score on Tuesday before a slight decline until a peak on a Friday shift. The percentage chance of high levels of sleepiness increases through the week and is generally below the value predicted by the Fatigue and Risk Index ("FRI"). We see an increase in the relative risk of fatigue during the natural circadian dip – in this instance from 14:00 which sustains through to the end of the shift. The eightieth percentile score is 3.5.

How is fatigue affecting or likely to affect your performance at work?

Table 26 – 5252 12+ hour shifts day shift, site staff, performance impact heatmap

Time	Monday	Tuesday	Wednesda	Thursday	Friday	Data poin	Overall	Fatigue interfere with work
6	Low	Low	High	Slight	High	165	Moderate	Low
7	Slight	High	Moderate	High	High	132	High	Slight
8	Slight	Low	Slight	High	Slight	52	Slight	Moderate
9	Slight	Low	Low	High	Low	27	Slight	High
10	High	High	Very high	Moderate	Low	42	High	Very high
11	Low	Moderate	Very high	Slight	Very high	64	Moderate	
12	Moderate	Slight	Low	High	High	112	Moderate	Shift rank
13	Slight	Slight	Moderate	High	High	131	Moderate	1 = Most difficult
14	Low	Slight	Slight	High	Very high	60	Moderate	5 = Easiest
15	Low	Slight	Moderate	Moderate	Very high	71	Moderate	
16	Slight	Very high	Slight	Very high	Moderate	43	High	
17	High	Very high	High	High	High	66	High	
18	High	High	Very high	Slight	Very high	56	High	
19		Very high	Low	Low	Low	8	Low	
	5	3	4	2	1	1029		

When we look at the responses to the likelihood of fatigue affecting work performance on the day shift there is a much clearer trend to the performance impact increasing as the week progresses. There is also a one to two hour delay on the impact on performance kicking in versus the increase in sleepiness in the afternoon.

5252 – five days on, 2 days off. Shift lengths 12+ hours. Site and both office and site (night shift)

Table 27 – 5252 12+ hour shifts night shift, site staff, sleepiness heatmap

Chance of being very tired (KSS >=7), Relative risk based on average KSS scores (1 to 9), # Data points																		
Time	Monday			Tuesday			Wednesday			Thursday			Friday			Overall		
18	9%	Slight	23	0%	Slight	24	6%	Slight	17	5%	Slight	20	11%	Slight	19	6%	Slight	103
19	0%	Low	3	0%	Low	1	0%	Slight	2	0%	Slight	5	0%	Low	1	0%	Low	12
20				0%	Low	1				0%	V high	1	0%	Low	2	0%	Mod	4
21	0%	High	3	100%	V high	1	0%	Low	1	0%	Low	2	0%	Low	1	13%	Mod	8
22	20%	Mod	10	0%	V high	1	0%	High	3							14%	High	14
23	0%	V high	1	0%	Low	2	0%	Slight	3	0%	High	1	0%	Low	3	0%	Mod	10
0	0%	Low	5	0%	Mod	7	0%	Mod	9	0%	Slight	2	0%	Mod	4	0%	Slight	27
1	0%	Mod	7	0%	High	6	0%	Mod	2	0%	Mod	6	0%	Slight	2	0%	Mod	24
2	0%	Mod	3	20%	High	5	0%	High	3	20%	Mod	5	0%	Mod	2	11%	High	18
3	20%	Mod	5	0%	V high	2				0%	V high	1				13%	High	8
4	67%	V high	3	50%	V high	4	20%	Mod	5	100%	V high	1	0%	Slight	4	35%	High	17
5	20%	High	5	57%	V high	7	44%	High	9	0%	Mod	6	25%	High	8	31%	High	35
6	50%	V high	2				0%	High	1	50%	High	2				40%	High	5
7										100%	V high	1				100%	V high	1
FRI	12.9%	3	32	13.1%	2	34	10.9%	4	38	9.4%	1	41	8.7%	5	43	11.2%		286

The figure in the off-blue box is the value the Fatigue index gives based on a 12-hour working day with two breaks (once every 4 hours) totalling an hour. We assume the workload is moderately demanding with little spare capacity and that the job requires continuous attention most of the time. Our results also assume a commute of 50 minutes each way – in line with the answers given to us by respondents during registration.

We see and increase in the average sleepiness score on Tuesday and again on a Thursday shift. In this study we often found the second night shift to be the most difficult of the shift pattern – most likely because workers have had their main sleep episode during the day for the first time. The percentage chance of high levels of sleepiness decreases through the week from the Monday and Tuesday and is consistently well below the value predicted by the Fatigue and Risk Index ("FRI"). We see an increase in the relative risk of fatigue during the natural early morning circadian dip – in this instance from 02:00 to 06:00 which sustains through to the end of the shift. The eightieth percentile score is 5.0.

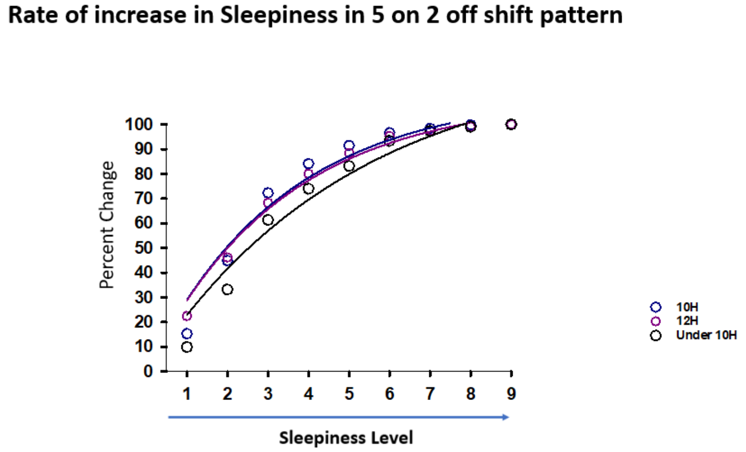
How is fatigue affecting or likely to affect your performance at work?

Table 28 – 5252 12+ hour shifts night shift, site staff, performance impact heatmap

Time	Monday	Tuesday	Wednesda	Thursday	Friday		Data point	Overall		Fatigue interfere with work
18	Slight	Slight	Slight	Slight	Slight		100	Slight		Low
19	Low	Low	Low	Slight	Low		11	Slight		Slight
20		Low		Very high	Low		4	Slight		Moderate
21	High	Very high	Low	Low	Low		8	Slight		High
22	Slight	Low	Moderate				12	Slight		Very high
23	Moderate	Slight	Slight	Moderate	Slight		10	Slight		
24	Slight	Moderate	Moderate	Moderate	High		27	Moderate		Shift rank
1	Moderate	High	Very high	Moderate	Slight		24	Moderate		1 = Most difficult
2	Very high	High	High	Moderate	Very high		18	High		5 = Easiest
3	Moderate	High		Moderate			8	Moderate		
4	High	High	Very high	Very high	Slight		15	High		
5	High	Very high	Moderate	Moderate	High		35	High		
6	Very high		Very high	Moderate			5	High		
7				Very high			1	Very high		
	2	4	3	1	5		278			

The impact of fatigue on performance on the night shift fluctuated as the week progressed, until a fall on a Friday. The average score is significantly higher on the night shift than on the day shift meaning there is a consistently higher impact of fatigue on work performance throughout the night shift.

Graph 8 – Rate of increase in sleepiness in the 5 on 2 off shift pattern



Analysis by Northumbria University show the accumulation in sleepiness in the different 5-on 2-off shift patterns. Note the trajectory for the three curves, which indicates that the acceleration to sleepiness is slightly slower in the under 10 hour shift.

5252 – five days on, 2 days off. Shift lengths less than 10 hours. Office staff

This shift pattern tends to stick to a Monday to Friday schedule with working hours between 06:00 and 19:00.

