



Sleep and Performance

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1



Factors Affecting Performance

- Time Awake (sleep/wake history)
- Time of Day (circadian rhythm)
- Time on Task (~shift length)
- Task Complexity
- Individual Differences in Response to
 - Time Awake
 - Time of Day

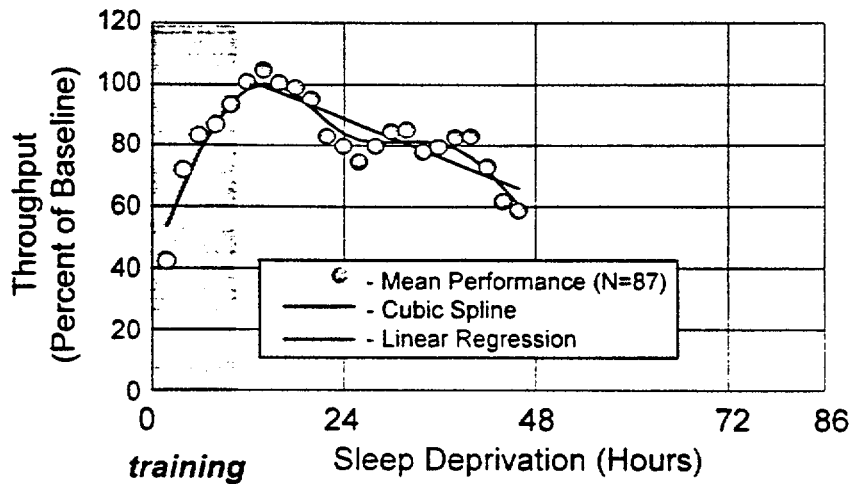
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2



48 Hours of Total Sleep Deprivation: Effect on Complex Mental Operations



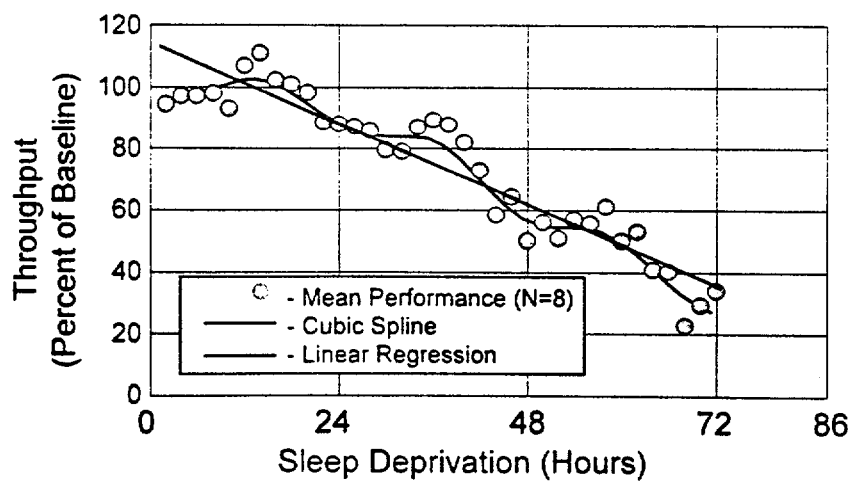
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72 Hours of Total Sleep Deprivation: Effect on Complex Mental Operations *Task*



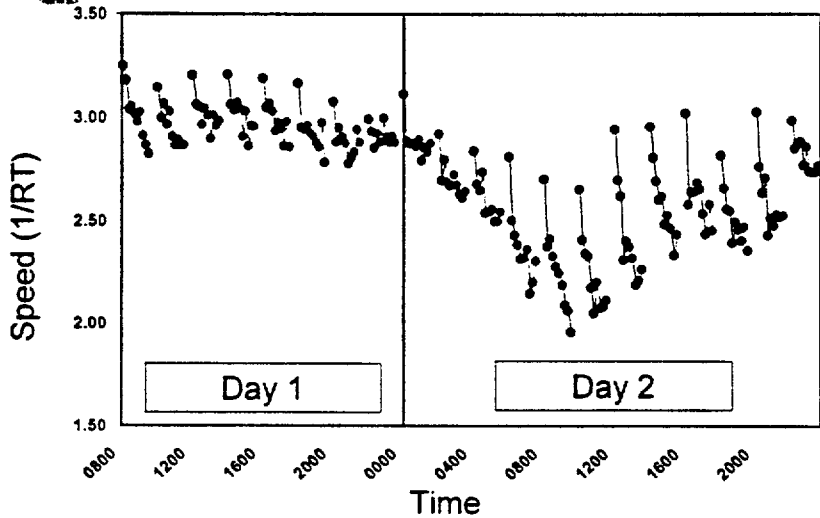
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Time on Task Effects on PVT Speed over 38 Hours of Total Sleep Deprivation



