Study into physical fatigue for Metronet Rail Ltd

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Sections

1. Acknowledgements

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Sponsorship of the study

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Professional advice

Dr Olivia Carlton London Underground

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Assistance in the study

Collection of field data

Amar Singh Metronet Rail.

Robert McGuire Metronet Rail

Literature review

Angela Eguakhide Metronet Rail

2 Executive Summary

In summer 2008 Metronet commissioned a study into fatigue. Three locations were selected, Neasden and Stonebridge Park depots and Templar House.

Thirty six members of staff were involved in the study which lasted twelve weeks.

The study made use of questionnaires and a pupillometer. The pupillometer provided the ability to check the level of fatigue almost instantly.

The study found marked differences between the sleep patterns of depot and office based staff.

The main findings of the study were;

- Staff at Neasden depot have the highest levels of fatigue
- Between 17.5% and 30% of all Metronet staff are suffering from some level of fatigue.
- Staff suffering from fatigue at both Stonebridge Park and Neasden depot appear to be less aware of their fatigue levels.

The study concludes that Metronet has a problem with fatigue and asks the question;

Since we have made things safer by eliminating drugs and alcohol as a hazard to the workforce. How much safer could we make things by eliminating fatigue as well?

In light of the conclusion the following recommendations have been made;

- A further comprehensive piece of research is commissioned by the business
- The introduction of specialist sleep advice from an external expert
- The introduction of pupillometry in safety critical areas of the business.

3 Introduction

The recent introduction of The Railways and Other Guided Transport Systems (Safety) Regulations 2006, more commonly referred to as ROGS, introduced specific requirements on the railway industry to control fatigue.

Regulation 25 of the regulations states;

> ***'*** *(1) Every controller of safety critical work shall have in place arrangements to ensure, so far as is reasonably practicable, that a safety critical worker under his management, supervision or control does not carry out safety critical work in circumstances where he is so fatigued or where he would be liable to become so fatigued that his health or safety or the health or safety of other persons on a transport system could be significantly affected.*
>
> *(2)The arrangements in paragraph (1) shall be reviewed by the controller of safety critical work where he has reason to doubt the effectiveness of those arrangements.'*

For their part Metronet introduced a fatigue calculator based on the calculator provided by the Health and Safety Executive. The company invested a great deal of management time in the application of the calculator and the required alterations to shift patterns across the business to achieve the theoretical inputs to the calculator.

However the question remained, is there a problem with fatigue in the company or does the calculator work? For this reason in the summer of 2008, a small scale study was commissioned by the head of central safety to attempt to answer this question.

Prior to this study London Underground had commissioned a more comprehensive study into fatigue amongst train drivers. This study was questionnaire based. The Metronet study made use of some of the questions LU had used in their study.

In addition, Metronet took the decision to trial a pupillometer to measure the fatigue levels of people completing the questionnaires. The puplillometer itself is piece of equipment that resembles a large set of binoculars; it measures the contraction and dilation of the pupil over a 3-second period and records a pass or fail result in terms of fatigue.

Over a twelve week period, data was collected from 36 Metronet staff using both questionnaires and the EyeCheck pupillometer. The data collected is contained in this report.

4 Literature review

What is fatigue?

Fatigue is a problem that cannot be easily measured and controlled but it can be identified and managed where the main issue in dealing with fatigue is that those suffering from fatigue are usually very reluctant to admit it.

Obtaining a clear definition of fatigue that would give the true picture of what fatigue really means is problematic. The Universal Dictionary (1998) defines fatigue as "physical or mental weariness or exhaustion resulting from exertion".

Another definition for fatigue is given by the health and safety executive which says that "fatigue is the decline in mental and/or physical performance that results from prolonged exertion, lack of quality sleep or disruption of the internal body clock. The degree to which a person is prone to fatigue is also related to their workload, that is, work that requires constant attention, is machine paced, complex or monotonous will increase the risk of fatigue.

A poor balance between the demands of work and time provided for rest and recovery, resulting from poorly designed shift pattern and long working hours is likely to result in chronic fatigue. Levels of fatigue are also affected by personal factors such as home life or individual characteristics. The consequences of fatigue include reduced alertness, poor and slow perception and sleepiness.

Types of fatigue

There are several types of fatigue which include

Sensory fatigue – looking at VDU display for long periods
Intellectual fatigue – associated with solving problems
Physiological fatigue – resulting from prolonged physical work e.g. muscular fatigue
Acute fatigue – experienced at the end of a long day
Cumulative fatigue – resulting from feeling tired even after a night's sleep

Why do we get fatigued?

Despite the absence of an agreed scientific definition, there has been a lot of research on fatigue to look at the various factors that can contribute to how fatigued a person can get. Some of these factors include loss of sleep, length of working hours, age, health status, general sleep quality, experience at work, motivation and home/family life and responsibilities and commuting times.

One of the main reasons why people get fatigued is due to insufficient rest. This occurs as a result of working at the wrong time (shift work), or working long hours. Konz (1998a) suggests that prolonged overtime of over 12 hours a day and 55 hours a week should be avoided. He also alerts us to the fact that an individual will have less of a chance of getting sufficient sleep if a long working day is extended by a long commute or moonlighting. In addition, he notes that fatigue can occur for other reasons, for example:

Too much, or too little stimulation at work
A large fatigue dose i.e. through too intensive work and not enough chance to rest
Lack of opportunity for different work tasks
Not taking sufficient short breaks while at work (fatigue increases exponentially with time)

Having insufficient time to recover from fatigue. For Konz, long term fatigue occurs when fatigue is carried over into the next day

In conclusion, there are several factors that may affect how fatigued an individual may become. Factors that are directly related to long hours include spending too much time doing work tasks and being exposed to stressors in the work environment and missing out on insufficient sleep due to long wok hours.

The effects of long hours on fatigue

There is no doubt that working long hours will have an effect on fatigue but in most cases it is had to find an objective means of testing this theory, this is because fatigue can be a very subjective measure since it down to the individual being questioned.

A recent study looking at fatigue and long hours is that of Park et al (2001). They looked at the relationship between working long hours and subjective fatigue complaints of a group of workers in South Korea. They were ultimately trying to determine whether subjective complaints of fatigue could be used as a screening tool for early detection of cumulative fatigue. They found that complaints of fatigue before going to work were lower for those men who worked shorter hours. Where shorter hours were defined as less than 60 hours a week, this is still considered 'long' hours where 48 hours is the working definition of long hours. This study relied on self reports of fatigue and was cross sectional meaning that casual relationship was difficult to determine.

So is there evidence to support the intuitive link between long working hours and fatigue? Studies have used subjective or objective measures of fatigue and in general the evidence available supports a line between long hours and fatigue.

Over 1 in 20 workers in Europe work extended hours. Extended hour are generally taken to mean working more than 48 hours a week. It is thought that individuals are working longer hours because of increasing workloads and job demands, job insecurity and performance standards and pressures and such long hours could affect an individual's health, well being and performance.

Kodz et al (2001) have provided statistics that suggest that UK workforce work some of the longest hours in Europe with employees in the UK averaging a total of 44.7 hours per week as opposed to 39.9 in Germany, 39 in Denmark and the Netherlands. They found that the UK is the only European state where weekly working hours have increased over the last decade. Indeed, they reported that 11% of people in the UK work 49-60 hours per week.

What are long working hours?

Certain issues could complicate the definition of long hours. There are many ways of defining long hours. Daily, weekly or annual hours, hours in main jobs and other jobs, commuting time, business travel time could all be considered when calculating time worked. As part of this research, the focus is on 48 hour week, in line with the working time directive.

Defining long hours in terms of the working time regulations is useful as it should hopefully be European wide and allow some consistency amongst studies, certainly from the EU.

Why do long hours lead to fatigue?

Fatigue is the result of putting effort (working) for long hours without sufficient rest. It is fair to say that the purpose of resting time is to overcome fatigue and fatigue increases with time. Van der Hulst and Geurts (2001) hypothesised that any cost associated with effort (working) will be stabilised if there is sufficient recovery time either in the working day or after work. If there is insufficient recovery time due to long work hours then eventually fatigue will accumulate and affect well being and health outcomes. So, fatigue seems to be the main cause of associated ill health.

Working time directive

The 1993 European Directive on working time, which came into force in the UK through the Working Time Directive in October 1998, was introduced to limit the number of hours worked because long or abnormal working hours were thought to be detrimental to health. The main features of the European Directive include working hours of no more than 48 hours a week averaged over a 17 week period, a minimum daily rest period of 11 consecutive hours, and a minimum weekly rest period of 1 day averaged over 14 days. There is an opt out clause, however, whereby workers can agree to work longer than 48 hours a week by signing a written agreement, although this currently being reconsidered.

The United Kingdom was initially in opposition to the introduction of the Directive, as it argued that there was insufficient evidence to support the view that long working hours had a negative effect on the health and safety of employees.

Limitations

There are some limitations that are inherent in the topic of discussion. The concept of fatigue is very personal to the individual in question. What makes one person fatigued will not make another person fatigued. Hence a lot of the research/study into fatigue uses self report. The problem with self report data is that we cannot be sure that the variables under consideration are the same across all studies or individuals within the studies. Generalising findings can be problematic. Also associated with using self report is the problem that study participants may not recall accurately.