Table 29 – 5252 less than 10 hour shifts, office staff, sleepiness heatmap

Chance of being very tired (KSS >=7), Relative risk based on average KSS scores (1 to 9), # Data points																		
Time	Monday			Tuesday			Wednesday			Thursday			Friday			Overall		
6	17%	Low	12	11%	Low	9	0%	Low	5	0%	Low	8	0%	Slight	4	8%	Low	38
7	13%	Mod	39	12%	Slight	42	7%	Mod	57	6%	Low	49	8%	High	50	9%	Mod	237
8	10%	Slight	48	6%	Mod	54	2%	Slight	64	2%	Slight	50	11%	Slight	46	6%	Slight	262
9	7%	Mod	42	4%	Low	45	6%	Low	35	14%	Slight	35	9%	Slight	35	8%	Slight	192
10	4%	Low	27	15%	Mod	41	5%	Low	22	0%	Low	35	0%	Low	42	5%	Low	167
11	2%	Low	42	7%	Slight	43	5%	Low	61	10%	Mod	49	7%	Slight	57	6%	Slight	252
12	6%	Mod	53	3%	Mod	59	3%	Mod	60	5%	Mod	76	0%	Slight	47	4%	Mod	295
13	5%	High	41	6%	High	51	5%	High	44	7%	Slight	44	0%	Slight	33	5%	Mod	213
14	16%	High	31	11%	V high	37	3%	Slight	37	15%	V high	33	4%	Slight	46	9%	High	184
15	8%	High	49	10%	High	60	16%	V high	64	11%	High	64	3%	Mod	72	9%	High	309
16	5%	Mod	41	9%	High	34	9%	High	32	6%	Mod	53	7%	Mod	28	7%	Mod	188
17	6%	V high	16	0%	V high	19	10%	V high	21	7%	V high	27	0%	High	12	5%	V high	95
18	31%	V high	13	33%	V high	3	13%	Slight	8	50%	V high	4	0%	V high	4	25%	V high	32
19	0%	V high	1	0%	V high	2	50%	V high	2				0%	V high	1	17%	V high	6
FRI	8.4%	1	1.0	7.8%	2	1.7	7.6%	5	2.5	7.6%	4	3.5	4.6%	3	4.4	7.5%		2470

The figure in the off-blue box is the value the Fatigue index gives based on a 9-hour working day with two breaks (once every 3 hours) totalling an hour. We assume the workload is moderately demanding with little spare capacity and that the job requires continuous attention most of the time. Our results also assume a commute of 50 minutes each way – in line with the answers given to us by respondents during registration.

There is a broad trend to a decrease in the average sleepiness scores as the week progresses. The percentage chance of high levels of sleepiness also decreases throughout the week, with a notable drop on Friday, which may be due to some office workers working from home and is consistently above the value predicted by the Fatigue and Risk Index ("FRI"). We see an increased relative risk of fatigue during the natural circadian dip – in this instance from 14:00 to 16:00 but a much higher relative risk of fatigue in the last two hours of a shift. The eightieth percentile score is 4.2, which is slightly above colleagues working on site and across site and office.

How is fatigue affecting or likely to affect your performance at work?

Table 30 – 5252 less than 10 hour shifts, office staff, performance impact heatmap

Time	Monday	Tuesday	Wednesda	Thursday	Friday	Data poin	Overall
6	Slight	Slight	Low	Moderate	High	36	Low
7	Slight	Slight	Slight	Low	Moderate	232	Slight
8	Low	Moderate	Slight	Low	Moderate	260	Slight
9	Slight	Slight	Slight	Low	Slight	187	Slight
10	Slight	Moderate	Slight	Moderate	Low	165	Slight
11	Moderate	High	Slight	Moderate	Moderate	248	Moderate
12	Moderate	Slight	High	Moderate	Slight	290	Moderate
13	Moderate	Moderate	Moderate	Moderate	Moderate	206	Moderate
14	Very high	High	High	Very high	Moderate	181	High
15	High	Very high	Very high	Very high	High	303	High
16	High	High	Very high	High	Very high	184	High
17	High	Very high	Very high	Very high	High	94	High
18	Very high	Very high	High	Very high	Moderate	32	Very high
19	Very high	High	Very high		Very high	6	Very high
	3	2	1	4	5	2424	

Fatigue interfere with work
Low
Slight
Moderate
High
Very high
Shift rank
1 = Most difficult
5 = Easiest

When we look at the responses to the likelihood of fatigue affecting work performance we see a slight parabola effect with a peak on Wednesday. We see an increase in the impact of fatigue in the afternoon dip with the highest impact in the last hour or two of a shift. The average impact value of 2.0 is also higher in office staff than those working on site and across both site and office (1.7).

5252 – five days on, 2 days off. Shift lengths 10 to 11 hours. Office staff

This shift pattern tends to stick to a Monday to Friday schedule with working hours from 06:00 to 19:00.

Table 31 – 5252 10-11 hour shifts, office staff, sleepiness heatmap

Chance of being very tired (KSS >=7), Relative risk based on average KSS scores (1 to 9), # Data points																		
Time	Monday			Tuesday			Wednesday			Thursday			Friday			Overall		
6	0%	Slight	6	0%	Mod	7	0%	Low	5	0%	Slight	3	0%	V high	5	0%	Slight	26
7	0%	High	5	14%	V high	7	0%	Low	4	0%	Slight	12	0%	Low	6	3%	Mod	34
8	0%	Slight	9	0%	Low	5	14%	V high	7	33%	High	3	0%	Mod	4	7%	Mod	28
9	0%	Slight	5	0%	Slight	6	0%	Mod	6	0%	High	6	0%	Low	8	0%	Mod	31
10	0%	Low	1	0%	Low	6	0%	Low	6	0%	High	5	0%	Low	5	0%	Low	23
11	0%	High	7	0%	Slight	5	0%	Low	1	0%	3.4	7	29%	V high	7	7%	Mod	27
12	0%	V high	2	17%	Slight	6	0%	Mod	7	10%	High	10	0%	High	5	7%	High	30
13	0%	High	12	0%	Slight	5	13%	Mod	8	0%	High	5	0%	Mod	9	3%	Mod	39
14	33%	V high	3	0%	Mod	6	0%	Mod	3	14%	High	7	0%	High	5	8%	High	24
15	0%	Low	3	20%	Mod	10	0%	Mod	7	0%	Mod	9	0%	Mod	6	6%	Mod	35
16	0%	High	3	0%	High	3	25%	High	4	0%	V high	3	0%	V high	2	7%	V high	15
17	0%	Mod	5	0%	V high	4	0%	V high	8	0%	Slight	3	0%	V high	2	0%	V high	22
18	100%	V high	1	0%	Low	1				0%	Slight	3	0%	Mod	2	14%	High	7
19				0%	Low	1				0%	V high	2				0%	Low	3
FRI	3.2%	2	1.9	5.6%	5	3.6	4.5%	4	6.1	3.8%	3	8.8	3.0%	1	11.3	4.1%		344

The figure in the off-blue box is the value the Fatigue index gives based on an 11-hour working day with two breaks (once every 3.5 hours) totalling an hour. We assume the workload is moderately demanding with little spare capacity and that the job requires continuous attention most of the time. Our results also assume a commute of 50 minutes each way – in line with the answers given to us by respondents during registration.

When looking at office-based workers doing 10 to 11 hour shifts after a relatively high score on a Monday there is then an increase as the week progresses. The Tuesday shift sees the highest chance of high levels of sleepiness. The highest relative risk of fatigue happens between 16:00 and

18:00. The eightieth percentile score is 4.4, which is 26% higher than colleagues working on site and across site and office.

How is fatigue affecting or likely to affect your performance at work?

Table 32 – 5252 10-11 hour shifts, office staff, performance impact heatmap

Time	Monday	Tuesday	Wednesda	Thursday	Friday	Data point	Overall
6	Very high	Moderate	Slight	Very high	High	26	High
7	Moderate	Low	Slight	High	Slight	34	Slight
8	Slight	Low	Moderate	Moderate	Very high	27	Moderate
9	Low	Low	Low	Low	Moderate	30	Low
10	Low	Slight	Moderate	Slight	Low	23	Low
11	Slight	High	Very high	Slight	Moderate	27	Moderate
12	Slight	Low	High	High	Very high	28	High
13	Low	Moderate	High	Very high	Moderate	39	Moderate
14	Moderate	High	Moderate	Moderate	High	24	Moderate
15	Moderate	High	Moderate	Moderate	High	35	Moderate
16	Moderate	Very high	Very high	Very high	Very high	14	Very high
17	Slight	Very high	Moderate	Very high	Very high	21	High
18	Very high	Low		Low	Low	7	Moderate
19		Very high		Very high		2	Very high
	5	4	3	1	2	337	

Fatigue interfere with work
Low
Slight
Moderate
High
Very high
Shift rank
1 = Most difficult
5 = Easiest

When we look at the responses to the likelihood of fatigue affecting work performance, we see we see an increase as the week progresses until a drop on a Friday. We see an increase in the impact of fatigue at 16:00 – in line with average sleepiness scores. The average impact value of 1.7 is in line with those working on site and across both site and office (1.7).

