Comparison of Alertness Levels in Ship Crew Working Fixed and Rotating Watch Schedules

MAJ (DR) S Arulanandam
LTC (DR) (NS) Chan CTG
Dr Lim CLF
Navy Medical Service, Republic of Singapore Navy
Defence Science Organisation, Singapore

Aim

- To compare crew alertness levels between a rotating and fixed watch schedule
  - Using saccadic velocity (eye movements) and pupillary light reflex measurements
- To compare crew's sleep duration during rotating and fixed watch schedules
  - With self-recorded sleep and activity diary

Background

- On long deployments, RSN ships traditionally use a counter-clockwise rotating watch schedule

	0000-0400	0400-0800	0800-1200	1200-1600	1600-1800	1800-2000	2000-2400
Day 1	A	B	C	A	B	C	A
Day 2	B	C	A	B	C	A	B
Day 3	C	A	B	C	A	B	C

- The 1600-2000 hour watch is broken into two 2-hour watches (split “dog-watch”)
- Waking times for each watch are progressively *earlier*
- Cycle repeats itself every three days

Background

- An alternative watch schedule is a fixed 1-in-3 watch system

0000-0400	0400-0800	0800-1200	1200-1600	1600-2000	2000-2400
A	B	C	A	B	C

- This pattern should be kept constant for about 14 days before rotating forward[1]

1. US Coast Guard Guide for the Management of Crew Endurance Risk Factors Version 1.1, Sept 2001. CG-D-13-01

Background

- Advantages of rotating watch schedule
  - Avoids one watch having permanent night or “middle watch” (midnight to 4am)
  - Allows variety of activities and duties from day to day
  - Allow all watches some time for recreational and social activities in the evening (“dog-watch”)

Background

- Disadvantages of rotating shift cycle
  - Disruption of the circadian rhythm, leading to decreased alertness and disruption of sleep patterns[2]
  - Counter-clockwise rotating schedules, where shift start timings move backward, result in progressive reduction of sleep and accumulation of sleep debt[3]

2. Signal TL, Gander PH. (Sleep/Wake Research Centre, Massey University, Ne Zealand) *Aviat Space Environ Med. 2007 Sep; 78(9):878-85*

3. Nesthus T et al (Federal Aviation Administration Civil Aerospace Medical Institute, Oklahoma City, USA) *J Hum Ergol (Tokyo), 2001 Dec;30(1-2):245-9*

Study Design

- Midshipmen-training deployment, February 2007
- 24 ship crew volunteers from bridge and engine room watch stations
- 3 watches (A, B and C)
- 1st phase (9-12 Feb), fixed watch schedule (4 hours on, 8 hours off)
- 2nd phase (19-22 Feb), counter-clockwise rotating watch schedule.
  - However, this phase was terminated early by the ship's Command due to concerns of crew fatigue
- There was a wash-out period of 6 days between 2 phases

Method

- FIT-2000 (*Pulse Medical Instruments, Inc.*) is an automated, computerised optical tracking and recording system
- Each FIT measurement is a 30-second non-invasive test that measures:

  a. Saccadic velocity (speed of side to side eye movement)

  b. Pupil diameter at rest

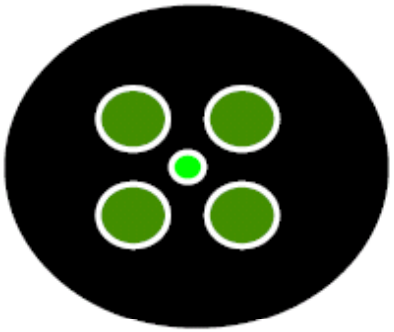
  c. Latency - time from flash of a light source to pupil constriction

  d. Amplitude - amount of constriction
- Measurements were taken immediately before and after each duty watch

