An extract from *Sleep, Wake and the Internal Body Clock: Homeostatic and Circadian Interactions on Performance*. PhD thesis submitted 28th February, 2015, by Dr Raymond W. Matthews, B.Sc., B.HSc. (Hons), PhD.

9.1 Using thesis findings to promote safe driving

One way of quantifying the effects of fatigue and the seriousness of its consequences is in making a direct comparison with the effects of alcohol intoxication. Driving with a BAC of 0.05% or greater is illegal in Australia and many western industrialised countries (Banks, Catcheside, Lack, Grunstein, & McEvoy, 2004). Measuring the effects of fatigue against this level of impairment gives a benchmark of what is unsafe. This does not mean that driving with some fatigue is safe; rather it is important to demonstrate that in some conditions the performance impairment from fatigue becomes so great that it is clearly an unsafe situation. Further research should be conducted to refine the fatigue threshold where performance moves from 'safe' to 'unsafe'. In the meantime, for the purpose of this thesis an impairment equivalent to a BAC of 0.05% acts as this significant safety threshold.

An early comparison of fatigue and a blood-alcohol equivalent was published by Dawson and Reid (1997). By sustaining continuous wakefulness, participants' cognitive psychomotor performance coincided with that of a BAC of 0.05% after approximately 17 hours. Beyond this point, performance declined further before rising again, presumably as a result of the participant's circadian rhythm of alertness. The aim of Dawson and Reid's (1997) study was to demonstrate to policy-makers and the community, with an easily grasped index, that moderate levels of fatigue could be dangerous. What should not be taken form their study is that 17 hours of prior wake equates to a BAC of 0.05% or that 24h prior wake equates to a BAC of 0.1%. These relationships are dependent upon a particular alignment of circadian phase and

sleep-wake cycle. Data from the current thesis, however, is able to show a broad spectrum of this relationship.

By considering pervious research that has been conducted on driving under the influence of alcohol, it was possible to plot the fatigue blood-alcohol equivalent threshold across the three dimensions of sleep, wake and time of day, (shown in Figure 9.8). To create this graph, the level of impairment in driving performance that equated to a BAC of 0.05% was attained from a study conducted by Arnedt, Wilde, Munt and MacLean (2001). In this study the simulated driving performance of 18 young males was assessed on the York Driving Simulator (the simulator used in the current thesis) at blood alcohol concentrations (BAC) of 0.00%, 0.05%, and 0.08%. The mean difference in performance from 0.00% to 0.05% (relative to baseline) was noted from the result section for the lane, speed and crash (off-road events) driving measures, for the first 10-minute interval of the simulated drive. This provided the driving impairment from baseline that was associated with driving with a BAC of 0.05%; hence, the 'blood-alcohol equivalent' for each participant. Following this, for each time of day and sleep condition, the level of prior wake that was needed to reach a participants blood-alcohol equivalent was calculated and plotted. The result of this is that each line on the graph reflects the same performance deficit, for a given time of day and amount of prior wake, following eight, six or four hours of sleep. The areas above each curve correspond to a combination of prior wake, sleep loss and time of day that will result in a performance deficit worse than that of being intoxicated with a BAC of 0.05%, and hence is unsafe. It should be noted that these data include the correction proposed in Chapter 8. By removing the 'longitudinal effect' across the experiment, each experimental day starts from a baseline of 'sufficient sleep' followed by a single period of sleep loss (of three doses) examined

across the various circadian phase and prior wake combinations. The current data corresponds remarkably well with Dawson and Reid's (1997) study. Highlighted in red, approximately 17 hours of prior wake after an 8 hour sleep, at approximately 0300, equates to the blood-alcohol equivalent of 0.05%. It can also be seen that this level of impairment can be reached with far less prior wake and earlier in the evening if sleep is reduced.