5252 – five days on, 2 days off. Shift lengths 12+ hours. Office staff

This shift pattern tends to stick to a Monday to Friday schedule with working hours between 06:00 and 19:00.

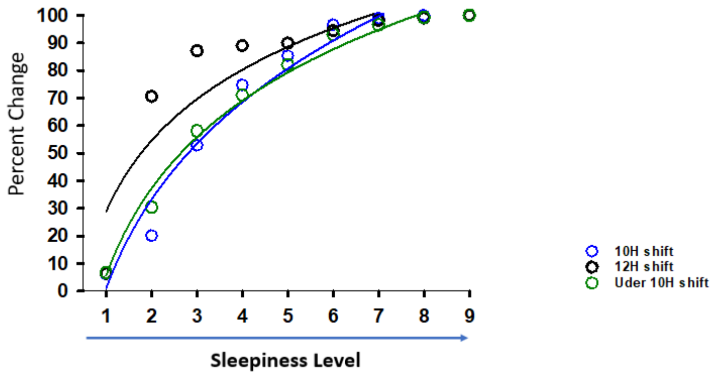
Table 33 – 5252 12+ hour shifts day shift, office staff, sleepiness & performance impact heatmap

Time	Sleepiness			Imapct on performance	
6	17%	High	6	Moderate	6
7	0%	Mod	11	Slight	11
8	0%	Low	11	Moderate	11
9	0%	Low	5	Low	5
10	0%	Slight	6	High	6
11	0%	Slight	7	High	7
12	10%	High	10	Low	10
13	0%	Low	10	Slight	9
14	0%	V high	6	Moderate	6
15	0%	Mod	6	Slight	6
16	0%	High	8	Very high	8
17	0%	High	8	Very high	8
18	0%	Mod	6	High	6
19	0%	V high	3	Very high	3
FRI	1.9%		103		102

We did not have enough data to do a full heatmap for office workers working 12+ hour shifts. We see an increase from 14:00 in sleepiness and from 16:00 in terms of the impact of fatigue on performance at work.

Graph 9 – Rate of increase in sleepiness in office staff working under 10, 10-11 or 12+ hour shifts

Rate of increase in Sleepiness in the Office Shift Pattern



Analysis by Northumbria University show the accumulation in sleepiness in office-based workers. Note the trajectory for the three curves, which indicates that the acceleration to sleepiness is slightly slower in the under 10 hour shift for those working in the office.

Commentary on 5 days on 2 days off shift patterns in the office and on site

We found different lengths of shift altered the patterns in fatigue risk. For those on site and working across site and office we saw increases in average sleepiness scores before they fell as the week progressed. When looking at the chances of high levels of sleepiness we saw contrasting trends. We saw a steady increase as the week progressed in shifts less than 10 hours and 12+ hours, whilst we saw a steady decrease as the week progressed for those working 10 to 11 hour shifts. This was mirrored when looking at the impact of fatigue on performance at work. The trends in office staff were often the reverse of the trends we saw in those working on site and across office and site. Again, there were no common trends in office workers and trends differed depending on shift length.

7473 – 7 nights on, 4 days off, 7 days on, 3 days off.
12 hour shifts (day shift)

This shift pattern operates seven consecutive shifts of 12 hours in length. A period of seven night shifts often starts on a Tuesday and finishes the following Tuesday morning. This is followed by three days off, typically Tuesday to Thursday. Seven days tend to start on a Friday morning, ending the following Thursday evening before four days off from Friday to Monday.

Table 34 – 7473 12 hour shifts day shift, sleepiness heatmap

Chance of being very tired (KSS >=7), Relative risk based on average KSS scores (1 to 9), # Data points

Time	Shift 1			Shift 2			Shift 3			Shift 4			Shift 5			Shift 6			Shift 7			Overall		
6	20%	Slight	5	0%	Low	2	25%	Mod	4				0%	Low	3	100%	V high	1	100%	V high	1	25%	Mod	16
7	0%	Slight	8	13%	Slight	8	0%	Slight	9	0%	Low	18	0%	Slight	4	0%	Low	7	0%	Slight	7	2%	Slight	61
8	0%	Mod	7	50%	High	4	33%	Mod	3	0%	Low	4				0%	Slight	2	0%	Low	1	14%	Slight	21
9				0%	V high	1	0%	High	3	0%	Low	3	0%	Slight	5	0%	Low	1	50%	High	4	12%	Mod	17
10	0%	Low	5	0%	Low	5	0%	Low	3	0%	Slight	3	0%	Low	1							0%	Low	17
11	0%	High	1							0%	Mod	2	50%	V high	2							20%	High	5
12	13%	Slight	8	13%	Mod	8	67%	High	3	67%	V high	3	0%	High	3	0%	Mod	2	0%	Low	1	21%	Mod	28
13	0%	Slight	6	0%	Mod	6	13%	Mod	8	11%	Mod	9	0%	Slight	3	0%	Slight	3	25%	Mod	4	8%	Mod	39
14	0%	Mod	6	100%	V high	1	0%	Mod	2	0%	Slight	2				100%	V high	1	0%	High	2	14%	High	14
15	0%	Low	1	0%	V high	1	0%	Mod	3	0%	Low	2	0%	High	1	0%	High	1	20%	High	5	7%	Mod	14
16				20%	High	5	0%	Mod	2	33%	High	3	0%	High	2	0%	Mod	3	0%	V high	2	12%	High	17
17	40%	High	5	0%	Slight	2	20%	Mod	5	25%	High	4	0%	High	2	0%	Mod	1	0%	Low	1	20%	Mod	20
18	17%	High	12	45%	V high	11	30%	Mod	10	20%	High	10	14%	High	7	33%	V high	6	60%	V high	5	30%	High	61
19	50%	V high	2	0%	V high	1	0%	V high	1	100%	V high	1				0%	V high	1				33%	V high	6
FRI	11%	7	2.4	20%	1	4.1	16%	5	6.9	13%	4	10	6%	6	12.7	14%	2	14.9	24%	3	16.6	15%		336

The figure in the off-blue box is the value the Fatigue index gives based on a 12-hour working day with two breaks (once every 3.5 hours) totalling an hour. We assume the workload is moderately demanding with little spare capacity and that the job requires continuous attention most of the time. Our results also assume a commute of 50 minutes each way – in line with the answers given to us by respondents during registration.

In terms of average KSS sleepiness score we see a peak on the second shift, which then fall and flatten through to the 6th and 7th shifts, which see elevated average scores. A similar trend is observed in the percentage chance of high levels of sleepiness. We see a spike in sleepiness around the fifth hour of the shift. This follows a trend we see in populations with more rigid start, finish and break times. On the day shift we often see a spike in sleepiness an hour after the first main break which is likely to be a post-prandial effect. The final two hours of the shift are the most difficult. The eightieth percentile score is 6.0.

How is fatigue affecting or likely to affect your performance at work?