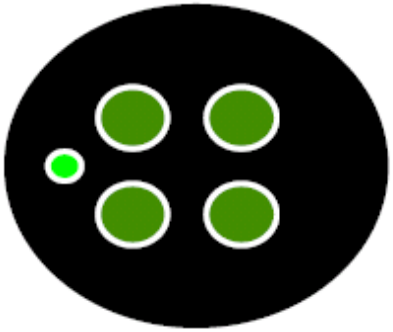
Method

Sequence of Measurements in FIT-2000

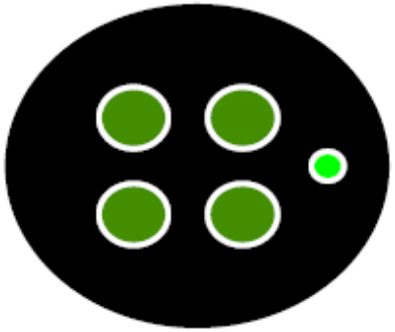
A. Moving Target



0 seconds

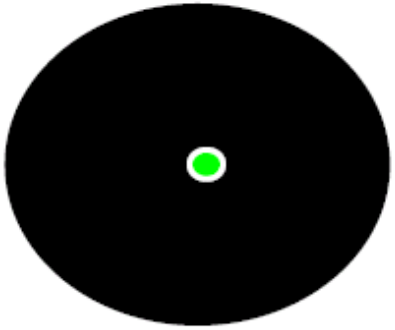


1 second



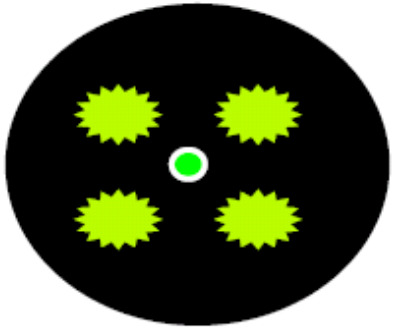
2 seconds

B. Pause



10 seconds

C. Flash



20 seconds

Method

- Sleep and nap diary
- Record the quantity of caffeinated drinks consumed
- Duration of any exercise done

Results

Sleep and Nap Times

- No significant difference in the main sleep period
  - 4.95 hours per day during fixed schedule
  - 4.99 hours per day during rotating schedule
- Statistically significant increase in the total rest time (sleep plus nap time)
  - 6.04 hours per day in fixed schedule
  - 5.43 hours per day in rotating schedule

Results

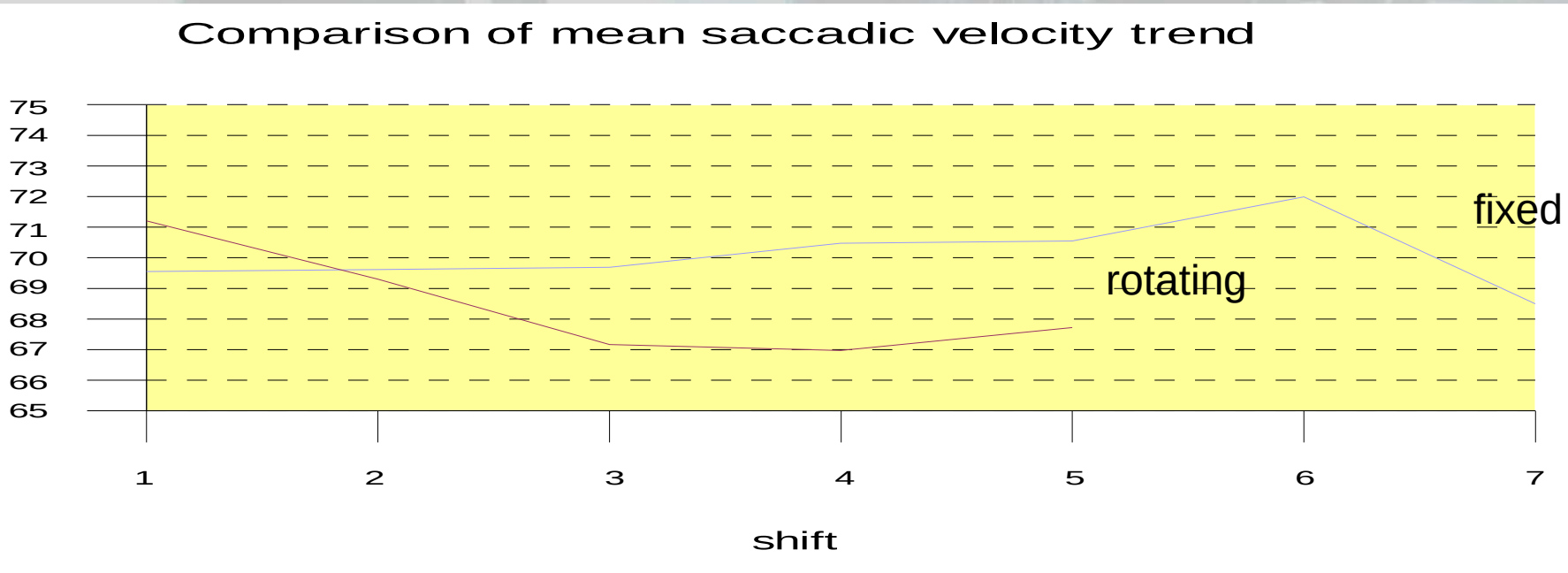
Caffeine Consumption.