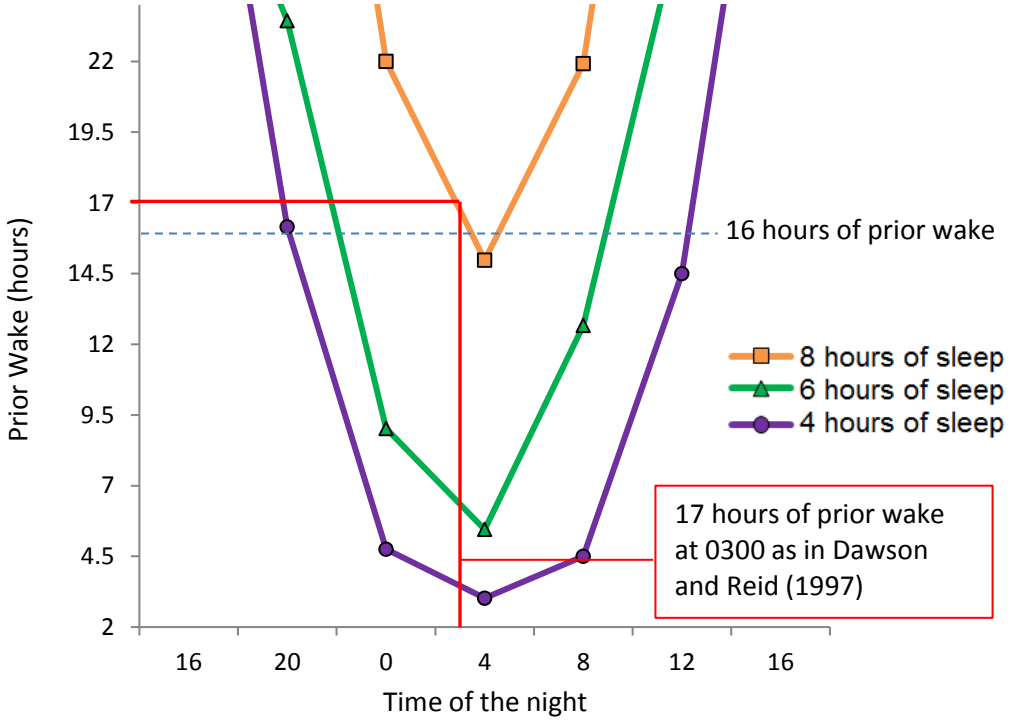

Figure 9.8. Simulated driving performance at a blood-alcohol equivalent of 0.05% brought about by combinations of prior wake, sleep does and time of the night.

Each plotted point on the graph represents a blood-alcohol equivalent of 0.05%. The area above each line reflects performance worse than the blood-alcohol equivalent and the area below reflects performance better than the blood-alcohol equivalent. The 16 hours dotted lines shows that if an individual obtains 8 hours sleep as well as not extending wake beyond 16h only a small portion of the night (around 0400) is critical zone for unsafe driving. However, if an individual only obtains 4 hours of sleep their driving performance is greatly impaired throughout the night even if they have recently slept. The red trace corresponds to the combination of prior wake and time of day reported by Dawson and Reid (1997).

The data in this thesis suggest that while there are challenges to having people perform tasks at night, the main issues are linked to how the fatiguing influences of

sleep, wake and time of day are arranged and combined. Fatigue risk management continues to remain a focus for industries and employers, but part of the problem may also be society's lack of understanding on how performance is affected by sleep, wake and time of day. Over time, society has come to deal with other causes of performance impairment such as alcohol intoxication (DeJong & Winsten, 1990). Yet, strategies that are encouraged to prevent alcohol-related performance impairment ignore the risk that fatigue presents, demonstrating this lack of awareness. An example of this is the 'designated driver' strategy such as the 'Harvard Alcohol Project in 1988', that has been widely campaigned as a safe action to avoid driving under the influence of alcohol (DeJong & Wallack, 1992; DeJong & Winsten, 1990). The basis of the strategy is to plan ahead and have someone not drink alcohol so they can drive themselves and others home (DeJong & Wallack, 1992). This means that the driver will not be under the influence of alcohol but in terms of fatigue, this behaviour may still be unsafe. Take the following example; a person gets up at 0600 and does 8 hours of work or study before going out with some friends in the evening. As the 'designated driver' the person abstains from alcohol and so drives his friend's home at 0200. This has been regarded as the safe action to avoid driving under the influence of alcohol. During the journey home the driver will have been awake for 20h at a time of day near their circadian early-morning phase. Figures 9.8 and 9.9 show that this combination equates to a performance deficit at worse than a blood-alcohol equivalent of 0.05%, yet this practice is regarded as the safe thing to do (DeJong & Wallack, 1992).

Addressing society's perspective on fatigue and driving will require a shift in thinking so that like alcohol, strategies and forward planning are used. What could be useful here are simple demonstrations of what constitutes unsafe conditions to drive. As an

example of how the findings and ideas within this thesis can be communicated in a relatively simple format, Figure 9.8 was adapted into ‘look-up table’ shown in Figure 9.9. This look-up table enables a shiftworker to plan ahead and see whether they will be unsafe to drive overnight. The demonstration here is that a deep understanding of the complex nature of the fatiguing factors, their relative contribution and how they interact is not needed to understand how to make safe choices regarding fatigue. The look-up table shown in Figure 9.9 serves as an example of how these ideas could be presented, but caution should be exercised in making real world decisions based on this table. The data that it represents has some limitations. First, it is important to note that the data reflects a short task—only 10 minutes in duration. It is likely that a longer drive would be associated with a greater performance decline than that observed. The benefit of the short drive is that it is free from time of day effects and so presents a best case for the effects of fatigue. The second point to consider is that the safety threshold was extrapolated from a separate dataset. In order to increase the validity of the thresholds, the characteristics of the table should be confirmed with additional research. Third, the driving performance was based on a simulated driving task rather than actual road driving. In this way the data reflects a decline in abilities that are suggested to be analogous to those used in driving. This is a good assumption as a large amount of research has been published showing that similar patterns of driver performance are observed between simulators and real world driving (Boyle & Lee, 2010; Underwood, Crundall, & Chapman, 2011). Expanding on this limitation, however, there may still be a wide spectrum of fatigue deficits that impact driving ability beyond the performance measured in these simulator tasks.