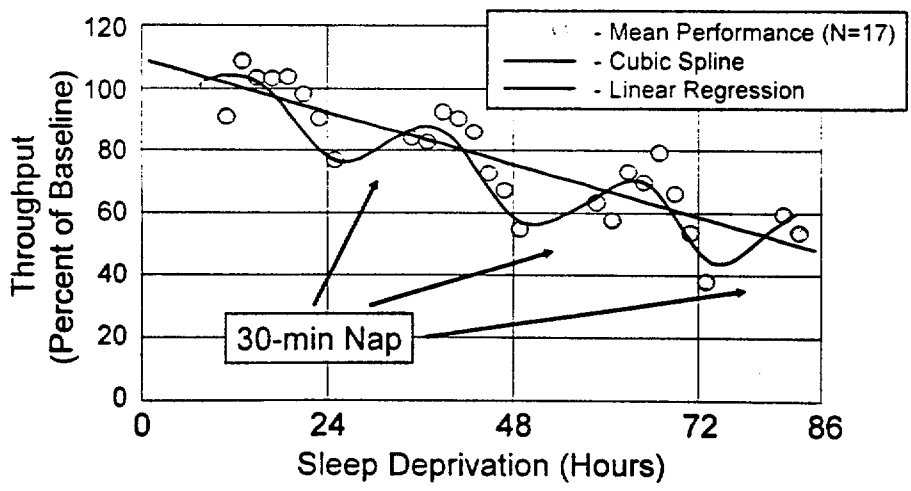
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5



85 Hours of Sleep Deprivation: 30-min Daily Nap & Complex Mental Operations



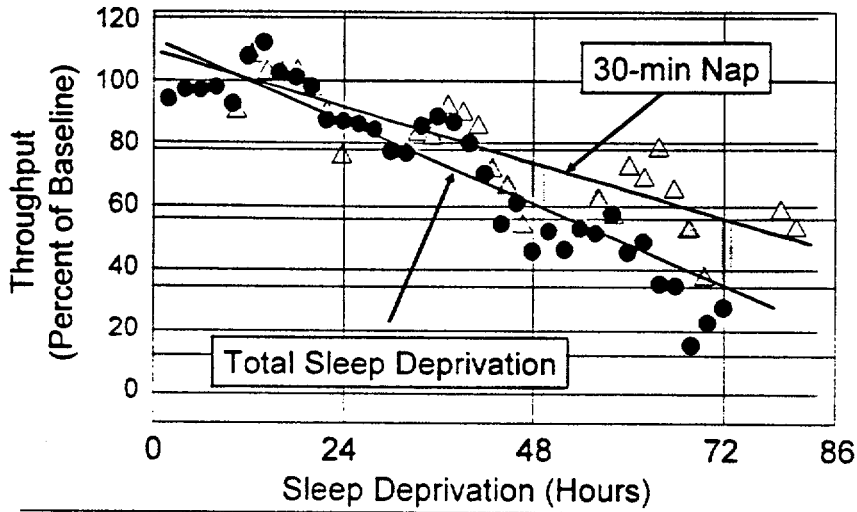
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Total Sleep Deprivation vs. Daily 30-min Nap: Effect on Complex Mental Operations



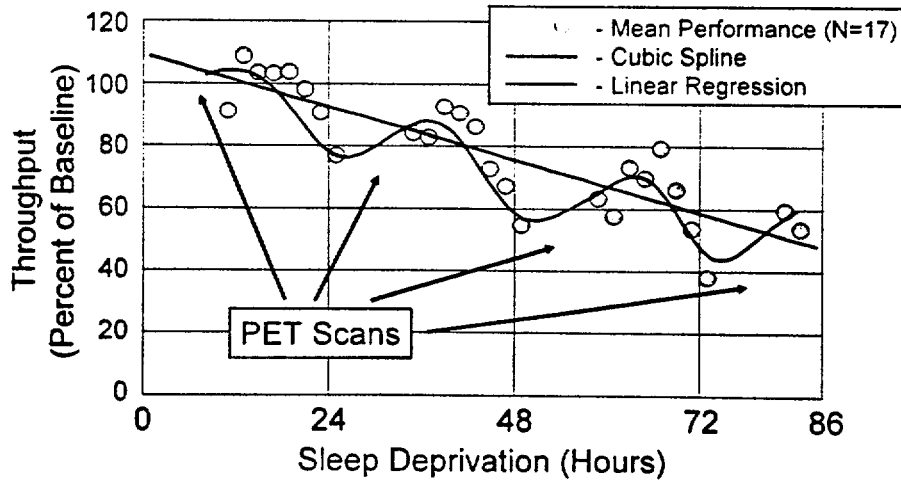
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85 Hours of Sleep Deprivation: 30-min Daily Nap & Complex Mental Operations