Table 35 – 7473 12 hour shifts day shift, performance impact heatmap

Time	Shift 1	Shift 2	Shift 3	Shift 4	Shift 5	Shift 6	Shift 7	Data point	Overall	Fatigue interfere with work
6	Slight	Moderate	Very high		Low	Very high	Very high	16	High	Low
7	Low	Slight	Low	Slight	Moderate	Slight	Moderate	61	Slight	Slight
8	Slight	Very high	Moderate	High		Moderate	Moderate	20	High	Moderate
9		Very high	Moderate	Low	Low	Low	High	17	Slight	High
10	Slight	Low	Slight	Low	Low			17	Low	Very high
11	Low			Moderate	Very high			5	Moderate	
12	High	Slight	High	Very high	High	Moderate	Low	27	High	Shift rank
13	High	Slight	Slight	High	High	Slight	Moderate	39	Moderate	1 = Most difficult
14	Moderate	Very high	High	Moderate		Very high	Very high	12	High	7 = Easiest
15	Low	Very high	High	Slight	Low	Very high	Moderate	14	Moderate	
16		High	Low	Very high	Low	Moderate	Moderate	16	Moderate	
17	Slight	Low	High	High	Slight	Very high	Low	19	Slight	
18	High	High	High	High	High	Slight	Very high	61	High	
19	Moderate	Moderate	Very high	Very high		Moderate		5	High	
	7	2	5	1	6	4	3	329		

When we look at the responses to the likelihood of fatigue affecting work performance, we see increases on the 2nd, 4th and 7th shifts with the peak on the 4th shift. We see an increase in the impact of fatigue at 14:00. The final two hours of the shift are the most difficult in terms of the impact of fatigue on performance.

7473 – 7 nights on, 4 days off, 7 days on, 3 days off. 12 hour shifts (night shift)

Table 36 – 7473 12 hour shifts night shift, sleepiness heatmap

Chance of being very tired (KSS >=7), Relative risk based on average KSS scores (1 to 9), # Data points

Time	Shift 1			Shift 2			Shift 3			Shift 4		
18	0%	Slight	2	0%	Slight	1	0%	Low	2			
19	0%	Low	5	0%	Low	5	0%	Low	4	0%	Mod	5
20	0%	Low	3				0%	Low	1	0%	Low	3
21	0%	Mod	2	0%	Slight	2	0%	High	1	0%	Mod	1
22	0%	Mod	2	0%	Slight	3	0%	Low	1	0%	Low	1
23	0%	Low	2	0%	Low	5	0%	High	2	0%	Low	2
0	33%	Mod	3	100%	V high	1	25%	Mod	4	0%	Slight	2
1	0%	Slight	5	14%	Mod	7	20%	Mod	5	14%	High	7
2	0%	Low	1	0%	Slight	1	33%	V high	3	0%	Slight	2
3	0%	Mod	2	50%	High	2	0%	High	1	0%	Mod	2
4	33%	High	3				50%	V high	2	100%	V high	1
5	33%	V high	3	50%	V high	6	50%	V high	2	100%	V high	1
6	50%	V high	6	67%	V high	6	71%	V high	7	50%	V high	2
7				0%	High	1						
FRI	15%	7	34.9	25%	3	37.5	29%	2	41.5	14%	5	44.6

Time	Shift 5			Shift 6			Shift 7			Overall		
18				0%	Low	2				0%	Low	7
19	0%	Slight	3	17%	Mod	6	25%	High	4	6%	Slight	32
20	0%	Slight	1							0%	Low	8
21	0%	Low	3				0%	Slight	2	0%	Mod	11
22	0%	Low	1	0%	Slight	2				0%	Slight	10
23	0%	Mod	3	0%	Slight	1	100%	V high	1	6%	Mod	16
0	0%	Slight	2	0%	Mod	4	0%	Slight	4	15%	Mod	20
1	33%	High	3	0%	Mod	4	0%	Slight	2	12%	Mod	33
2				0%	High	2	0%	High	3	8%	Mod	12
3	50%	High	6	50%	Mod	2	0%	High	1	31%	High	16
4	33%	Slight	3	0%	Slight	1	33%	High	3	38%	High	13
5	100%	V high	2	33%	V high	3	0%	Mod	2	47%	V high	19
6	50%	V high	2	40%	High	5	50%	V high	4	56%	V high	32
7	0%	High	1							0%	High	2
FRI	27%	4	46.8	16%	6	48.3	19%	1	49.4	21%		231

The figure in the off-blue box is the value the Fatigue index gives based on a 12-hour working day with two breaks (once every 3.5 hours) totalling an hour. We assume the workload is moderately demanding with little spare capacity and that the job requires continuous attention most of the time. Our results also assume a commute of 50 minutes each way – in line with the answers given to us by respondents during registration.

In terms of average KSS sleepiness score we see fluctuations throughout the week with the peak on the 7th and final night shift. We see increases in the percentage chance of high levels of sleepiness on the 2nd, 3rd and 5th night shifts. Average scores increase in the early morning and the relative risk of fatigue is highest in the last three hours of the night shift. The eightieth percentile score is 6.3.

How is fatigue affecting or likely to affect your performance at work?

Table 37 – 7473 12 hour shifts night shift, performance impact heatmap

Time	Shift 1	Shift 2	Shift 3	Shift 4	Shift 5	Shift 6	Shift 7		Data point	Overall		Fatigue interfere with work
18	Very high	Moderate	Low			Low			7	Slight		Low
19	Low	Slight	Low	Slight	Low	Moderate	Slight		30	Slight		Slight
20	Low		Moderate	Low	Low				8	Slight		Moderate
21	Moderate	Slight	Very high	Low	Low		Moderate		11	Slight		High
22	Very high	Slight	Moderate	Low	Very high	Slight			10	Moderate		Very high
23	High	Low	Moderate	High	Slight	Moderate	Moderate		14	Moderate		
0	High	Moderate	Moderate	Low	Slight	Moderate	Moderate		19	Slight		Shift rank
1	Slight	High	Slight	Moderate	Moderate	Moderate	Low		33	Slight		1 = Most difficult
2	Low	Moderate	Very high	Moderate		Moderate	High		12	High		7 = Easiest
3	Moderate	Moderate	Very high	Moderate	Very high	Slight	Very high		15	High		
4	Moderate		Moderate	Moderate	High	Low	Moderate		13	Moderate		
5	Very high	High	Very high	Very high	Very high	High	Moderate		19	Very high		
6	High	Very high	High	Moderate	Very high	High	Very high		32	High		
7		Low			Very high				2	Moderate		
	3	7	5	6	1	#DIV/0!	4		225			

As with KSS scores we see fluctuations in the impact of fatigue on performance at work over the week. There is an increase in the impact of fatigue on performance from 02:00 to 06:00, in line with our natural circadian dip at that time of the day.

6_1 – 6 days nights on. 1 day off. 10 to 11 hour shifts

This shift pattern operates six consecutive shifts of 10 or 11 hours in length from Monday to Saturday with Sunday as a rest day.

Table 38 – 6_1 10-11 hour shifts, sleepiness heatmap

Chance of being very tired (KSS >=7), Relative risk based on average KSS scores (1 to 9), # Data points

Time	Monday			Tuesday			Wednesday			Thursday			Friday			Saturday			Overall		
6	0%	Mod	2	0%	Mod	2	0%	Slight	3				0%	V high	1	0%	Slight	3	0%	High	11
7	0%	Low	5	0%	Low	5	0%	Low	9	0%	Low	8	0%	Low	5	0%	Low	4	0%	Low	36
8	0%	Mod	2	25%	V high	4	0%	Slight	3	0%	Low	3	0%	Slight	7	0%	Slight	1	5%	Slight	20
9	0%	Mod	2	0%	Slight	3				0%	Low	4	0%	Slight	2	0%	Slight	1	0%	Slight	12
10	0%	Mod	4	0%	Slight	5	0%	High	7	0%	High	3	0%	Mod	3	0%	Mod	8	0%	Mod	30
11	0%	Low	4	0%	Slight	10	0%	Slight	5	0%	Low	8	0%	Low	7	0%	Mod	3	0%	Slight	37
12	0%	Slight	8	0%	V high	6	0%	High	5	0%	Low	6	0%	High	7	8%	High	12	2%	Mod	44
13	0%	High	6	0%	Slight	7	0%	Mod	7	0%	Mod	2	0%	Mod	2	0%	Slight	3	0%	Mod	27
14	0%	Mod	4	0%	High	4	0%	High	3	0%	Mod	4	0%	High	9	0%	High	3	0%	High	27
15	0%	V high	3	0%	Mod	4	0%	Slight	10	0%	Slight	4	0%	Slight	4	0%	Slight	3	0%	Mod	28
16	0%	V high	6	0%	High	13	0%	Mod	6	0%	V high	5	0%	High	9	0%	Slight	1	0%	High	40
17	0%	V high	3	0%	Mod	4	0%	V high	2	0%	V high	3	0%	Slight	2	17%	V high	6	5%	V high	20
18	0%	V high	3	0%	V high	2	0%	V high	3	0%	High	4	0%	V high	1	0%	Slight	1	0%	High	14
19	0%	V high	1																0%	V high	1
FRI	0%	1	1.7	1.4%	2	3.3	0%	3	5.8	0%	5	8.6	0%	4	11	4%	6	13.1	0.9%		347

The figure in the off-blue box is the value the Fatigue index gives based on a 10-hour working day with two breaks (once every 3.5 hours) totalling an hour. We assume the workload is moderately demanding with little spare capacity and that the job requires continuous attention most of the time. Our results also assume a commute of 50 minutes each way – in line with the answers given to us by respondents during registration.