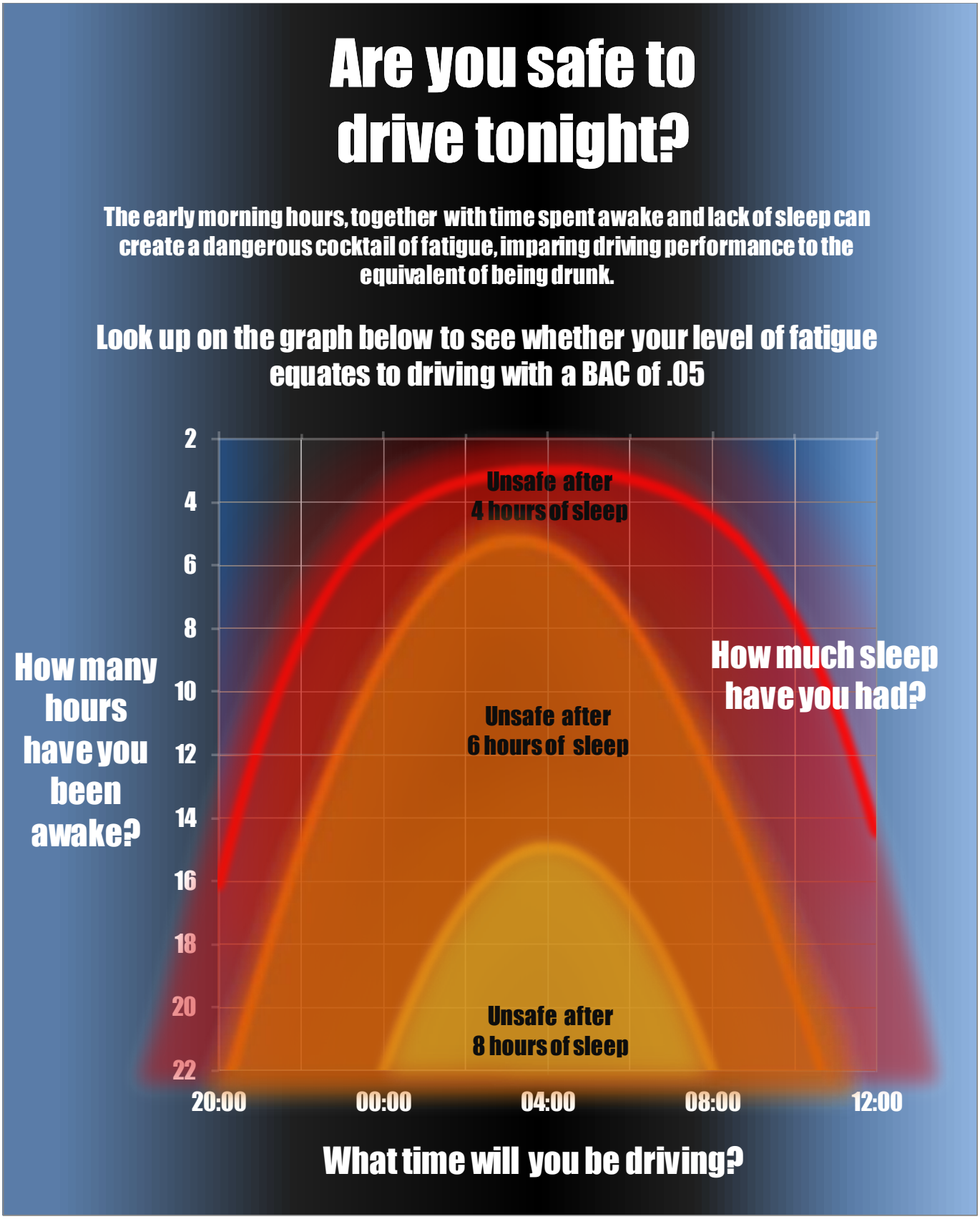

Figure 9.9. Look up table of the prior sleep, wake and time of night combinations that equate to a performance decline equal to or greater than driving with a BAC of 0.05%

This graph aims to communicate the implication of the two and three way interactions between prior wake, time of day and sleep loss in an easy to read manner. The intention is that a shiftworker could use this as a tool to plan ahead and determine whether driving in the early morning is an unsafe option.