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PET Study of Sleep Deprivation: Findings



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9



Positron Emission Tomography (PET) Study of Sleep



Frontal areas are
deactivated during Slow
Wave Sleep



Frontal areas remain
deactivated during
REM



Frontal areas are
re-activated only after
awakening

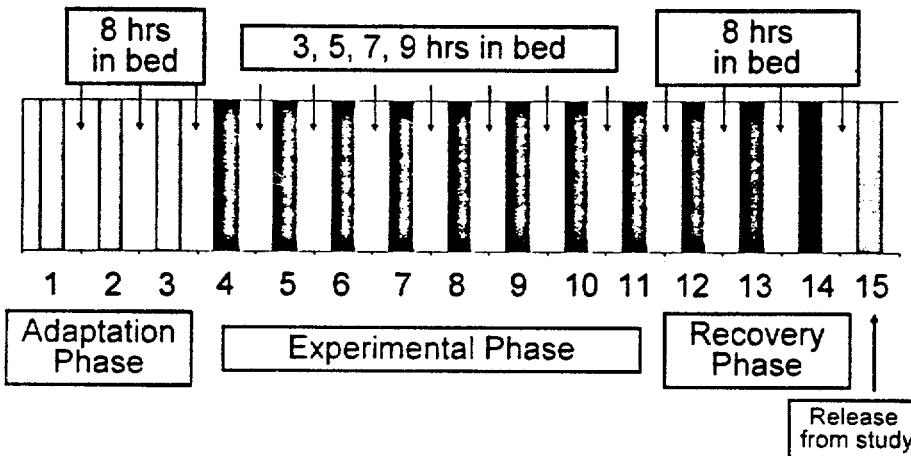
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Sleep Dose-Response (SDR)

Study: Design



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11



Subjects, Number/Sleep Group, Time in Bed

- 66 commercial drivers
 - in good general health
 - non smokers
 - light caffeine users (2-4 cups/day)
- 16 women
 - mean age 39 (range 24-55)
- 50 men
 - mean age 37 (range 24-62)
- 3 hr sleep group
 - Time in bed: 0400-0700
 - n = 18
- 5 hr sleep group
 - Time in bed: 0200-0700
 - n = 16
- 7 hr sleep group
 - Time in bed: 2400-0700
 - n = 16
- 9 hr sleep group
 - Time in bed: 2200-0700
 - n = 16

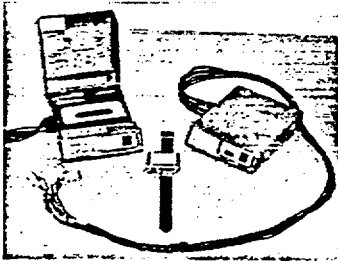
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12