- 0.94 cups per person during fixed schedule
- 1.24 cups per person during rotating schedule
- No significant difference

Results

Comparison of FIT measures

- No oculometric changes for the first 36 hours
- Saccadic velocity (SV) had the most significant correlation (SV decreased with increasing fatigue)
- SV after 4th duty watch, and before and after 5th duty watch were slower in the rotating schedule than in fixed schedule
  - this was statistically significant in the measurement after 4th duty watch ($p<0.05$)
- SV was consistently lower in the rotating schedule throughout the study period, as early as after the first 24 hours

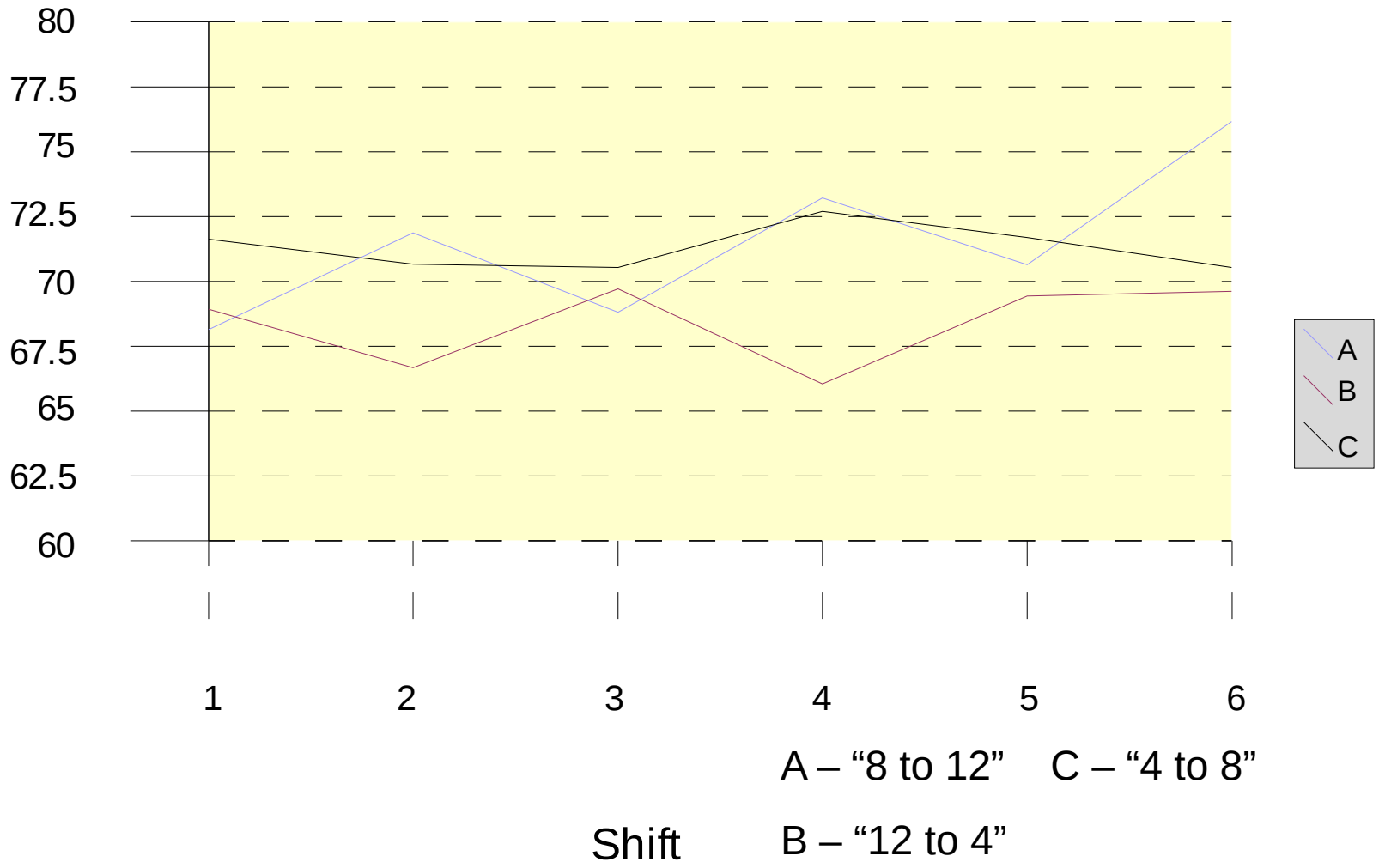


Results

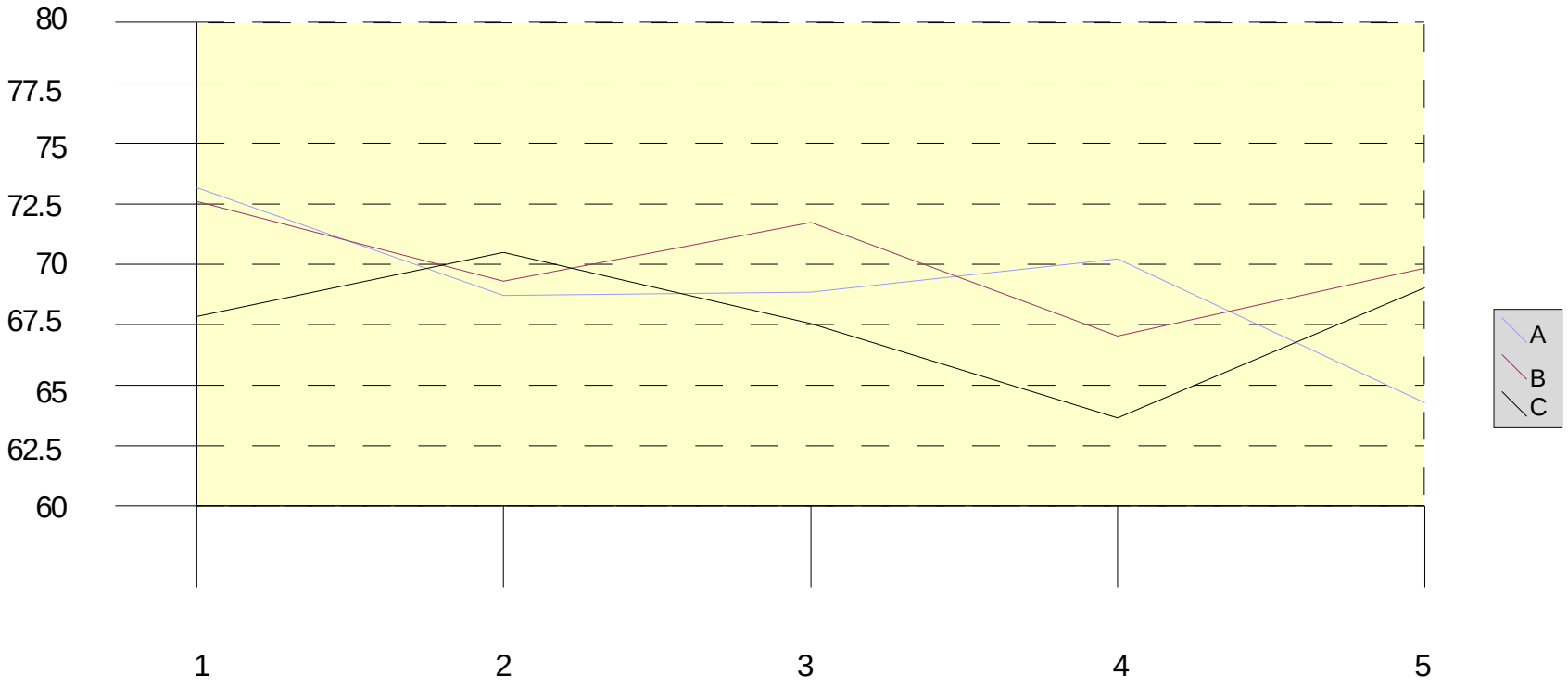
Differences between Watches A, B and C. In