Most studies are based on questionnaire completion. If it is not mandatory within the work group, the likelihood of the sample studied being self selected is high. This means that there is a possible bias within the sample, this is because most people may be more likely to complete a questionnaire about health effects of fatigue if they feel they have health problems resulting from fatigue and long hours. There is no assurance that the sample taken for study is a true representative of the population under consideration.

5 Study Design

The fatigue study was designed following consultation with John P. Dal Santo from MCJ inc. and Dr Olivia Carlton from LU occupational health.

Data was to be collected over a period of twelve weeks from September 2008 to December 2008. Three locations were involved in the study, Templar House, Stonebridge Park and Neasden depots. 36 Metronet staff volunteered to be involved in the study, 9 from Templar House, 12 from Neasden depot, and 15 from Stonebridge Park depot.

The study collected two sets of data, the first was an initial questionnaire about their general sleep patterns. This initial questionnaire was based on a questionnaire London Underground had recently used for a fatigue study on their drivers. Although not as comprehensive as the LU questionnaire, the following questions were asked;

a) How many hours a week do you normally work?
b) How many continuous days have you worked this week?
c) Do you prefer fixed or variable shifts?
d) Do you usually work fixed or variable shifts?
e) In the last two weeks what was the most frequent start of your shift?
f) What is your preferred start time?
g) What is the start time that works best with your home and family commitments?
h) How often do you get to work your preferred shifts?
i) What is your total travelling time to get to work?
j) If you were to start at 9am what time would you go to bed?
k) If you were to start work at 9am what time would you wake?
l) Do you usually wake before your alarm goes off?
m) How hard is it for you to get up on workdays?
n) After you have woken up how do you feel for the first hour?
o) What time of day would your peak performance be?
p) Do you have difficulty getting to sleep?
q) Are you disturbed during your sleep?
r) Do you have good quality sleep?
s) If you had nothing to do next day what time would you go to bed?
t) If you had nothing to do next day what time would you get up?

The results from these questionnaires are shown in the results section.

Once initial data was collected from the volunteers they were then visited over the next twelve weeks to provide further data. This involved the use of a smaller questionnaire based on the Epworth Sleepiness Scale, two questions were left out of this questionnaire at the request of the trades unions.

Once the data was collected on the Epworth questionnaire, the volunteer was asked by a member of the research team to use the EyeCheck pupillometer. Using the EyeCheck we could immediately determine if someone was feeling fatigue.

Once the data was collected over the twelve weeks, a further two months was spent analysing the data recorded to compare the passes and fails from the EyeCheck with the data collected from the questionnaires to determine underlying trends and patterns.

5.1 The pupillometer

Technological breakthroughs in modern day Pupillometry have increased knowledge of pupillary dynamics. Pupillometry has helped focus such applications as diagnosing Alzheimer's disease, human fatigue and for other ophthalmologic diagnostic applications. For these and other applications, it is important to monitor the time response of the pupil as the eye is subjected to various lighting conditions. A Pupillometer flashes a beam of light on the subject's eyes and records their pupillary response.

The Pupillometer resembles a large pair of binoculars. The test subject raises the Pupillometer to his/her eyes and holds it there during the test. The Pupillometer will determine when proper alignment occurs with the test subject's eye and then initiates a flash of light originating from two green light emitting diodes (LED's). The duration of the flash is approximately 100 milliseconds. The flash causes the test subjects pupils to contract rapidly and then begin to dilate. The Pupillometer measures the contraction and dilation of the pupil over a 3-second period starting when the LED initiates its flash. The test is repeated another 2 times and at the conclusion of the final test, the Pupillometer will determine an average of the 3 tests. Algorithms have been developed with a PASS/FAIL indicator.

It should be noted that although the pupillometer was used in this study purely to measure fatigue, elsewhere in the world the non-invasive Pupillometer is also designed to give a strong indication that there may be impairment from Bio-Chemical Inhalants, Biological Agents, Alcohol or Drugs. Over time it can therefore be reasonably assumed that this type of technology will be increasingly seen in use.

6 Results

In terms of the working week, the study found that staff at Stonebridge Park depot work the longest hours, people at Neasden the fewest.

Staff at Templar house spend the most time travelling (124 minutes), staff at Stonebridge the least time of 101 minutes, a difference of 23 minutes. Expressed as a percentage, staff at Templar House spend 22% more time travelling than staff at Stonebridge Park.

Asked about their sleep habits and what time they would go to bed if expected to start at 09h00, staff at Templar House would retire latest at 23h00, staff at Stonebridge the earliest at 22h00. Similarly when asked what time they would get up if expected to start at 09h00, staff at Templar House would rise at 06h00, staff at Stonebridge would rise at 07:00. Overall staff at Templar House would expect to sleep for 7.5 hours, 1.5 hours less per night than their colleagues based at Stonebridge Park.

Table 1 overview of sleep patterns

	Sample size	How many hours a week do you normally work?	What is your total travelling time to get to work (minutes)?	If you were to start at 9am what time would you go to bed?	If you were to start work at 9am what time would you wake?	If you had nothing to do next day what time would you go to bed?	If you had nothing to do next day what time would you get up?
Average used		Mean	Mean	Median	Median	Median	Median
Location							
Neasden	12	36.8	103.8	22:15:00	06:35:00	22:30:00	08:00:00
Stonebridge Park	15	40.9	101.0	22:00:00	07:00:00	23:00:00	09:00:00
Templar House	9	38.2	124.4	23:00:00	06:30:00	23:00:00	09:00:00
Overall average	N/A	38.9	107.8	22:30:00	07:00:00	23:00:00	09:00:00

Staff based at Templar House would retire later and rise earlier than their depot based colleagues, this can be partly explained by their longer commute to work.

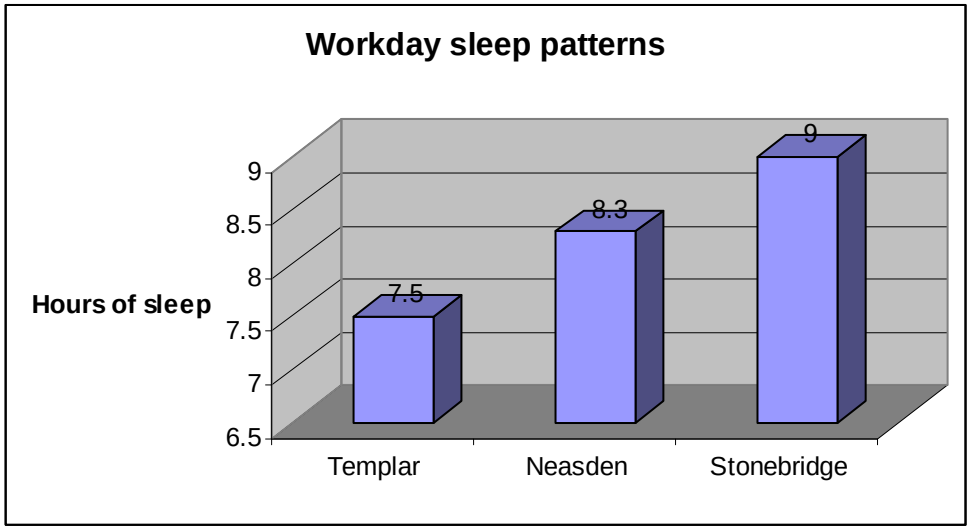


Figure 1 Workday sleep patterns

For a work day staff at Templar House would retire the latest (23h00) and staff at Stonebridge the earliest (22h00). Staff at Templar would also rise the earliest (23h00) and staff at Stonebridge the latest (07h00). Templar House based staff sleep on for 7.5 hours per night. 1.5 hours less than the 9 hours sleep enjoyed by their colleagues at Stonebridge Park, on a normal workday.