Instrumented Volunteers



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13



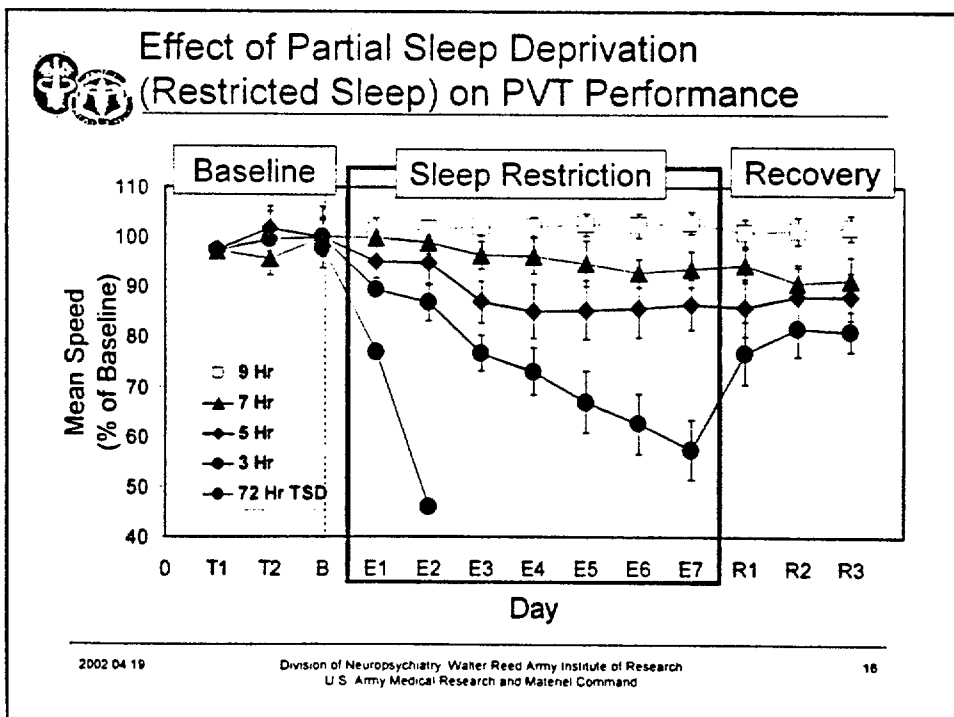
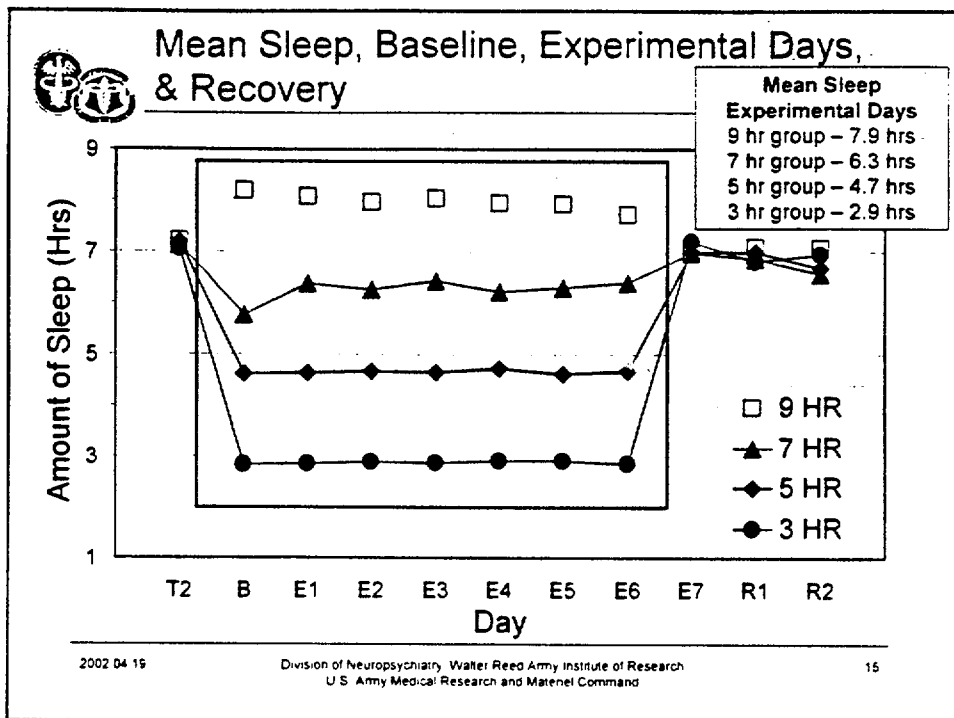
Measures

- 24 hr. Polysomnography (EEG, EOG, EMG) (Oxford Medilog)
 - Sleep scoring
 - Sleep latency testing
- 24 hr. Actigraphy (Precision Control Design, Inc.)
- Psychomotor Vigilance Task (PVT)
- Driving Simulator (STI, Inc)
- Oculomotor Responses - Fitness Impairment Tester (FIT) (PMI, Inc.)
- WRAIR Performance Assessment Battery (PAB)
- Synthetic Work Task
- Stanford Sleepiness Scale
- Profile of Mood States

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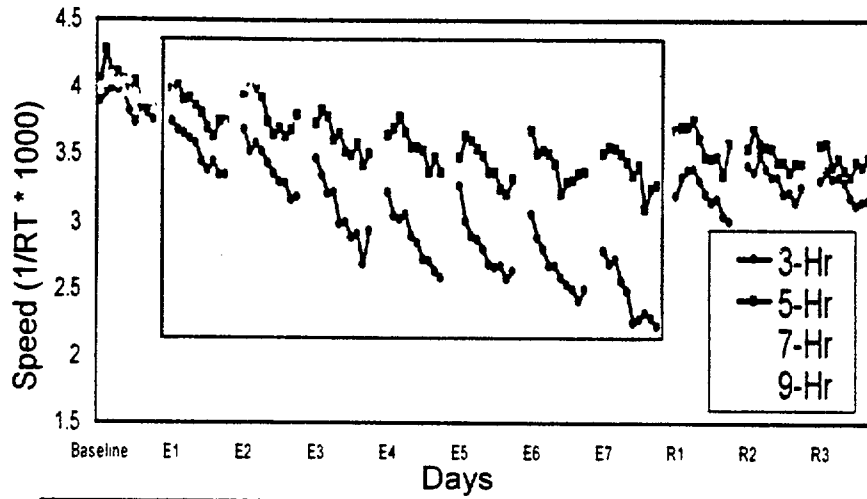
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14