In terms of average KSS sleepiness the peak occurs on the first shift, suggesting one day off is not sufficient to allow for recovery from six consecutive days of work. There is a slight trend to average sleepiness scores decreasing as the week progresses. The final shift on Saturday sees the highest risk of high levels of sleepiness. We see a jump in the relative risk of fatigue from 14:00 and it is highest in the last three hours of the shift. The eightieth percentile score is 3.0.

How is fatigue affecting or likely to affect your performance at work?

Table 39 – 6_1 10-11 hour shifts, performance impact heatmap

Time	Monday	Tuesday	Wednesda	Thursday	Friday	Saturday	Data poin	Overall	Fatigue interfere with work
6	Moderate	Moderate	Low		Very high	High	11	Moderate	Low
7	Low	Low	Slight	Slight	Low	Low	36	Slight	Slight
8	Moderate	High	High	Low	Slight	Low	20	Slight	Moderate
9	Moderate	Moderate		Low	Low	Low	10	Slight	High
10	High	High	High	Very high	Slight	Moderate	29	High	Very high
11	Slight	Slight	Low	Low	Slight	Low	36	Slight	
12	Moderate	Moderate	High	Slight	High	High	42	Moderate	Shift rank
13	Moderate	Slight	Slight	Very high	Moderate	Slight	26	Moderate	1 = Most difficult
14	High	Very high	High	Moderate	Very high	Very high	26	High	6 = Easiest
15	Very high	High	Slight	Slight	Slight	Slight	28	Moderate	
16	Very high	High	High	High	High	Low	40	High	
17	Very high	Moderate	Moderate	Low	Low	Very high	20	Moderate	
18	High	Very high	Very high	High	Very high	Low	14	High	
19	Very high						1	Very high	
	1	2	3	5	4	6	339		

When we look at the responses to the likelihood of fatigue affecting work performance, we see a similar trend with the impact peaking on the first shift and then decreasing as the week progresses. The average performance impact of 1.5 compares well to the other shift patterns.

6_1 – 6 days / nights on. 1 day off. 12 hour shifts (Day shift)

This shift pattern operates six consecutive shifts of 12 hours in length from Monday to Saturday with Sunday as a rest day.

Table 40 – 6_1 12 hour shifts, day shift, sleepiness heatmap

Chance of being very tired (KSS >=7), Relative risk based on average KSS scores (1 to 9), # Data points

Time	Monday			Tuesday			Wednesday			Thursday			Friday			Saturday			Overall		
6				0%	Low	2	0%	Low	2	0%	Mod	1	0%	V high	3	0%	Slight	2	0%	Slight	10
7	0%	High	11	0%	Mod	10	0%	V high	8	0%	High	9	0%	High	13	8%	V high	12	2%	High	63
8	0%	Mod	1	0%	Low	7	0%	Mod	3	0%	Low	4	0%	Low	4	0%	Slight	8	0%	Slight	27
9	0%	V high	4	0%	Slight	3	0%	Mod	5	0%	Slight	7	0%	Slight	4	0%	High	7	0%	Mod	30
10	0%	Slight	12	0%	Slight	5	0%	Mod	9	0%	Slight	4	0%	Mod	9	0%	Mod	3	0%	Slight	42
11	0%	Slight	7	0%	Slight	6	11%	Slight	9	0%	Low	9	0%	Low	9	0%	Low	5	2%	Low	45
12	0%	Low	7	0%	Slight	6	0%	High	6	14%	V high	7	0%	Low	5	0%	Slight	6	3%	Mod	37
13	0%	Mod	11	0%	Slight	14	0%	Slight	6	0%	High	8	0%	High	6	0%	Slight	11	0%	Mod	56
14	0%	Mod	5	0%	Mod	8	17%	V high	6	0%	High	5	0%	Low	7	0%	Mod	5	3%	Mod	36
15	0%	Mod	3	0%	Mod	6	0%	Slight	6	0%	Low	6	0%	Mod	6	0%	V high	3	0%	Mod	30
16	0%	Slight	6	0%	High	5	0%	Mod	2	0%	Slight	3	0%	Low	4	0%	Mod	2	0%	Slight	22
17	6%	High	18	0%	High	9	21%	V high	14	8%	High	12	7%	High	15	20%	High	10	10%	High	78
18	100%	V high	1	25%	V high	4	25%	V high	4	40%	V high	10	20%	V high	5	25%	V high	4	32%	V high	28
19													100%	V high	1		3.0		100%	V high	1
FRI	2.3%	1	2.4	1.2%	6	4.1	7.5%	3	6.9	7.1%	5	10	3.3%	2	12.7	5.1%	4	14.9	4.4%		505

The figure in the off-blue box is the value the Fatigue index gives based on a 12-hour working day with two breaks (once every 3.5 hours) totalling an hour. We assume the workload is moderately demanding with little spare capacity and that the job requires continuous attention most of the time. Our results also assume a commute of 50 minutes each way – in line with the answers given to us by respondents during registration.

In terms of average KSS sleepiness the peak occurs on the first shift, which again suggests one day off is not sufficient to allow for recovery from six consecutive days of work. Otherwise, this value fluctuates over the week. Wednesday and Thursday see the highest chances of high levels of sleepiness. The relative risk of fatigue is highest in the last three hours of the day shift. The eightieth percentile score is 3.7.

How is fatigue affecting or likely to affect your performance at work?

Table 41 – 6_1 12 hour shifts, day shift, performance impact heatmap

Time	Monday	Tuesday	Wednesda	Thursday	Friday	Saturday	Data point	Overall	Fatigue interfere with work
6	High	Slight	Low	High	Very high	Low	10	Slight	Low
7	High	Moderate	Very high	High	High	Very high	63	High	Slight
8	High	Slight	High	Low	Low	Slight	27	Slight	Moderate
9	Slight	Low	High	Slight	Moderate	Low	30	Slight	High
10	Low	Moderate	Moderate	Low	Low	Low	41	Slight	Very high
11	Slight	Moderate	Slight	Moderate	Slight	Slight	45	Slight	
12	Slight	Moderate	Moderate	Very high	Slight	Moderate	37	Moderate	Shift rank
13	Slight	Moderate	Moderate	Moderate	High	Moderate	56	Moderate	1 = Most difficult
14	Moderate	Low	Very high	Moderate	Low	Moderate	36	Moderate	6 = Easiest
15	Moderate	Low	Slight	Slight	High	High	30	Moderate	
16	Very high	Very high	Slight	Moderate	Slight	High	22	High	
17	Very high	Very high	Very high	Very high	High	High	78	Very high	
18		Very high	Very high	Very high	Very high	Very high	28	Very high	
	1	4 =	2	3	4 =	4 =	503		

When we look at the responses to the likelihood of fatigue affecting work performance, we see a similar trend to the KSS sleepiness scores. The peak is on the first shift with an increased impact on the Wednesday and Thursday. Again, the impact is pronounced in the last three hours of the shift.

6_1 – 6 days / nights on. 1 day off. 12 hour shifts (Night shift)

This shift pattern operates six consecutive shifts of 12 hours in length from Monday to Saturday with Sunday as a rest day.