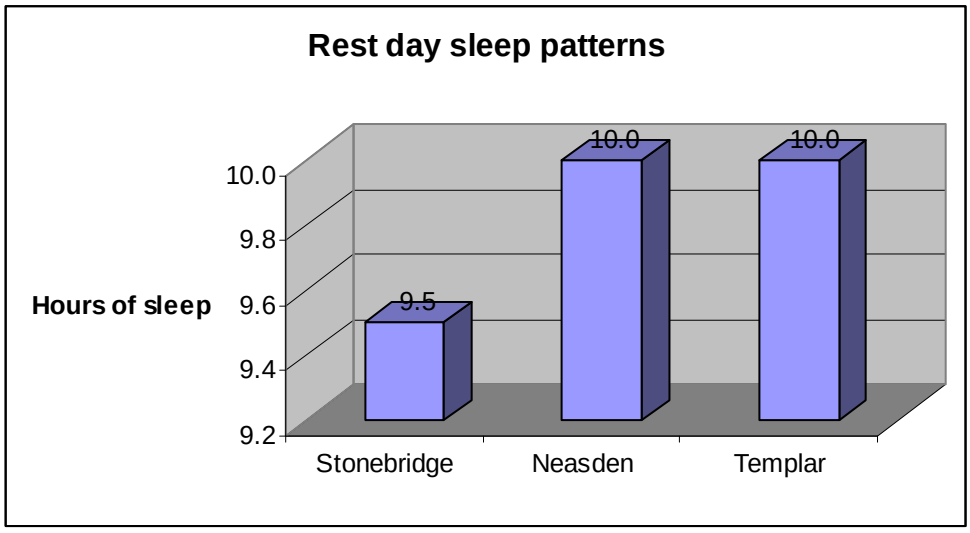


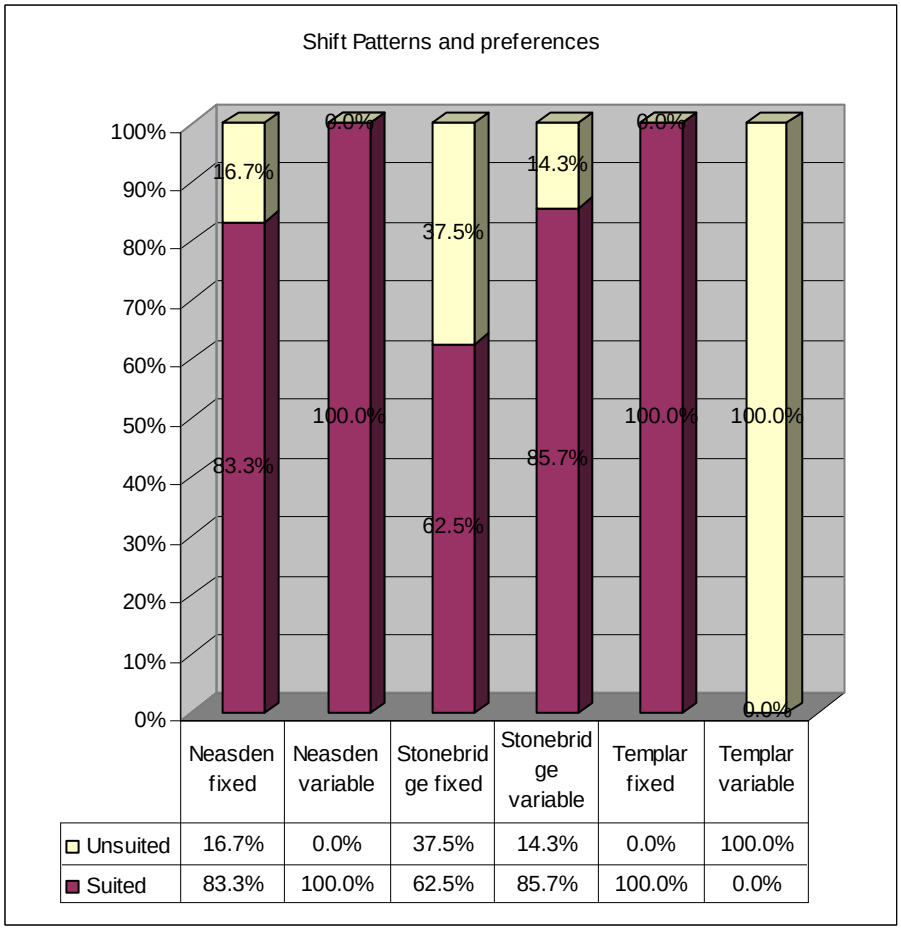
Figure 2 Rest day sleep patterns

When asked what time they would go to bed if they had nothing to do the next day staff at both Templar and Stonebridge Park would retire at 23h00, staff at Neasden would retire earlier at 22h30. Neasden staff would arise at 08h00, one hour earlier than their colleagues at Templar House and Stonebridge Park who would rise at 09h00. In total Neasden staff would expect to sleep 9.5 hours compared to Templar and Stonebridge who would sleep for 10 hours.

Comparing workday sleep patterns with rest day sleep patterns, the data does suggest that Templar House based staff do seem to try and catch up on sleep on their rest days. Interestingly Stonebridge Park based staff seem to show little change in their sleep patterns between work days and rest days.

Shift patterns

Staff were asked about whether their shift pattern was fixed or variable and if they were actually working the shift pattern they preferred. The table below shows the number of staff working fixed or variable shift patterns at each location.



	Neasden fixed	Neasden variable	Stonebridge fixed	Stonebridge variable	Templar fixed	Templar variable
Unsuited	16.7%	0.0%	37.5%	14.3%	0.0%	100.0%
Suited	83.3%	100.0%	62.5%	85.7%	100.0%	0.0%

Figure 3 Shift Patterns

Neasden depot showed the most staff working shift patterns they felt suited them with only one member of staff working a fixed shift pattern who preferred variable shift patterns.

Stonebridge Park had three people working fixed shifts who preferred variable and one person working variable who preferred fixed.

All staff working fixed shifts at Templar House were working the shifts that suited them; however all of the staff working variable shifts preferred working fixed shifts.

Choice of shift patterns

The ability to choose shift pattern seemed to show that most people are often given the opportunity to choose. Only one person, based at Stonebridge Park was rarely given the chance to choose. Templar house based staff seemed to enjoy the most freedom in this respect, all staff responding that they were often given the ability to chose. Comparing the two depots, staff based at Neasden reported a greater freedom in their ability to choose their shift pattern.

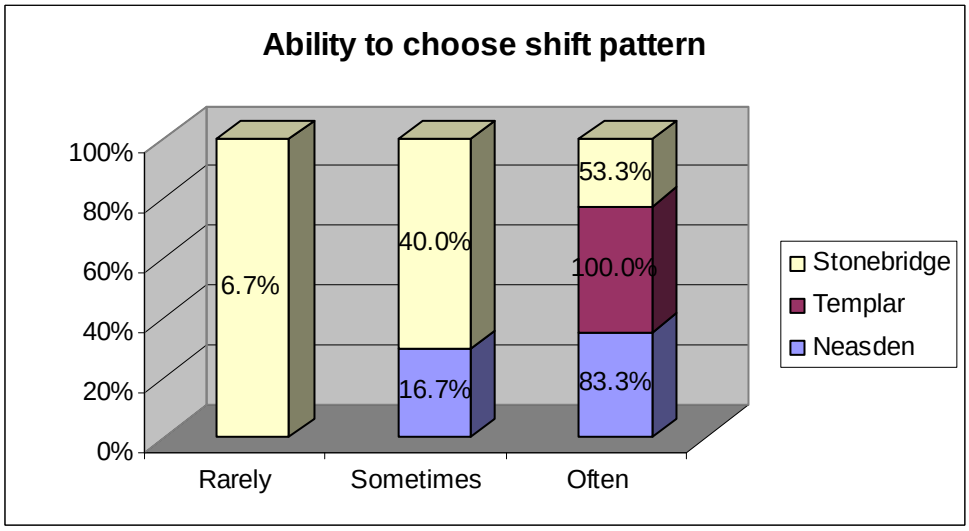


Figure 4 Ability to choose shift pattern

Waking before the alarm rings.

Staff were asked if they woke up before their alarm sounded. Templar House and Neasden showed a similar response, 83% and 88% respectively of their staff reported that they awoke before their alarm sounded. In the case of Stonebridge Park this figure fell to 73%.

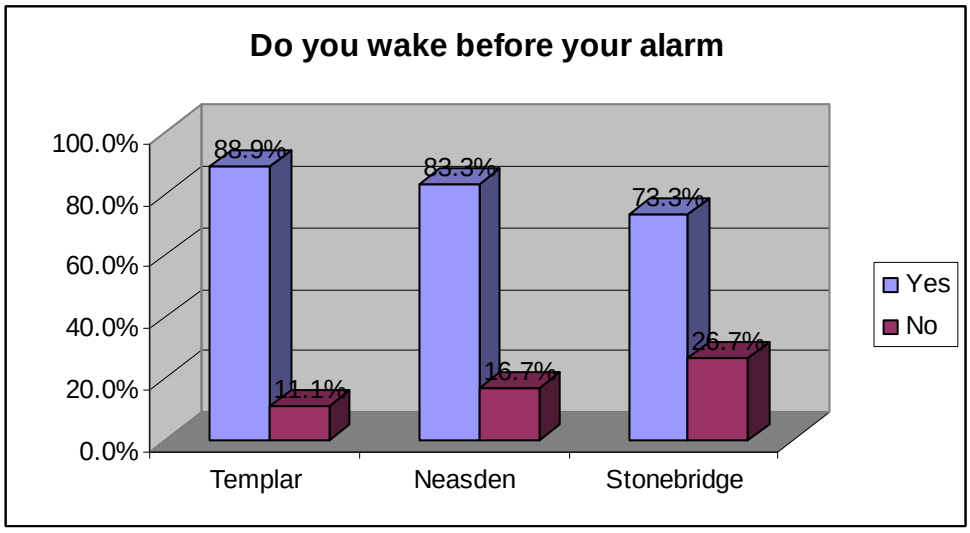


Figure 5 Do you wake before your alarm?

How hard is it for you to wake up?

Both Neasden and Stonebridge Park depots showed a similar response to this question, the majority of their staff reporting they found it ‘easy’ or at least ‘OK’ to wake up. Staff based at Templar House showed the greatest range of responses, a third of them reported finding it hard to wake up and less than half found waking up ‘OK’.