Psychomotor Vigilance Task (PVT) Time on Task Effects @ 1200



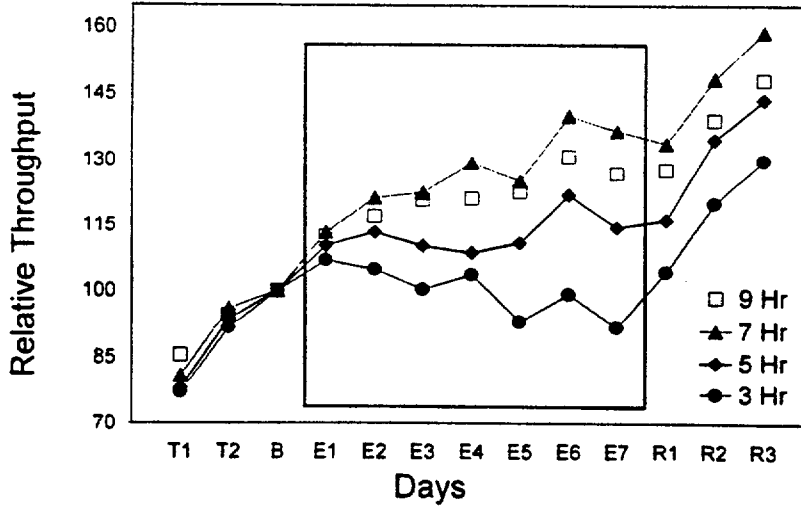
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17



Serial Addition Subtraction



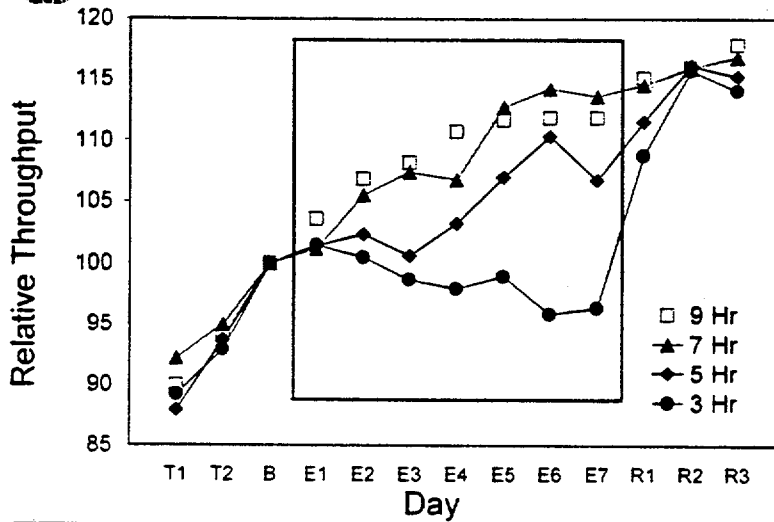
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18



10 Choice Reaction Time



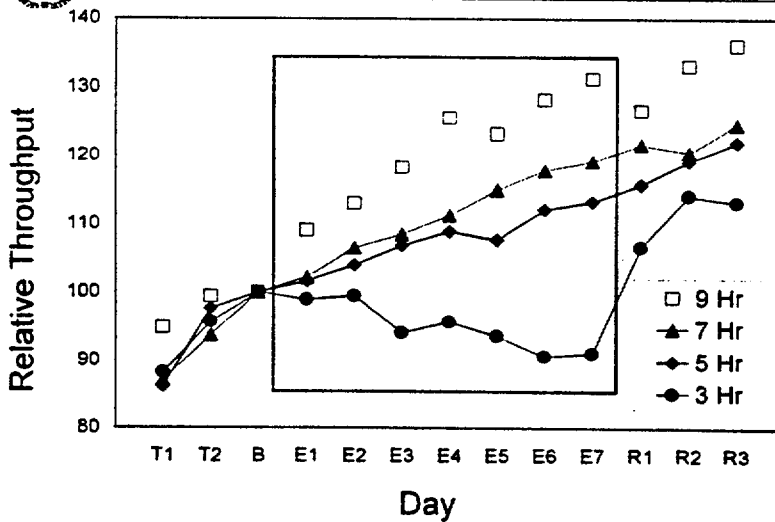
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19