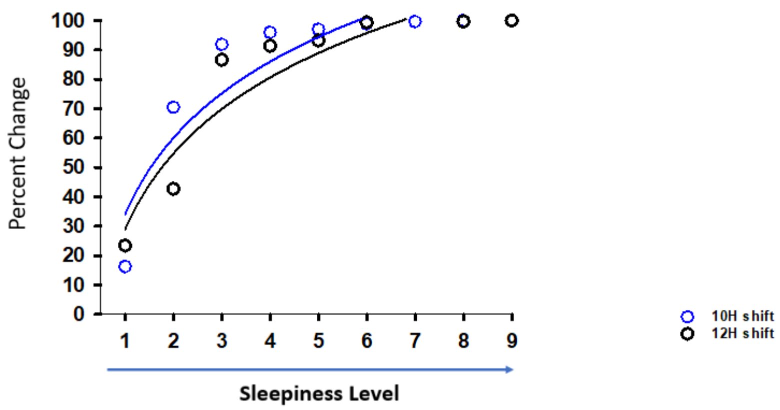
Table 42 – 6_1 12 hour shifts, night shift, sleepiness and performance impact heatmap

Time	Sleepiness			Imapct on performance	
18	0%	Mod	10	Low	10
19	0%	Mod	6	High	5
20	0%	Low	1	Slight	1
21	0%	High	4	Moderate	4
22	0%	Low	1	Low	1
23	0%	V high	1	Very high	1
0					
1	0%	V high	5	Very high	5
2	0%	V high	1	Slight	1
3	0%	Slight	2	Slight	2
4	0%	Slight	2	Moderate	2
5	14%	High	7	Very high	7
6					
7					
FRI	2.5%		40		39

We did not have quite enough data to draw any meaningful conclusions from the six days on one day off 12 hour night shift pattern.

Graph 10 – Rate of increase in 6_1 10 to 11 and 12+ hour shifts

Rate of increase in Sleepiness in 6-on 1-off shift pattern



Analysis by Northumbria University show the accumulation in sleepiness in the different 6-on 1-off shift pattern. Note the trajectory for the curves, which indicates that the acceleration to sleepiness is similar in both sift patterns. However, the 12 hour shift reaches a higher level of sleepiness.

12_2 – 12 days / nights on. 2 days off. 12 hour shifts (Day shift)

This shift pattern operates twelve consecutive shifts of 12 hours in length with two rest days.

Table 43 – 12_2 12 hour shifts, day shift, sleepiness heatmap

Chance of being very tired (KSS >=7), Relative risk based on average KSS scores (1 to 9), # Data points

Time	Shift 1	Shift 2	Shift 3	Shift 4	Shift 5	Shift 6	Shift 7	Shift 8	Shift 9	Shift 10	Shift 11	Shift 12	Overall	
7	0% Mod	0% Mod	0% Mod	0% Mod	0% Mod	33% VH	0% Mod	0% Mod	0% High	0% Slight	0% Mod	0% Slight	3% Mod	38
8	0% High	0% Mod				0% High		0% Mod	0% Slight				0% Mod	7
9	0% Slight				0% Slight			0% Slight	0% Mod	0% Slight	0% Low		0% Slight	12
10		0% Mod	0% Slight		0% Slight	0% Slight	0% Mod		0% Slight	0% Slight	0% Slight	0% Mod	0% Slight	12
11	0% Low		0% Slight	0% Mod	0% Slight		0% Slight	0% High	0% Slight				0% Slight	11
12	0% Slight	0% High		0% Slight	0% Slight					0% Slight			0% Mod	5
13	0% High	0% Slight	0% Slight	0% Mod		0% High	0% Mod		0% High	0% Slight	25% VH	0% Slight	7% Mod	15
14		0% High	0% High		0% Mod	50% High	0% High	0% Slight	0% High	0% High		0% Mod	6% High	16
15	0% High	0% Slight	0% Mod	0% VH			0% Slight	0% VH		0% Slight	0% Slight		0% Mod	10
16	33% Mod								0% Slight			50% VH	33% High	6
17		50% High	100% High	50% VH	0% High	50% VH	25% VH	67% VH	67% VH	50% VH	67% VH	0% High	42% VH	26
18	20% VH		0% VH	0% VH	100% VH			0% Slight		0% Slight	0% Mod	100% VH	29% VH	14
19										67% VH			50% VH	4
	11% 7	10% 8	7% ###	9% 2	9% 6	30% 1	7% 9 =	14% 5	11% 9 =	16% 9 =	14% 12	14% 3	13%	176

In terms of average KSS sleepiness the figure fluctuates over the twelve days with the peak occurring on the 6th shift. There is an increased chance of high levels of sleepiness on the first two shifts, which again suggests two days off is not sufficient to allow for recovery from twelve consecutive days of work. We see a sustained increase in high levels of sleepiness from the 8th shift onwards. As with many of the 12-hour patterns the relative risk of fatigue is highest in the last three hours of the day shift. The eightieth percentile score is 5.1.

How is fatigue affecting or likely to affect your performance at work?

Table 44 – 12_2 12 hour shifts, day shift, performance impact heatmap

Time	Shift 1	Shift 2	Shift 3	Shift 4	Shift 5	Shift 6	Shift 7	Shift 8	Shift 9	Shift 10	Shift 11	Shift 12	Data point	Overall
7	High	High	Moderate	High	Moderate	Very high	Moderate	Moderate	Moderate	Moderate	Moderate	Slight	37	Moderate
8	Moderate	High				High		Slight	Low				7	Moderate
9	Low				Slight			Slight	Slight	Slight	Low		12	Low
10		Slight	Slight		Slight	Slight	Slight		Low	Slight		Slight	12	Low
11	Slight		Slight	Slight	Slight		3.0	3.0	Slight		Slight		11	Moderate
12	Slight	Slight		Slight	Slight					Slight			5	Slight
13	Slight	Slight	Slight	High		High	Moderate		Moderate	Slight	Moderate	Slight	15	Moderate
14		High	Moderate		High	High	Moderate	Slight	Moderate	High		Moderate	16	High
15	Moderate	Slight	Slight	High			High	High		Slight	Slight		10	Moderate
16	High								Slight			Very high	6	High
17		High	High	Very high	Moderate	Very high	Very high	High	Very high	Very high	High	High	25	Very high
18	High		Very high	High	Very high					Slight	High	High	14	Very high
19										Very high		Slight	4	High
	11	4 =	8 =	2	6 =	1	3	6 =	12	8 =	10	4 =	170	

Fatigue interfere with work
Low
Slight
Moderate
High
Very high
Shift rank
1 = Most difficult
12 = Easiest

When we look at the responses to the likelihood of fatigue affecting work performance, we see a similar trend to the KSS sleepiness scores. The peak is on the 6th shift. We see a circadian effect on the impact on performance from 14:00 with the last four hours of the shift particularly difficult. An average score of 2.5 suggests a considerable sustained impact on performance over the whole shift pattern.

12_2 – 12 days / nights on. 2 days off. 12 hour shifts (Night shift)

Table 45 – 12_2 12 hour shifts, night shift, sleepiness and performance impact heatmap

Time	Sleepiness				Imapct on performance	
18	0%	Slight	3		Low	3
19	0%	High	13		High	12
20						
21	0%	Mod	6		Slight	6
22	0%	Low	3		Low	3
23						
0						
1	0%	Mod	1		High	1
2	33%	V high	3		High	3
3	0%	Slight	2		Slight	2
4	0%	Low	4		Slight	4
5	17%	High	6		High	6
6	50%	V high	2		Very higih	2
7						
FRI	7.0%		43			42

We did not have quite enough data to draw any meaningful conclusions from the twelve days on one day off 12 hour night shift pattern.

Risk by time of day for day shift and night shift

For our final piece of analysis, we combined the scores for all workers working the day shift and the night shift to see if there were any clear time of day patterns.