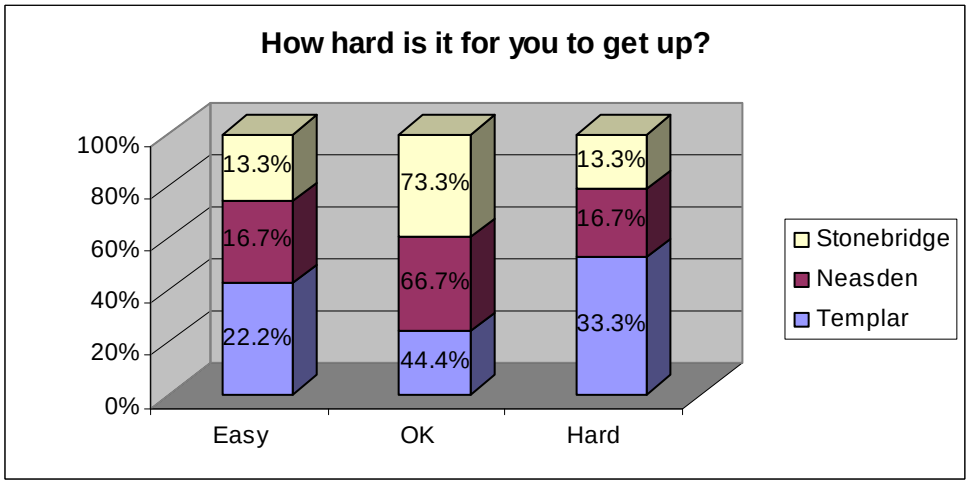


Figure 6 How hard is it for you to get up?

Tiredness after one hour

Much like the previous question, staff based at the depots showed a similar response, the majority felt tired one hour after waking and a quarter felt refreshed. Once again it was staff based at Templar House who had the greatest range of responses.

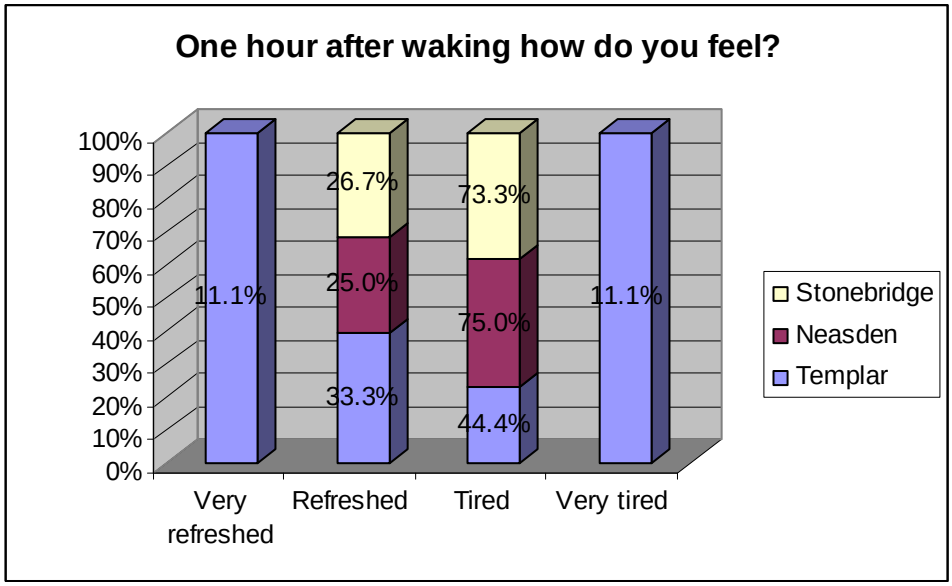


Figure 7 One hour after waking how do you feel?

6.1 EyeCheck data

The previous section considered the background to sleep and shift patterns for the three groups involved in the study. This section concerns itself with the results obtained from the EyeCheck.

Over a period of twelve weeks, each of the respondents from the original questionnaire was visited by a researcher, they were asked to complete a short questionnaire based on the Epworth sleepiness scale to assess the level of fatigue they felt at the time.

Epworth Sleepiness Scale

The Epworth Sleepiness Scale is used to determine the level of daytime sleepiness.

0 = would *never* doze or sleep.
1 = *slight* chance of dozing or sleeping
2 = *moderate* chance of dozing or sleeping
3 = *high* chance of dozing or sleeping

Situation	Chance of Dozing or Sleeping
Sitting and reading	____
Watching TV	____
Sitting inactive in a public place	____
Being a passenger in a motor vehicle for an hour or more	____
Lying down in the afternoon	____
Sitting and talking to someone	____

Total score (add the scores up)
(This is your Epworth score) ____

For the study two questions were not used, i.e. sitting quietly after lunch (no alcohol) and stopped for a few minutes in traffic while driving. It was agreed with the trade unions from the outset of the study not to introduce these questions at this point.

Prior to using the EyeCheck, the respondent was asked to score the sleepiness scale against the six questions shown above. The respondent was then asked to take the EyeCheck.

The results of the EyeCheck were then compared against the sleepiness questionnaires, the charts and tables below reflect the basis statistics and use the standard deviations from the data to compare the results.

6.2 EyeCheck Results

160 responses were collected during the study, 112 of these resulted in a pass using the EyeCheck, 48 showed a failure. Expressed as a percentage 30% of the tests resulted in a failure.

Table 2 shows the mean averages across all the data for the pass / fail responses from the questionnaires.

Table 2 Mean averages for all the data.

Sitting and reading	Watching TV	Sitting inactive	As a passenger	Lying down to rest	Sitting and talking	Epworth mean
0.7125	1.2625	0.2875	0.55625	1.275	0.075	4.16875

Table 3 shows the standard deviations, the first row shows all of the data, the second shows the SDs for all of the passes and the bottom row the SDs for all of the failures.

Table 3 Comparison of all the EyeCheck data

	Sitting and reading	Watching TV	Sitting inactive	As a passenger	Lying down to rest	Sitting and talking	Epworth mean
all the data	0.638	0.942	0.576	0.716	0.990	0.287	2.645
Passes	0.635	0.979	0.607	0.744	1.033	0.316	2.865
Fails	0.641	0.841	0.504	0.652	0.893	0.202	2.067

The pass / fail data is shown in the graph below; the graph suggests that respondents who failed the EyeCheck test seemed to underestimate their level of sleepiness.

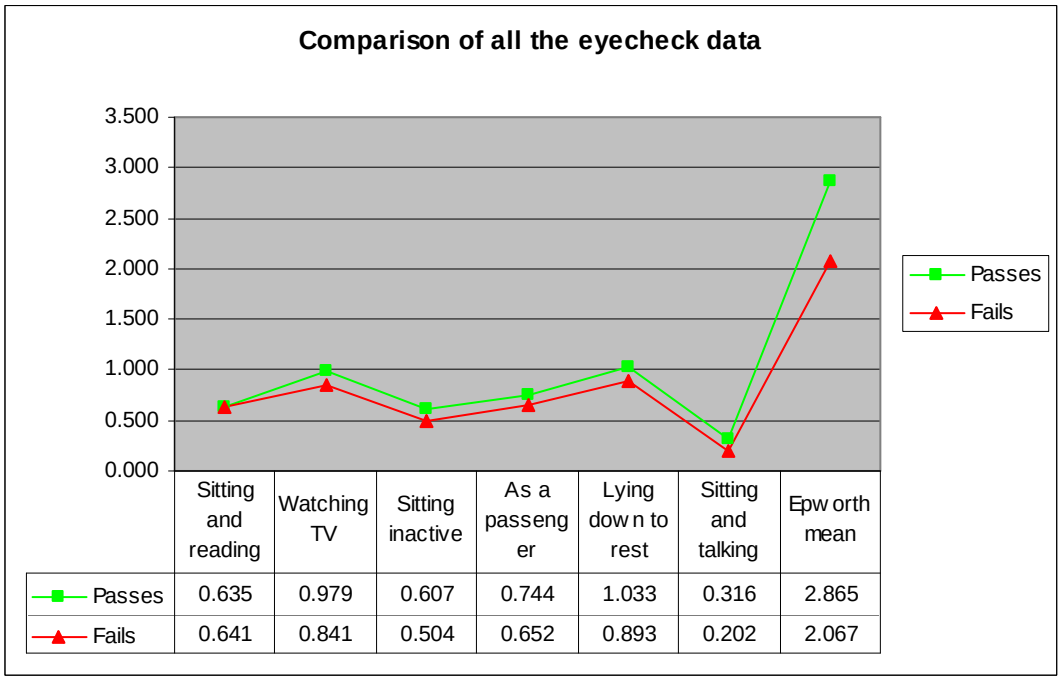
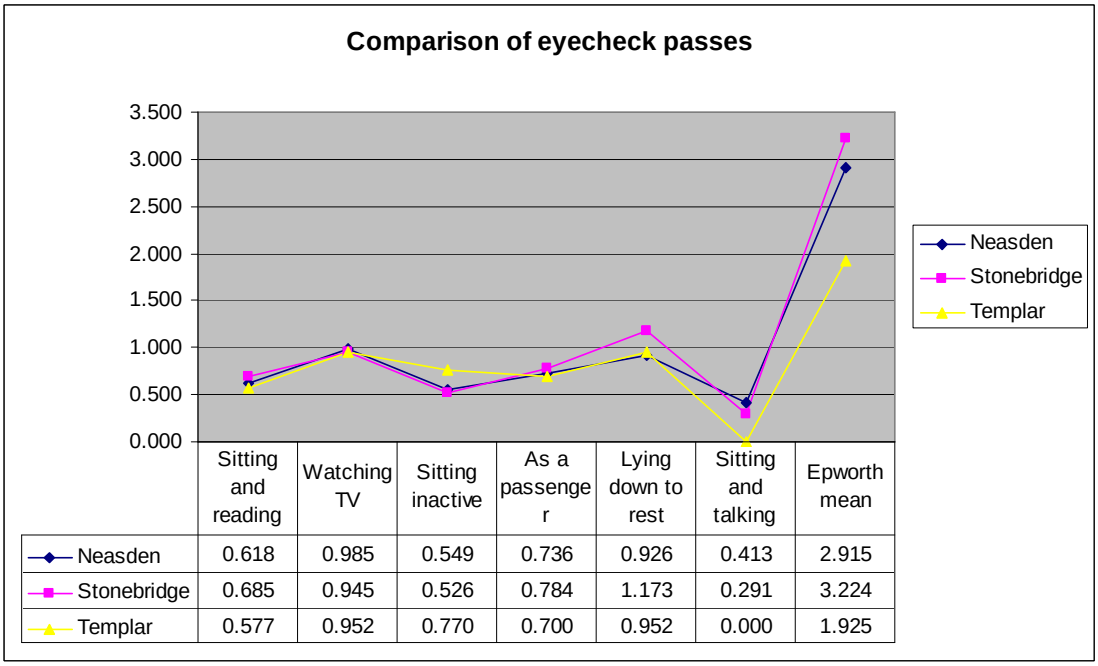