Wilkinson 4-Choice Reaction Time



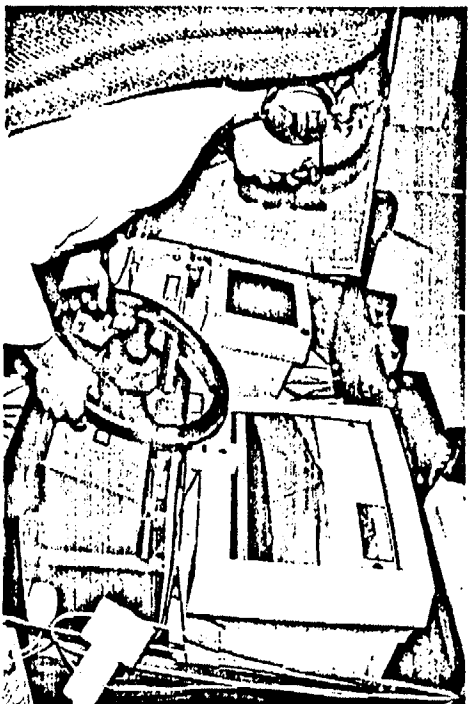
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20



Driving Simulator



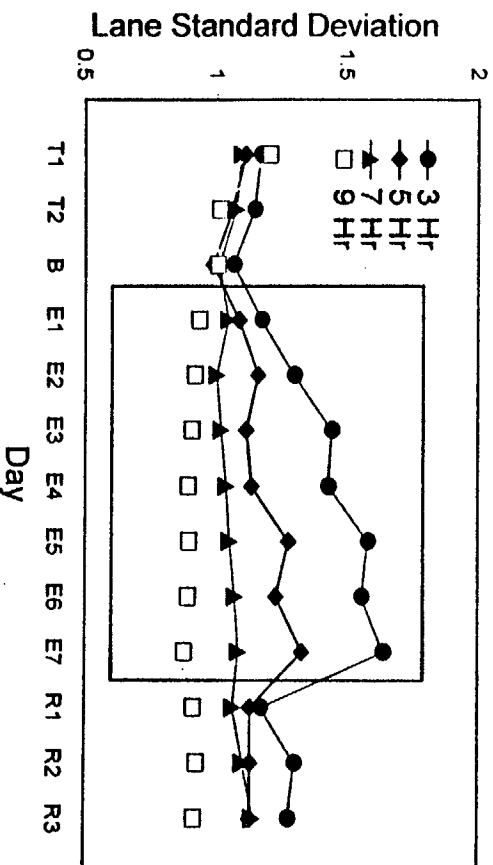
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21



Driving Simulator: Lane Tracking



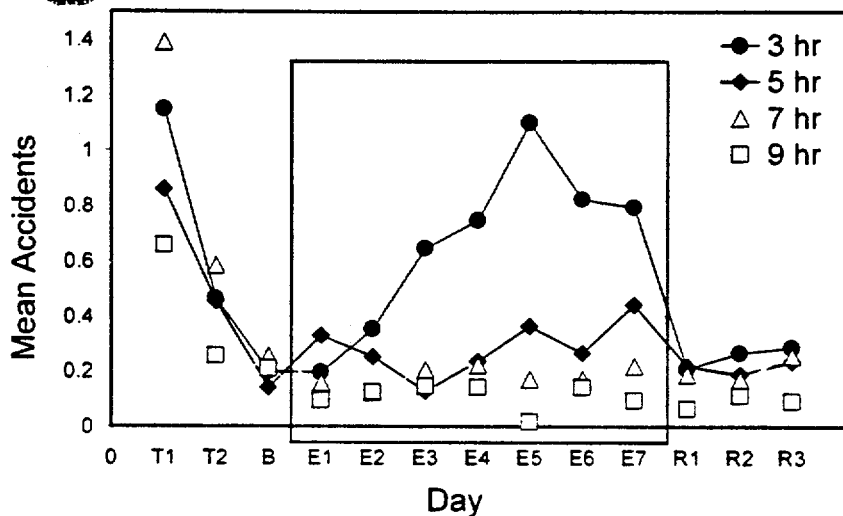
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Driving Simulator: Accidents



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Microsleeps and Accidents

- Microsleep –
 - the occurrence of theta in the absence of artifact
 - with a duration up to 15 s
 - Anything longer scored as R&K Stage 1 sleep
- Occurrence during the minute preceding the accident
- During the sleep restriction phase
 - No R&K Stage 1 Sleep
 - all groups - 33% preceded by microsleep
 - 3 hr sleep group - 49%
 - 9 hr sleep group - 29%