- There was no difference in fatigue parameters between the 3 watches.
- There was also no evidence that the “middle-watch” (12 midnight to 4 a.m.) was more fatigued in terms of FIT measures, using ANOVA post-hoc Scheffe tests.

Comparison of Mean Saccadic Velocity between 3 Watches while Working Fixed Watch Schedule



Comparison of Mean Saccadic Velocity between 3 Watches while Working Rotating Watch Schedule



* No significant difference between 3 watches

Discussion

- Oculomotor functions have been shown to be predictive of sleep deprivation-induced operational performance degradation[4]
- Saccadic velocity (SV) is the most sensitive[5] for measuring sleep deprivation-induced impairment
  - SV decreases with increasing levels of sleep deprivation
  - Decreasing SV and increasing pupillary diameter were significantly correlated with increased incidence of driving accidents and impaired simulated driving performance
  - SV is resistant to changes in ambient light and time-of-day effects[6]

4. Rowland LM et al (Walter Reed Army Institute of Research) *Aviat Space Environ Med 2005 Jul;76(7 Suppl):C104-13*

5. M Russo et al (Walter Reed Army Institute of Research) *Clin Neurophysiol 2003 April; 114(4): 723-736*

6. Yu M et al (US Army Aeromedical Research Laboratory, Fort Rucker). *Opthalmic Physiol Opt 2007 Mar 27(2):130-41*

Discussion

- Duration of main sleep period is very short (<5 hours) in crew working 1-in-3 watches during operations
- Fixed watch schedule allowed for a longer nap time
  - Longer time between shifts (24 hour cycle)
- Significant decrease in mean SV in the rotating shift schedule after 36 hours
  - Disruption of circadian rhythm may be greater in a rotating shift schedule,
  - Correlates with findings in previous studies