Figure 8 Comparison of all the EyeCheck data

Table 4 Comparison of EyeCheck passes

	Sitting and reading	Watching TV	Sitting inactive	As a passenger	Lying down to rest	Sitting and talking	Epworth mean
Neasden	0.618	0.985	0.549	0.736	0.926	0.413	2.915
Stonebridge	0.685	0.945	0.526	0.784	1.173	0.291	3.224
Templar	0.577	0.952	0.770	0.700	0.952	0.000	1.925

Comparing the EyeCheck passes, the data from the two depots shows little variance; however the responses from Templar House do show a difference when the Epworth mean is taken into account. Staff at Templar House reported a lower level of sleepiness than their colleagues at Stonebridge and Neasden depots.



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Templar	0.577	0.952	0.770	0.700	0.952	0.000	1.925

Figure 9 Comparison of EyeCheck passes

Table 5 Comparison of EyeCheck failures

EyeCheck failures	Sitting and reading	Watching TV	Sitting inactive	As a passenger	Lying down to rest	Sitting and talking	Epworth mean
Neasden	0.588	0.873	0.429	0.581	0.858	0.000	1.812
Stonebridge	0.772	0.636	0.606	0.686	0.951	0.332	2.278
Templar	0.500	1.118	0.500	0.726	0.667	0.000	2.449

When considering EyeCheck failures, it was staff at Neasden who reported a lower level of sleepiness than the EyeCheck results seem to suggest. Staff based at Templar House responded more highly on the Epworth mean. Interestingly Templar House based staff reported a higher sleepiness score when watching TV than staff based at the depots. This could be explained by the fact that their work involves more reliance on computers.

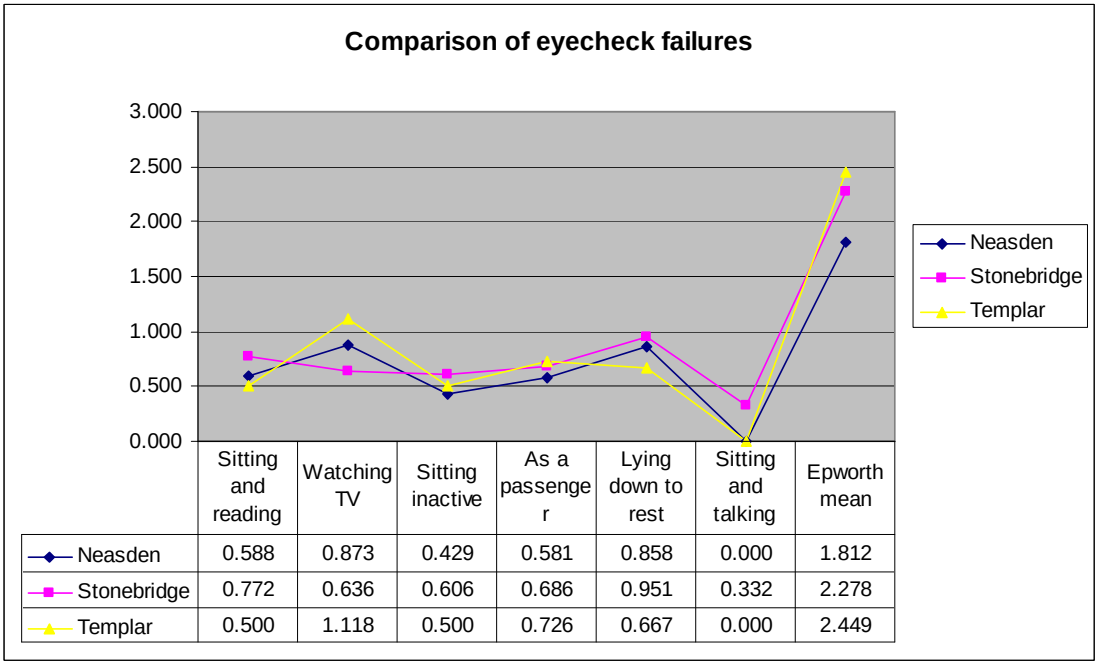


Figure 10 Comparison of EyeCheck failures

There were 65 responses from Neasden depot, 22 of whom failed the EyeCheck. Expressed as a percentage some 34% of staff at Neasden showed evidence of fatigue.

Table 6 Neasden EyeCheck results

	Sitting and reading	Watching TV	Sitting inactive	As a passenger	Lying down to rest	Sitting and talking	Epworth mean
Neasden Pass	0.618	0.985	0.549	0.736	0.926	0.413	2.915
Neasden Fail	0.588	0.873	0.429	0.581	0.858	0.000	1.812

Comparing the EyeCheck pass and failure rate for Neasden we again see that respondents who failed the EyeCheck reported a lower level of sleepiness than those that passed.

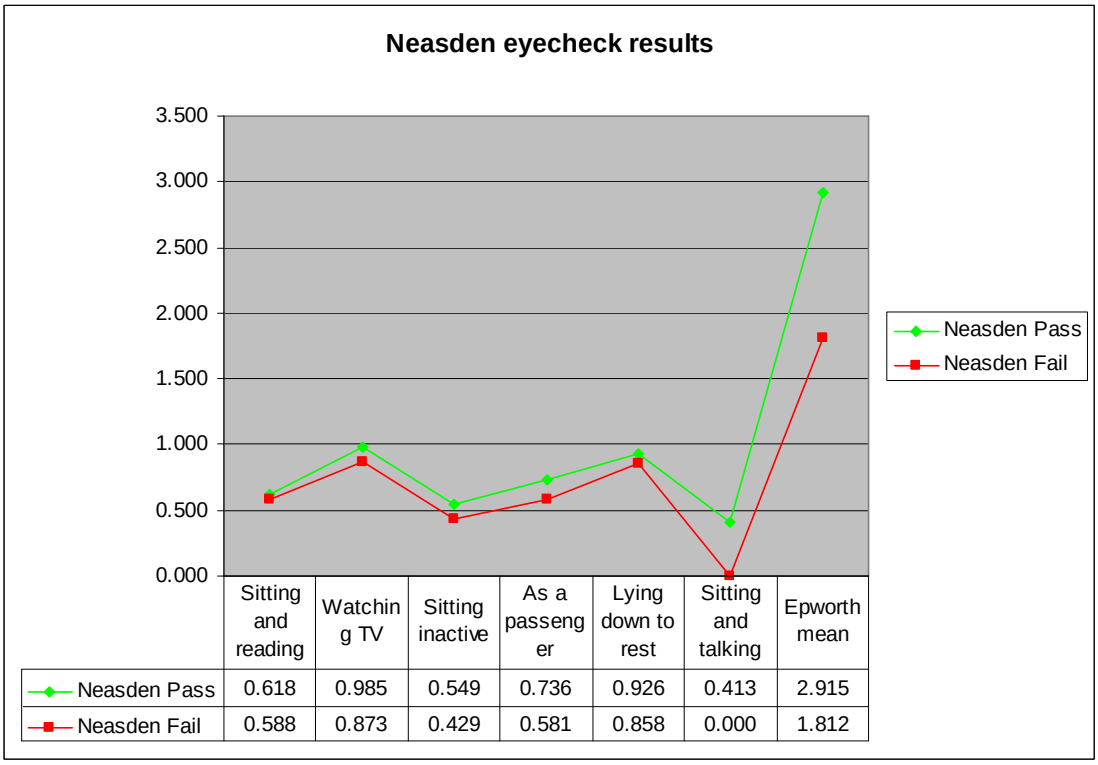


Figure 11 Neasden EyeCheck results

There were 61 responses from Stonebridge Park, 17 of these failed the EyeCheck. Expressed as percentage 31% of staff at Stonebridge showed evidence of suffering from fatigue.