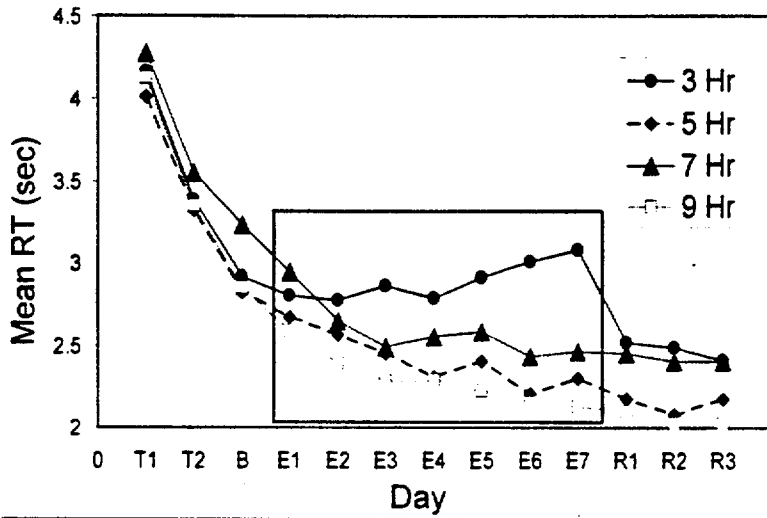
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24



Driving Simulator: Peripheral Attention Task



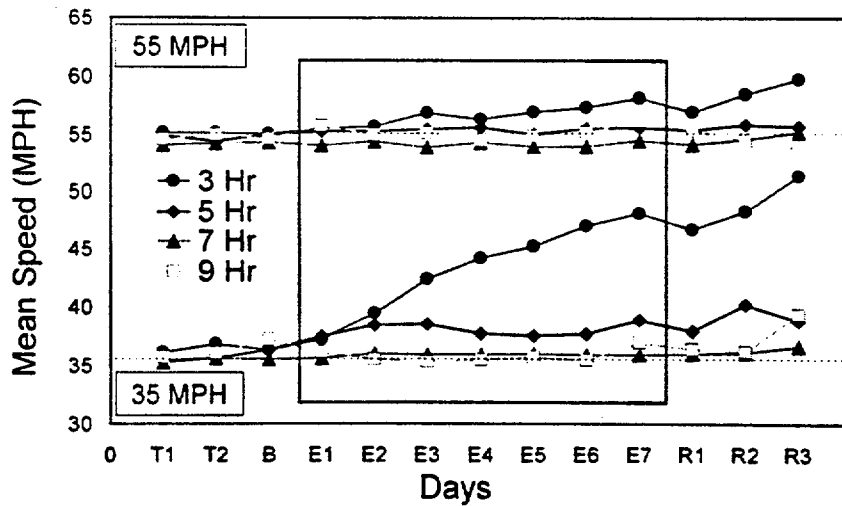
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Driving Simulator: Average Speed Across Zones



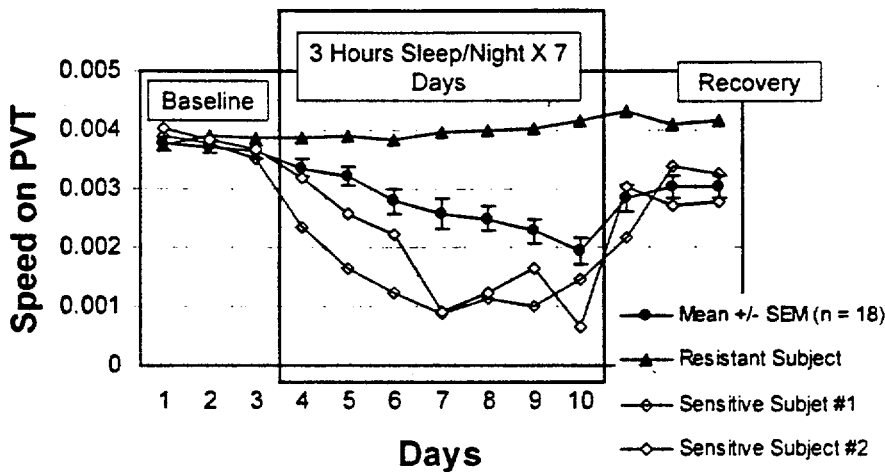
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26



Variation between Individuals in Resistance and Sensitivity to Sleep Restriction



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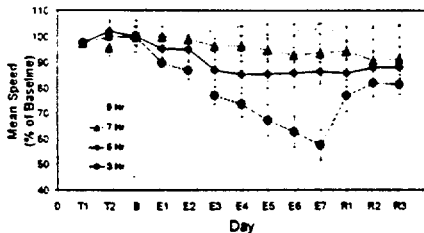
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27



Conclusion: Restructuring the Sleep Debt

Sleep Restriction & Performance



- Sleep Debt - Restructured
 - As long as performance is degrading sleep debt is accumulating
 - Once performance stabilizes sleep debt no longer accrues
 - Sleep debt is paid off rapidly
- The brain adapts to sleep restriction by capping operational capacity
- This adaptation persists into recovery, restricting performance
- Sleep Debt - Traditional view
 - Sleep debt accumulates continuously, linearly
 - Sleep debt takes days, weeks, or months to pay off