Table 46 – Combined time of day risk by day and night shift for all types of worker

Time	**Day shift**		Time	**Night shift**
6	Slight		18	Low
7	Slight		19	Low
8	Low		20	Low
9	Low		21	Slight
10	Low		22	Slight
11	Slight		23	Slight
12	Slight		0	Moderate
13	Moderate		1	Moderate
14	High		2	High
15	High		3	High
16	High		4	Very high
17	Very high		5	Very high
18	Very high		6	Very high

We had a combined 19,743 data points for the day shift and 1,014 data points for the night shift. Combining sleepiness scores with the impact on performance, we see the following combined risk profiles by time of day. These results are in line with what we would expect to see. On the day shift the increase to high risk happens during the afternoon circadian dip (from 14:00). Those working over 10 hours will then see the highest risk of sleepiness and fatigue at the end of their shifts. On the night shift we would expect to see the increase in risk of sleepiness as the early morning circadian dip kicks in around 02:00 before increasing between 04:00 and 7:00. Fatal road traffic accident data indicates an increased risk of fatal accidents between 02:00 and 07:00.

Appendix 3 – Responses, by worker group, to the Third Pillar of Health sleep health self-assessment

As part of the study all workers were given an opportunity to run a version of the Third Pillar of Health sleep health self-assessment. After respondents completed thirty working days of data, they were able to download a personalised report of their results. The report contained helpful hints and tips as well as the chance to download up to ten factsheets that explained in greater depth how certain lifestyle factors can inhibit our ability to obtain sufficient good quality sleep.

We have run the assessment for over 10,000 workers from over fifty different organisations in a wide range of industries. Below we break down the results by the different workers groups.

Table 46 – Responses by key workers groups to the sleep health self-assessment

	Number of participants n. =	Average sleep duration before work	Percent sleeping < 7 hours before work	Percent carrying a sleep debt	Percent at risk of sleep apnoea but undiagnosed	Percent at risk of insomnia but undiagnosed	Sleepiness interfere with work at least a few times a	Average life satisfaction score
HS2 Overall	528	6.63	49%	83%	15%	31%	35%	6.86
JV1	173	6.74	47%	84%	17%	30%	31%	7.14
JV2	206	6.48	52%	86%	14%	29%	38%	6.61
JV3	20	6.93	40%	90%	15%	40%	35%	7.25
JV4	31	6.89	42%	63%	10%	19%	16%	6.84
JV5	38	6.44	55%	79%	11%	37%	37%	6.66
JV6	38	6.72	45%	84%	21%	53%	58%	6.74
Office-based workers	144	6.57	52%	89%	19%	41%	43%	6.79
Site-based workers	219	6.61	48%	77%	11%	25%	29%	7.09
Both office and site	165	6.71	49%	84%	19%	31%	36%	6.71
Day workers	368	6.69	47%	83%	15%	30%	36%	6.88
Night workers	7	6.51	67%	83%	17%	43%	29%	5.43
Rotating shift workers	153	6.08	54%	81%	16%	33%	34%	6.88
Working shifts < 6 months	27	6.55	46%	84%	4%	11%	26%	6.81
Working shifts 6m - 2 years	73	6.63	50%	80%	21%	33%	37%	6.96
Working shifts 2 - 5 years	24	6.49	58%	92%	4%	42%	38%	6.54
Working shifts 5 - 10 years	12	5.83	83%	75%	25%	50%	33%	6.92
Working shifts 10+ years	24	6.35	58%	79%	22%	42%	29%	6.33
Work above ground	379	6.62	49%	83%	15%	32%	36%	6.88
Work below ground	56	6.60	53%	83%	20%	38%	36%	6.57
About the same	93	6.70	49%	80%	12%	24%	32%	6.95
Physically demanding work	31	6.70	53%	55%	10%	26%	32%	6.90
Mentally demanding work	203	6.70	47%	88%	22%	40%	42%	6.74
Both	235	6.52	53%	82%	12%	29%	34%	6.86
Not demanding	59	6.78	39%	71%	7%	14%	15%	7.25
Operative	239	6.64	50%	83%	12%	26%	34%	6.77
Supervisor	71	6.53	51%	75%	20%	38%	30%	6.75
Manager	141	6.55	52%	85%	14%	33%	39%	6.82
Professional	32	6.81	50%	78%	19%	44%	31%	7.19
Senior Manager	42	6.87	33%	86%	27%	32%	36%	7.31
Male	417	6.66	48%	80%	15%	28%	32%	6.88
Female	107	6.54	56%	91%	15%	40%	49%	6.86
16-25	54	6.85	44%	87%	13%	28%	43%	6.11
26-35	160	6.67	47%	88%	15%	36%	44%	6.69
36 - 45	148	6.61	49%	80%	16%	25%	32%	7.14
46 - 55	104	6.54	56%	77%	13%	34%	29%	6.93
56 - 65	56	6.54	45%	82%	20%	32%	23%	7.45
Work away from home	417	6.70	46%	82%	15%	31%	35%	6.94
Work near home	107	6.36	63%	83%	18%	29%	34%	6.56

Highlights from the results of the voluntary Third Pillar of Health sleep health self-assessment

1. **Office versus site workers**

Office-based respondents compared poorly on all key sleep metrics. Insufficient and poor quality sleep is translating to sleepiness, which in many instances is interfering with daily work activities. **Site-based workers compared well on almost all key sleep health metrics.** Those working across site and office sat in between. Research released in early January from the University of South Florida showed increased insomnia risk in those with more sedentary job roles.

2. **Day versus shift workers**

Day workers were broadly in line with overall averages. Those working permanent night shifts appear to suffer from short sleep duration. This group appears not to experience sleepiness at work as frequently. Their average life satisfaction score is of notable concern. It would be interesting to do more research with permanent night workers to test these results further. Those on rotating shifts had lower sleep duration, which is a trend we find in almost all populations we assess. Otherwise, they were broadly in line with overall averages.

3. **How long workers have been working shifts**

Broadly speaking, key sleep metrics decline as the number of years working shifts increases. This is especially the case with sleep duration prior to work and the experience of sleepiness during work hours. **An observation is the increased risk of sleep disorders, especially insomnia after shift working for two or plus years.**

4. **Those working above or below ground**

Those working below ground were at higher risk of insomnia and sleep apnoea and compared unfavourably on life satisfaction. Those working above ground were broadly in line with the HS2 average.

5. **Those with jobs they consider to be physically or mentally demanding**

Those with both physically and mentally demanding roles were broadly in line with the HS2 average. Those with roles they did not feel are demanding compared favourably on all key sleep health metrics. Those with physically demanding roles also compared well on many key sleep health metrics. **Despite higher than average sleep duration those with mentally demanding roles compared poorly on all other key sleep health metrics.**

6. **Those working away from home**

The transient workforce obtains less sleep prior to work. Anecdotally , this may be due to staying in digs away from home, albeit this is not something we asked specific questions on. Life satisfaction scores also trail the non-transient workforce.

7. **The impact of seniority on sleep**

Results were mixed based on seniority. Operatives compared favourably on sleep disorder risk and experiencing sleepiness at work but compared slightly lower on life satisfaction. Supervisors compared poorly on sleep duration, sleep disorder risk and life satisfaction. Given the impact of sleep duration and sleep quality, it is perhaps an anomaly then that they compared favourably on the experience of sleepiness at work and sleepiness interfering with work activities. Managers were more likely to experience sleepiness at work and for it to interfere with daily work activities. Other than sleep disorder risk professionals compared favourably, albeit we had fewer participants to analyse. Senior managers compared well on sleep duration and life satisfaction but they were much more likely to be at risk of sleep apnoea. Running sleep disorder screening for senior managers would be a worthwhile intervention as the consequences of impaired decision making in this group could have a detrimental impact on project delivery.

8. The impact of age on sleep

There was a clear trend for sleep duration prior to work to fall as age increased. However, counter intuitively the experience of sleepiness at work and sleepiness interfering with work activities fell as age increased. There was a broad trend towards life satisfaction increasing with age. **Those 26 to 35** are not meeting their sleep need over the course of a week / shift cycle, are at higher risk of insomnia, experience sleepiness at work more regularly and sleepiness is more likely to interfere with daily work activities.

9. Male versus female workers

The responses to the KSS sleepiness scores and the impact on performance at work for female workers are perhaps surprising, given they are sleeping less before work, are at greater risk of insomnia, are more likely to experience sleepiness at work and are more likely to say that fatigue regularly interferes with daily work activities.

Appendix 4 – The impact of continued wakefulness on KSS sleepiness scores

In the table below we have plotted the number of hours of wakefulness in the rows and the KSS score (1 to 9) in the columns. You would expect to see a higher proportion of low KSS scores soon after waking and a higher proportion of high KSS scores as the number of hours of wakefulness increases.