Table 7 Stonebridge Park EyeCheck results

	Sitting and reading	Watching TV	Sitting inactive	As a passenger	Lying down to rest	Sitting and talking	Epworth mean
Stonebridge Pass	0.685	0.945	0.526	0.784	1.173	0.291	3.224
Stonebridge Fail	0.772	0.636	0.606	0.686	0.951	0.332	2.278

Like Neasden depot, staff at Stonebridge Park who failed the EyeCheck quite often recorded a lower level of sleepiness than the results suggested. On only one question, sitting and inactive did respondents indicate that their sleepiness reflected the results obtained from the EyeCheck.

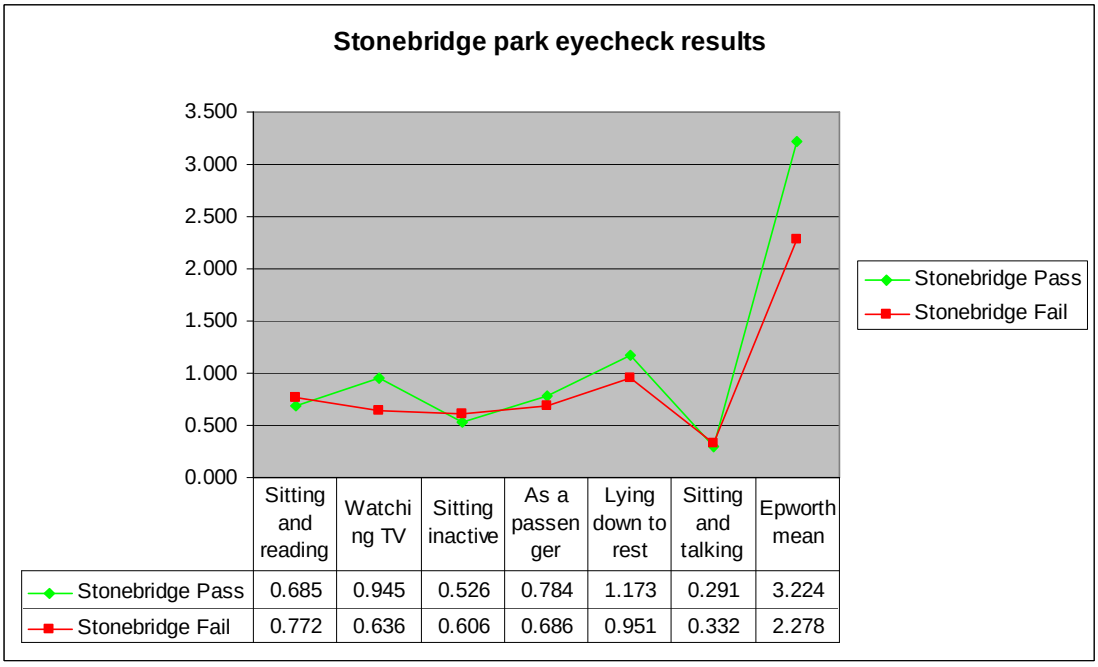


Figure 12 Stonebridge Park EyeCheck results

There were 34 responses for Templar House, 9 of which resulted in a failure on the EyeCheck. Expressed as percentage some 26% of staff at Templar House was found to be fatigued.

Table 8 Templar House EyeCheck results

	Sitting and reading	Watching TV	Sitting inactive	As a passenger	Lying down to rest	Sitting and talking	Epworth mean
Templar Pass	0.577	0.952	0.770	0.700	0.952	0.000	1.925
Templar Fail	0.500	1.118	0.500	0.726	0.667	0.000	2.449

Staff at Templar House who failed the EyeCheck did record more highly on the sleepiness scale overall. This suggests that at least for staff at Templar House there is some recognition of the fatigue the EyeCheck results indicate.

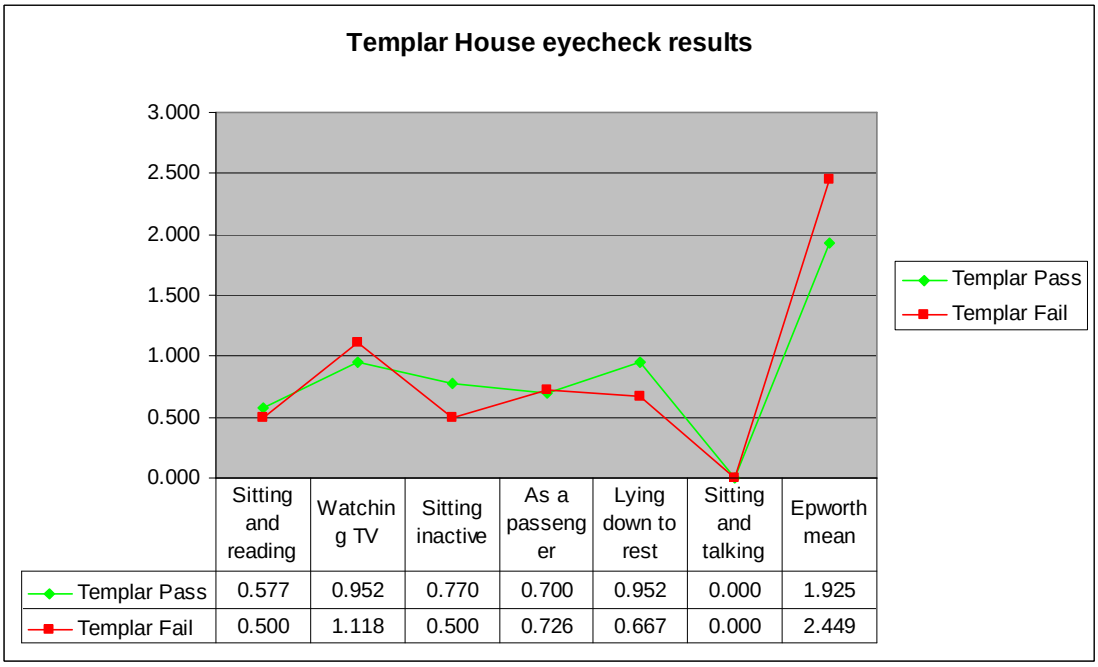


Figure 13 Templar House EyeCheck results

7 Discussion

It is common currency amongst safety professionals that all accidents are caused by people. It also recognised that of two of the main impairments to peoples behaviour is the effects of drugs and alcohol and fatigue.

The railway industry enjoys a tough alcohol and drugs monitoring regime. Certainly in the case of London Underground this could be said to be very effective, failure rates are exceedingly low when it is considered that in the population in general 9.3% of people between the ages of 16 and 59 have taken drugs in the past year (Home Office 2008).

London Underground enjoys a very good safety record, the contribution of the drugs and alcohol policy to this record are not always appreciated and very rarely understood by non experts. Nonetheless if the benefits of the drugs and alcohol policy are taken as a given, there is another question that could be asked.

Since we have made things safer by eliminating drugs and alcohol as a hazard to the workforce. How much safer could we make things by eliminating fatigue as well?

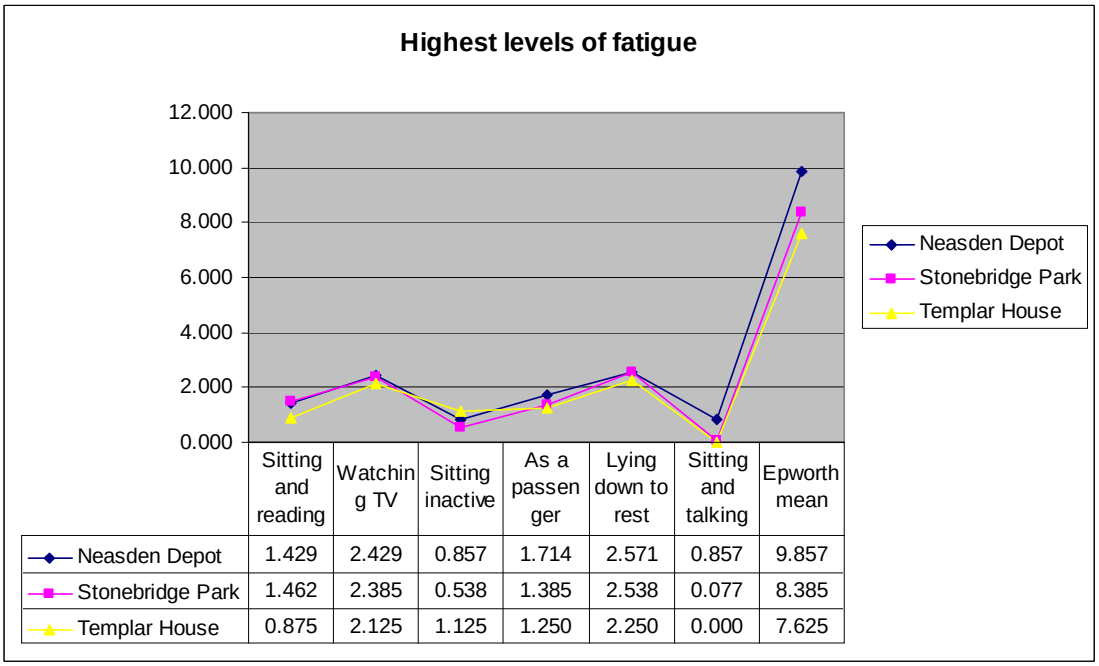
If taken at face value then the data shows that some 30% of Metronet staff are suffering from fatigue. Whilst it can be reasonably assumed in a study of this nature that there will be some evidence of fatigue, one third of the workforce is unexpectedly high.