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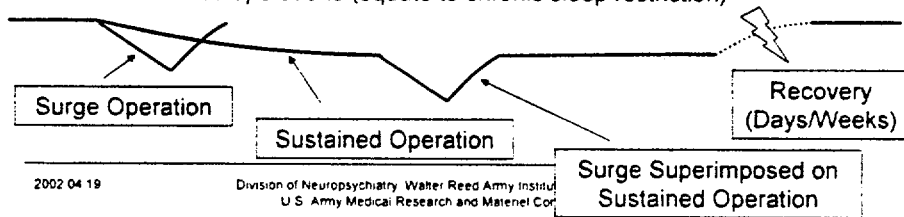
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28

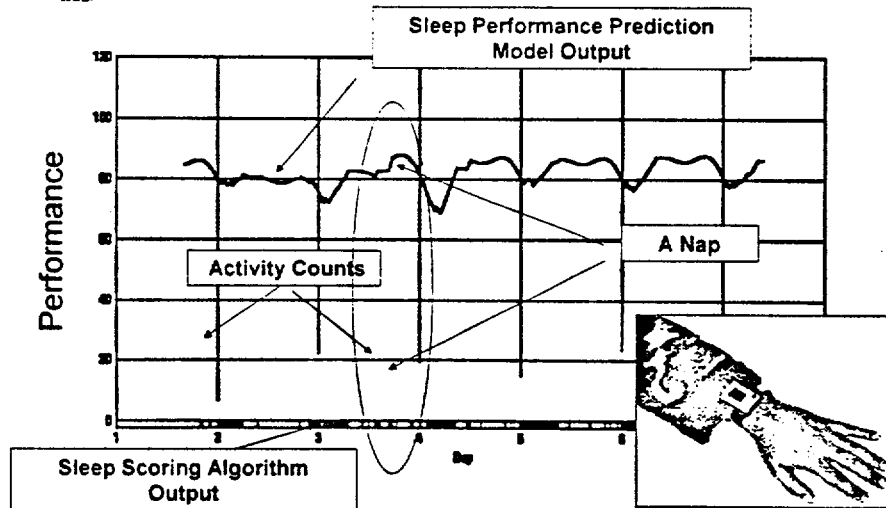


Issues in Modeling

- Current models are simple one-quantity reservoir models
 - A single quantity depleting
 - The same quantity replenishing
 - Typically different functions govern depletion and replenishment
- Simple reservoir models cannot account for the effects of sleep deprivation and sleep restriction on performance
- The performance effects and neurobiology are distinct for surge vs. sustained operations
 - Surge operations (equate to acute, severe/total sleep deprivation)
 - Sustained operations (equate to chronic sleep restriction)

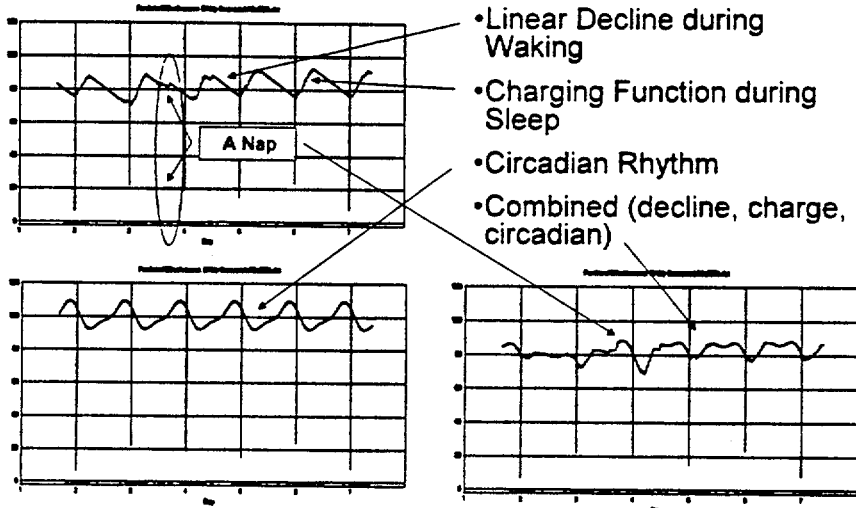


Sensors, Circuits, and Software Models in Real-World Application: The Sleep Watch





Sleep Performance Model Based on Leading Facts from Sleep Research



- Linear Decline during Waking
- Charging Function during Sleep
- Circadian Rhythm
- Combined (decline, charge, circadian)

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31



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32