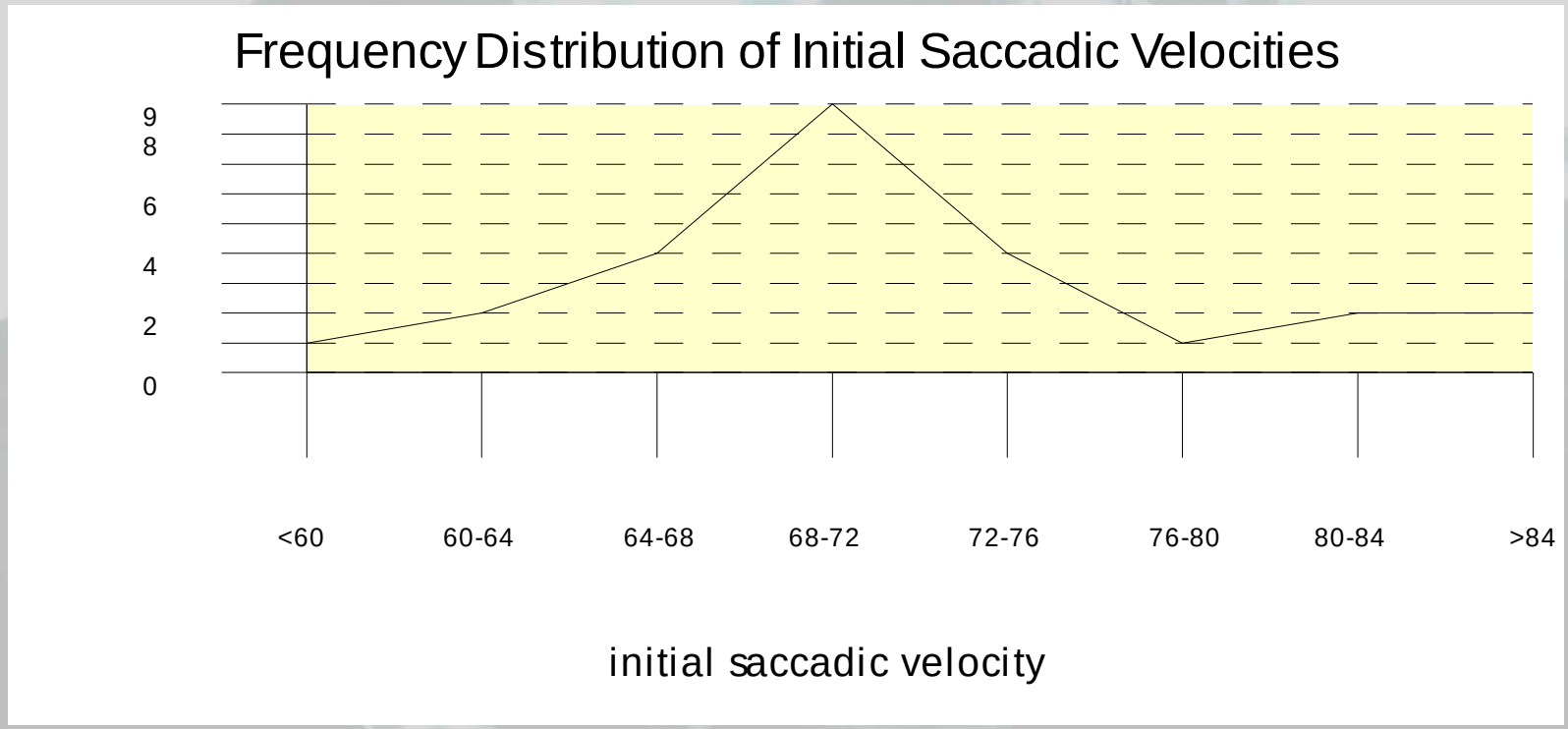
Discussion

Limitations of the Study

- Premature termination of the rotating shift phase due to training considerations
  - Training vs operational vs research environment
  - Differences in SV may have been even more significant over next few shifts
  - Unable comment on long term effects of working permanent “night watch”

Discussion

- Small sample population.
  - Possibility of sampling error
  - Minimised by normal distribution of baseline saccadic velocities of the study population (taken pre-phase 1)



Conclusion

- Changing sleep and wake times may disrupt circadian rhythm, resulting in increased fatigue despite receiving equal sleep as in a fixed watch schedule
- Differences may be observed as early as 36 hours from commencing shift work
- Accumulation of “sleep debt” over weeks may affect mental fitness for operational duties