Perhaps a way to test this is to set aside the EyeCheck results and concentrate for now on the Epworth tests. The full Epworth scale involves eight questions and assumes a value of 0-9 is normal and 10 and above recommends sleep specialist advice. This study used a scaled down version of the Epworth scale, leaving out two questions, or 25% of the range. A scaled version of this would be 0 - 6.75 as normal and anything above as requiring specialist advice.

28 responses in the data set returned a value of 6.75 and above, some 17.5%, so even allowing for a sizeable margin of error in the EyeCheck there still appears to be a problem. The data for these responses is shown in table 9 and figure 14.

Table 9 Highest levels of fatigue

	Sitting and reading	Watching TV	Sitting inactive	As a passenger	Lying down to rest	Sitting and talking	Epworth mean
Neasden Depot	1.429	2.429	0.857	1.714	2.571	0.857	9.857
Stonebridge Park	1.462	2.385	0.538	1.385	2.538	0.077	8.385
Templar House	0.875	2.125	1.125	1.250	2.250	0.000	7.625



	Sitting and reading	Watching TV	Sitting inactive	As a passenger	Lying down to rest	Sitting and talking	Epworth mean
Neasden Depot	1.429	2.429	0.857	1.714	2.571	0.857	9.857
Stonebridge Park	1.462	2.385	0.538	1.385	2.538	0.077	8.385
Templar House	0.875	2.125	1.125	1.250	2.250	0.000	7.625

Figure 14 Highest levels of fatigue

Neasden depot shows the highest rate in fatigue at 34% failures from the EyeCheck, Neasden also shows the highest Epworth mean shown in table 9 above. This is slightly higher than the results obtained from another depot, Stonebridge Park.

The gap between the two depots is not that great that any substantive explanations can be made, Neasden staff seemed more able to choose their shift patterns. Neasden staff who worked variable shifts indicated this suited them better, so what else could explain the difference?

From the earlier questionnaire data we can see that on a workday staff at Neasden depot seem to sleep less than their colleagues at Stonebridge depot (8.3 hours per night compared to 9 hours).

However when we compare this with staff at Templar House we find that fewer of them suffer fatigue (26%) but seem to able to manage with 7.5 hours sleep per night on a workday. Here at least there is a possible explanation, Templar House staff are office based and as such are not involved in physically demanding work.

Another peculiarity of this comparison is that office based staff seem to bank their sleep, the data suggests that on a workday they sleep the fewest hours and then make up for this by sleeping longer on rest days.

The study also showed that people in general seem to prefer fixed shifts. However in the case of Stonebridge Park this preference was smaller, a possible explanation for this difference is that the shift itself – although fixed, is not fixed at a convenient time for the individual concerned. Of note when compared with the 100% of Templar House based staff who reported satisfaction with their fixed shifts, these shifts being traditional nine to five hours.

With regard to the differences in travelling time between Templar House based staff and depot staff, a simple explanation for this could be the geographical differences, Templar House is in central London (Holborn), Stonebridge and Neasden are further out from the centre. It may also be the case that depot staff are more likely to spend the best part of their career spent at one location; this long term world view would encourage staff to live closer to their place of work.

Staff based in the Head office are probably less likely to live in central London for a couple of reasons, the most obvious being the cost of housing in central London. The second is the risk of being relocated elsewhere in the business every few years. Social factors such as the desire of many white collar workers to ‘move out to the country’ could also provide some explanation of this difference.

8 Conclusion

Resource and time constraints only permitted a limited scope for this study. For this reason a business style was adopted with every effort made to be as scientific as resource would allow. Despite these limitations, the data that has been gathered does indicate a problem with fatigue within the business.

The literature review suggests that there is an association between working long hours and fatigue. The strongest link is with long hours and subjective reports of fatigue, although some studies that have used more objective measurements of fatigue have also found a link. Fatigue has been defined in different ways within the literature review. It can be measured indirectly by looking at performance and there is evidence to show that long hours is related to fatigue and can have an effect on accident and performance.

It could be argued to be a reasonable assumption that staff who failed the EyeCheck test would have recorded a much higher score on the Epworth questionnaire. However staff at Neasden consistently reported feeling less fatigue than the EyeCheck actually showed, a similar response was recorded at Stonebridge Park. Only for staff at Templar House did the data begin to reflect this assumption.

A possible explanation for this greater awareness of their fatigue levels is their longer commute and fewer sleeping hours than their colleagues at the depots. In other words they already know the effects of their lifestyle and projected this into their responses to the questionnaire.

This difference in certain industries could remain of academic interest, however the railways are a safety critical industry, staff working in depots are often safety critical workers. This is not to suggest that the fatigue of office based staff should be dismissed, many of them are required to make business critical decisions on a daily basis. The point here is to focus on the immediate safety implications of the fatigue levels found in safety critical workers.

The study concludes that between 17.5% and 30% of staff engaged in safety critical work in depots are suffering from fatigue. Perhaps of most concern is that a sizeable proportion of these staff seem unaware of the level of fatigue they are experiencing.

9 Recommendations

1. Further studies

It is recommended that a further more detailed study is commissioned by the business to look into other safety critical asset areas such as track and signals.

2. Specialist sleep advice

It is recommended that in the three areas of the business where data has already been collected, a sleep specialist is engaged to educate staff on effective techniques to improve the quality and amount of rest they get.

3. Fatigue checking equipment (pupillometers)

It is recommended that the company procure a number of fatigue monitoring devices for use in the two depots already studied.

4. Random checks and post incident

The business is to consider the use of this technology as part of a monitoring regime for safety critical workers and their fatigue levels. Some thought will need to be given as to how we manage this process; the purpose after all is to eliminate fatigue in safety critical work not to punish individuals for being tired.

Additionally the use of the EyeCheck or similar technology should be considered for post incident records i.e. to rule out fatigue as a causal factor.

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11 Descriptive Statistics

All the data

Column1	Sitting and reading	Watching TV	Sitting inactive	As a passenger	Lying down to rest	Sitting and talking	Epworth mean
Mean	0.7125	1.2625	0.2875	0.55625	1.275	0.075	4.16875
Standard Error	0.05046	0.074441	0.045547	0.056598	0.078282	0.022692	0.209113
Median	1	1	0	0	1	0	4
Mode	1	1	0	0	1	0	2
Standard Deviation	0.638271	0.941613	0.576123	0.715919	0.990204	0.287036	2.64509
Sample Variance	0.40739	0.886635	0.331918	0.512539	0.980503	0.08239	6.996502
Kurtosis	0.067283	-0.66335	5.938888	0.038398	-1.01202	17.20289	2.324422
Skewness	0.481802	0.41262	2.287417	0.997498	0.210275	4.035629	1.149127
Range	3	3	3	3	3	2	16
Minimum	0	0	0	0	0	0	0
Maximum	3	3	3	3	3	2	16
Sum	114	202	46	89	204	12	667
Count	160	160	160	160	160	160	160
Largest(1)	3	3	3	3	3	2	16
Smallest(1)	0	0	0	0	0	0	0
Confidence Level(95.0%)	0.099658	0.147021	0.089954	0.111781	0.154607	0.044817	0.412997

All the Passes

Column1	Sitting and reading	Watching TV	Sitting inactive	As a passenger	Lying down to rest	Sitting and talking	Epworth mean
Mean	0.669643	1.321429	0.285714	0.571429	1.276786	0.089286	4.214286
Standard Error	0.060014	0.092525	0.057328	0.070293	0.097598	0.02989	0.270679
Median	1	1	0	0	1	0	4
Mode	1	1	0	0	2	0	2
Standard Deviation	0.635133	0.979191	0.606698	0.743916	1.032881	0.316329	2.864598
Sample Variance	0.403394	0.958816	0.368082	0.553411	1.066844	0.100064	8.20592
Kurtosis	0.502824	-0.86785	6.761131	0.054211	-1.16581	14.80833	2.207196
Skewness	0.623493	0.309254	2.47963	1.020371	0.168939	3.751375	1.173532
Range	3	3	3	3	3	2	16
Minimum	0	0	0	0	0	0	0
Maximum	3	3	3	3	3	2	16
Sum	75	148	32	64	143	10	472
Count	112	112	112	112	112	112	112
Largest(1)	3	3	3	3	3	2	16
Smallest(1)	0	0	0	0	0	0	0
Confidence Level(95.0%)	0.118923	0.183344	0.113598	0.139291	0.193397	0.05923	0.536368