Table 47 – Impact of continued wakefulness on sleepiness scores

Hours awake / KSS	1	2	3	4	5	6	7	8	9	Total
<=1	81	121	172	68	44	62	17	17	2	584
	14%	*21%*	*29%*	*12%*	*8%*	*11%*	*3%*	*3%*	*0%*	*3.4*
<=2	136	207	181	50	41	66	16	11	5	713
	19%	*29%*	*25%*	*7%*	*6%*	*9%*	*2%*	*2%*	*1%*	*3.0*
<=3	119	143	201	50	54	55	6	7	2	637
	19%	*22%*	*32%*	*8%*	*8%*	*9%*	*1%*	*1%*	*0%*	*3.0*
<=4	77	123	140	44	34	22	2	4	1	447
	17%	*28%*	*31%*	*10%*	*8%*	*5%*	*0%*	*1%*	*0%*	*2.9*
<=5	53	120	154	44	26	25	3	6	1	432
	12%	*28%*	*36%*	*10%*	*6%*	*6%*	*1%*	*1%*	*0%*	*3.0*
<=6	63	155	200	60	43	44	8	9	1	583
	11%	*27%*	*34%*	*10%*	*7%*	*8%*	*1%*	*2%*	*0%*	*3.1*
<=7	74	153	180	55	46	41	11	7	2	569
	13%	*27%*	*32%*	*10%*	*8%*	*7%*	*2%*	*1%*	*0%*	*3.1*
<=8	50	121	184	61	52	43	16	6	2	535
	9%	*23%*	*34%*	*11%*	*10%*	*8%*	*3%*	*1%*	*0%*	*3.3*
<=9	47	112	193	90	55	59	12	15	2	585
	8%	*19%*	*33%*	*15%*	*9%*	*10%*	*2%*	*3%*	*0%*	*3.5*
<=10	41	139	189	77	54	46	14	8	5	573
	7%	*24%*	*33%*	*13%*	*9%*	*8%*	*2%*	*1%*	*1%*	*3.4*
<=11	31	96	156	80	45	58	16	5	3	490
	6%	*20%*	*32%*	*16%*	*9%*	*12%*	*3%*	*1%*	*1%*	*3.6*
<=12	20	77	82	41	39	47	10	9	4	329
	6%	*23%*	*25%*	*12%*	*12%*	*14%*	*3%*	*3%*	*1%*	*3.8*
<=13	22	52	115	31	25	34	12	4	4	299
	7%	*17%*	*38%*	*10%*	*8%*	*11%*	*4%*	*1%*	*1%*	*3.6*
<=14	28	46	82	35	28	47	24	10	2	302
	9%	*15%*	*27%*	*12%*	*9%*	*16%*	*8%*	*3%*	*1%*	*4.0*
<=15	22	33	57	15	17	33	21	12	6	216
	10%	*15%*	*26%*	*7%*	*8%*	*15%*	*10%*	*6%*	*3%*	*4.2*
<=16	7	14	26	20	13	20	12	12	4	128
	5%	*11%*	*20%*	*16%*	*10%*	*16%*	*9%*	*9%*	*3%*	*4.6*
<=17	7	4	16	5	8	10	4	3	4	61
	11%	*7%*	*26%*	*8%*	*13%*	*16%*	*7%*	*5%*	*7%*	*4.4*
<=18	5	4	12	10	7	6	3	6	3	56
	9%	*7%*	*21%*	*18%*	*13%*	*11%*	*5%*	*11%*	*5%*	*4.6*
<=19	1	6	5	0	3	7	2	4	2	30
	3%	*20%*	*17%*	*0%*	*10%*	*23%*	*7%*	*13%*	*7%*	*5.0*
<=20	4	1	4	2	6	3	1	0	0	21
	19%	*5%*	*19%*	*10%*	*29%*	*14%*	*5%*	*0%*	*0%*	*3.9*
<=21	1	0	3	1	2	0	2	1	0	10
	10%	*0%*	*30%*	*10%*	*20%*	*0%*	*20%*	*10%*	*0%*	*4.6*
<=22	1	0	3	1	2	1	2	1	1	12
	8%	*0%*	*25%*	*8%*	*17%*	*8%*	*17%*	*8%*	*8%*	*5.1*
Total	888	1727	2349	838	640	728	210	155	55	7590

We looked at KSS sleepiness scores based on the number of hours of continued wakefulness. These scores were collected from 335 gold users who provided us with their wake time. Key findings include:

- The average time from waking to starting work was 2 hours and 18 minutes on the day shift, 6 hours 45 minutes on the back shift and 6 hours 21 minutes on the night shift.
- The percentage chance of recording a KSS score of 7, 8 or 9, indicating high levels of sleepiness, jumps after 10 hours of continued wakefulness and again (more significantly) after 13 hours
- We know from research that our alertness is impaired after 17 hours of wakefulness to an equivalent blood alcohol concentration of 0.05%, after 20 hours 0.08% (England's drink drive limit) and after 24 hours 0.10% (12)
- Average total commute was 86 minutes – 43 minutes each way. Long commutes can impact fatigue.

Appendix 5 – The impact of continued wakefulness on the effect on work performance

Table 48 – Impact of continued wakefulness on the impact on performance

Hours awake / KSS	Not at all	Slightly	Moderately	Very	Extremely	Total
<=1	273	234	58	10	9	584
	47%	40%	10%	2%	2%	1.7
<=2	407	228	52	20	4	711
	57%	32%	7%	3%	1%	1.6
<=3	347	220	52	18	1	638
	54%	34%	8%	3%	0%	1.6
<=4	236	156	40	6	2	440
	54%	35%	9%	1%	0%	1.6
<=5	202	180	37	4	1	424
	48%	42%	9%	1%	0%	1.6
<=6	296	213	55	8	4	576
	51%	37%	10%	1%	1%	1.6
<=7	269	216	68	6	3	562
	48%	38%	12%	1%	1%	1.7
<=8	232	208	72	10	5	527
	44%	39%	14%	2%	1%	1.8
<=9	229	227	102	17	1	576
	40%	39%	18%	3%	0%	1.8
<=10	228	223	94	15	5	565
	40%	39%	17%	3%	1%	1.8
<=11	153	201	109	16	4	483
	32%	42%	23%	3%	1%	2.0
<=12	117	120	72	13	3	325
	36%	37%	22%	4%	1%	2.0
<=13	102	117	56	16	6	297
	34%	39%	19%	5%	2%	2.0
<=14	99	89	71	37	2	298
	33%	30%	24%	12%	1%	2.2
<=15	57	78	48	24	6	213
	27%	37%	23%	11%	3%	2.3
<=16	28	39	39	13	4	123
	23%	32%	32%	11%	3%	2.4
<=17	13	23	15	5	4	60
	22%	38%	25%	8%	7%	2.4
<=18	12	20	13	6	4	55
	22%	36%	24%	11%	7%	2.5
<=19	8	5	9	5	3	30
	27%	17%	30%	17%	10%	2.7
<=20	5	7	7	0	0	19
	26%	37%	37%	0%	0%	2.1
<=21	2	2	4	1	0	9
	22%	22%	44%	11%	0%	2.4
<=22	3	4	2	2	1	12
	25%	33%	17%	17%	8%	2.5
Total	3313	2804	1069	249	71	7506
	44%	37%	14%	3%	1%	1.8

We also looked at the effect of fatigue at work based on the number of hours of continued wakefulness. Key findings include:

- We see a sustained increase in the chance of fatigue being very or extremely likely to affect performance at work after 13 hours of continued wakefulness, as is the case with sleepiness scores
- Somone working a 12 hour night shift will start work roughly six hours after waking, meaning by the time they return home they will have been awake for potentially 18 or 19 hours (for those with longer commutes). After 10 hours of wakefulness – 4 hours into a shift, they will start to feel more tired. After 17 hours of wakefulness, 11 hours into a shift, performance will be equivalent to a BAC impairment of 0.05% (the drink drive limit in Scotland). They will still have 1 more hour of their shift and their commute home still to navigate.