All the fails

Column1	Sitting and reading	Watching TV	Sitting inactive	As a passenger	Lying down to rest	Sitting and talking	Epworth mean
Mean	0.8125	1.125	0.291667	0.520833	1.270833	0.041667	4.0625
Standard Error	0.092523	0.121402	0.072679	0.094106	0.128892	0.029148	0.29835
Median	1	1	0	0	1	0	4
Mode	1	1	0	0	1	0	4
Standard Deviation	0.641018	0.841099	0.503534	0.651988	0.892989	0.201941	2.067028
Sample Variance	0.410904	0.707447	0.253546	0.425089	0.797429	0.04078	4.272606
Kurtosis	-0.55234	0.187177	1.232742	-0.25398	-0.47611	21.32325	0.003942
Skewness	0.183725	0.650623	1.457622	0.881238	0.361496	4.736641	0.682109
Range	2	3	2	2	3	1	9
Minimum	0	0	0	0	0	0	0
Maximum	2	3	2	2	3	1	9
Sum	39	54	14	25	61	2	195
Count	48	48	48	48	48	48	48
Largest(1)	2	3	2	2	3	1	9
Smallest(1)	0	0	0	0	0	0	0
Confidence Level(95.0%)	0.186132	0.244229	0.146211	0.189317	0.259297	0.058637	0.600202

Descriptive Statistics for Passes

Neasden Passes

Column1	Sitting and reading	Watching TV	Sitting inactive	As a passenger	Lying down to rest	Sitting and talking	Epworth mean
Mean	0.627907	1.069767	0.27907	0.488372	1.372093	0.139535	3.976744
Standard Error	0.094261	0.150287	0.083696	0.112222	0.141277	0.062977	0.444591
Median	1	1	0	0	1	0	3
Mode	1	1	0	0	2	0	2
Standard Deviation	0.61811	0.985498	0.548833	0.735886	0.926418	0.412968	2.915381
Sample Variance	0.38206	0.971207	0.301218	0.541528	0.85825	0.170543	8.499446
Kurtosis	-0.59442	-0.51902	2.798655	-0.08549	-0.8819	10.17249	2.07182
Skewness	0.436455	0.637834	1.884132	1.169802	-0.07705	3.150167	1.511518
Range	2	3	2	2	3	2	12
Minimum	0	0	0	0	0	0	1
Maximum	2	3	2	2	3	2	13
Sum	27	46	12	21	59	6	171
Count	43	43	43	43	43	43	43
Largest(1)	2	3	2	2	3	2	13
Smallest(1)	0	0	0	0	0	0	1
Confidence Level(95.0%)	0.190226	0.303292	0.168906	0.226472	0.285109	0.127093	0.897222

Stonebridge Passes

Column1	Sitting and reading	Watching TV	Sitting inactive	As a passenger	Lying down to rest	Sitting and talking	Epworth mean
Mean	0.636364	1.386364	0.159091	0.613636	1.136364	0.090909	4.022727
Standard Error	0.103281	0.142523	0.079262	0.118196	0.176862	0.04384	0.486051
Median	1	1	0	0	1	0	3.5
Mode	1	1	0	0	0	0	2
Standard Deviation	0.685087	0.945391	0.525763	0.784024	1.173167	0.290803	3.2241
Sample Variance	0.469345	0.893763	0.276427	0.614693	1.376321	0.084567	10.39482
Kurtosis	1.84973	-0.79586	20.28202	0.643852	-1.34103	7.004355	2.95433
Skewness	1.070799	0.17059	4.21598	1.120992	0.447801	2.9475	1.304544
Range	3	3	3	3	3	1	16
Minimum	0	0	0	0	0	0	0
Maximum	3	3	3	3	3	1	16
Sum	28	61	7	27	50	4	177
Count	44	44	44	44	44	44	44
Largest(1)	3	3	3	3	3	1	16
Smallest(1)	0	0	0	0	0	0	0
Confidence Level(95.0%)	0.208285	0.287425	0.159847	0.238365	0.356675	0.088412	0.980215

Templar Passes

Column1	Sitting and reading	Watching TV	Sitting inactive	As a passenger	Lying down to rest	Sitting and talking	Epworth mean
Mean	0.8	1.64	0.52	0.64	1.36	0	4.96
Standard Error	0.11547	0.190438	0.154056	0.14	0.190438	0	0.385054
Median	1	1	0	1	1	0	5
Mode	1	1	0	0	1	0	4
Standard Deviation	0.57735	0.95219	0.770281	0.7	0.95219	0	1.925271
Sample Variance	0.333333	0.906667	0.593333	0.49	0.906667	0	3.706667
Kurtosis	-0.02372	-1.00979	3.296985	-0.64087	-0.79102	#DIV/0!	-0.30371
Skewness	8.05E-17	0.192382	1.711414	0.642667	0.122379	#DIV/0!	0.099491
Range	2	3	3	2	3	0	8
Minimum	0	0	0	0	0	0	1
Maximum	2	3	3	2	3	0	9
Sum	20	41	13	16	34	0	124
Count	25	25	25	25	25	25	25
Largest(1)	2	3	3	2	3	0	9
Smallest(1)	0	0	0	0	0	0	1
Confidence Level(95.0%)	0.238318	0.393045	0.317956	0.288946	0.393045	0	0.794712

Descriptive Statistics for Fails

Neasden Fails

Column1	Sitting and reading	Watching TV	Sitting inactive	As a passenger	Lying down to rest	Sitting and talking	Epworth mean
Mean	0.818182	1	0.227273	0.363636	1.545455	0	3.954545
Standard Error	0.125466	0.186097	0.091449	0.123888	0.182897	0	0.386332
Median	1	1	0	0	1	0	4
Mode	1	1	0	0	1	0	4
Standard Deviation	0.58849	0.872872	0.428932	0.581087	0.857864	0	1.812057
Sample Variance	0.34632	0.761905	0.183983	0.337662	0.735931	0	3.28355
Kurtosis	0.010638	-0.42311	-0.05721	1.199003	-0.5681	#DIV/0!	1.278072
Skewness	0.025489	0.472578	1.398823	1.389967	0.592443	#DIV/0!	1.024777
Range	2	3	1	2	3	0	7
Minimum	0	0	0	0	0	0	2
Maximum	2	3	1	2	3	0	9
Sum	18	22	5	8	34	0	87
Count	22	22	22	22	22	22	22
Largest(1)	2	3	1	2	3	0	9
Smallest(1)	0	0	0	0	0	0	2
Confidence Level(95.0%)	0.260922	0.38701	0.190178	0.25764	0.380356	0	0.803421

Stonebridge Fails

Column1	Sitting and reading	Watching TV	Sitting inactive	As a passenger	Lying down to rest	Sitting and talking	Epworth mean
Mean	0.705882	1.176471	0.352941	0.705882	1.176471	0.117647	4.235294
Standard Error	0.187175	0.154237	0.147059	0.166378	0.230653	0.080547	0.552597
Median	1	1	0	1	1	0	4
Mode	0	1	0	1	2	0	4
Standard Deviation	0.771744	0.635934	0.606339	0.685994	0.951006	0.332106	2.278415
Sample Variance	0.595588	0.404412	0.367647	0.470588	0.904412	0.110294	5.191176
Kurtosis	-0.97543	4.086102	1.899337	-0.61094	-1.05175	5.44	-0.08847
Skewness	0.591894	1.509591	1.596466	0.455543	0.102587	2.609612	0.282364
Range	2	3	2	2	3	1	9
Minimum	0	0	0	0	0	0	0
Maximum	2	3	2	2	3	1	9
Sum	12	20	6	12	20	2	72
Count	17	17	17	17	17	17	17
Largest(1)	2	3	2	2	3	1	9
Smallest(1)	0	0	0	0	0	0	0
Confidence Level(95.0%)	0.396794	0.326967	0.311751	0.352706	0.488962	0.170753	1.171453

Templar Fails

Column1	Sitting and reading	Watching TV	Sitting inactive	As a passenger	Lying down to rest	Sitting and talking	Epworth mean
Mean	1	1.333333	0.333333	0.555556	0.777778	0	4
Standard Error	0.166667	0.372678	0.166667	0.242161	0.222222	0	0.816497
Median	1	1	0	0	1	0	4
Mode	1	1	0	0	1	0	2
Standard Deviation	0.5	1.118034	0.5	0.726483	0.666667	0	2.44949
Sample Variance	0.25	1.25	0.25	0.527778	0.444444	0	6
Kurtosis	4	-0.8	-1.71429	0.1852	-0.04018	#DIV/0!	-0.28571
Skewness	0	0.536656	0.857143	1.014259	0.254464	#DIV/0!	1.049781
Range	2	3	1	2	2	0	6
Minimum	0	0	0	0	0	0	2
Maximum	2	3	1	2	2	0	8
Sum	9	12	3	5	7	0	36
Count	9	9	9	9	9	9	9
Largest(1)	2	3	1	2	2	0	8
Smallest(1)	0	0	0	0	0	0	2
Confidence Level(95.0%)	0.384334	0.859398	0.384334	0.558425	0.512446	0	1.882846

Comparison of Means

	Sitting and reading	Watching TV	Sitting inactive	As a passenger	Lying down to rest	Sitting and talking	Epworth mean
Neasden Pass	0.628	1.070	0.279	0.488	1.372	0.140	3.977
Neasden Fail	0.818	1.000	0.227	0.364	1.545	0.000	3.955
Stonebridge Pass	0.636	1.386	0.159	0.614	1.136	0.091	4.023
Stonebridge Fail	0.706	1.176	0.353	0.706	1.176	0.118	4.235
Templar Pass	0.800	1.640	0.520	0.640	1.360	0.000	4.960
Templar Fail	1.000	1.333	0.333	0.556	0.778	0.000	4.000