Evaluation of Techniques for Vigilance Measurements

by

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Abstract

Prior studies have demonstrated a need to find effective countermeasures to operator fatigue and drowsiness in the transportation industry. The objectives of this study were to refine experimental designs and protocols for future phases of the fatigue/alertness project at the Volpe Center and to evaluate some alertness/fatigue monitoring techniques and devices. Techniques and devices tested were the Arithmetic Alerter, the Train Sentry Alerter, Oasis, PVT, FIT2000, and Waypoint. Experiments on human subjects were conducted in the train simulator lab at the Volpe National Transportation Systems Center in Cambridge, MA and subjective as well as objective data was collected and analyzed. The experimental results indicated that the alertness/fatigue monitoring techniques and devices were not effective. However, more experiments on more subjects are needed to support this possible conclusion. This is a preliminary study that serves as a test bed for future studies.

Thesis Supervisor: Dr. Thomas B. Sheridan
Ford Professor of Engineering and Applied Psychology

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1. Introduction

1.1 Background & Motivation

There has been an emergence of interest in the transportation industry in the study of fatigue/drowsiness and its contribution to human error resulting in accidents or near accidents. A near accident is defined as an incident that may have happened due to unintentional errors in human performance that may have resulted in accidents had circumstances been different, e.g. if the error had occurred during rush hour traffic. Unintentional human performance error is the most frequently identified cause of accidents (Dinges, 1995). In aviation, 68% of accidents were attributable to errors performed by the cockpit crew (Dinges 1995). In the USA in 1993, over 25% of all single motor vehicle crashes occurred in which no alcohol was involved (Dinges 1998). Although many factors may contribute to the single-vehicle crashes, there is evidence that fatigue/drowsiness may contribute to more crashes than current estimates show. Studies have shown that operator fatigue may contribute to as many as 41% of truck accidents (Scerbo, 1998) and in 2% to 23% of motor vehicle crashes (Dinges, 1998). Fatigue has also been linked to the grounding of the Exxon Valdez (Scerbo, 1998) and to locomotive accidents.

On September 16, 1998, the Administrator of the Federal Railroad Administration (FRA) stated before the Senate Subcommittee on Surface Transportation and Merchant Marine that "about one-third of train accidents and employee injuries and deaths are caused by human factors. We know fatigue underlies many of them" (National Transportation Safety Board, 1999). There were about 2,500-3,000 train accidents per year from 1988-1994 and thus approximately 833-1000 human factor related accidents per year (Department of Transportation Bureau of Transportation Statistics, 1995). Although the exact number of accidents due to fatigue is difficult to determine, estimates of alertness-related accidents have been made from witness statements and the locomotive operator's behavior and work/sleep schedule prior to the accident.

The relationships between railway accidents and locomotive crew fatigue, shift duration, and circadian rhythms have been documented as early as 1866 (Buck, 1993). However, minimal attempts to address this issue have been made until recently. Therefore, policies are needed that address and work to minimize fatigue/drowsiness in locomotive engineers as well as technologies to detect and counter dangerous levels of fatigue/drowsiness before an accident occurs are needed.

1.2 Prior Research & Technology

The Federal Railroad Administration (FRA) has mandated studies exploring methods and technologies to prevent fatigue/drowsiness-related accidents. Recent efforts in fatigue/drowsiness countermeasures include studies in employee time management, work hours and scheduling, possible federal work regulations, and the development of fatigue/drowsiness detection technologies. Not all efforts are equally effective or acceptable to all interested parties: the government, industry, labor, public, and science (Dinges, 1995). The scope of this study is on the detection technologies, so perspectives on the different efforts will not be presented here. Instead, the discussion will focus on technologies aimed at detecting, predicting, managing or preventing fatigue/drowsiness.

The concept of keeping locomotive engineers awake and alert by countering fatigue/drowsiness has existed since the early days of the railroad industry. Initial countermeasure devices were of the "deadman" variety. For example, deadman's pedal required a locomotive engineer to apply constant foot pressure to a heavy pedal. Otherwise, the train would come to an emergency stop. The reasoning was that as long as the pedal was being pushed, the locomotive engineer must be awake or at least "not dead". There were many shortcomings to the deadman devices because they required locomotive engineers to maintain tiring static muscular contractions and could be easily circumvented (Buck, 1993). For example some locomotive engineers placed a heavy object such as some bricks on the deadman pedal rather than their foot.

The next line of devices aimed at keeping the locomotive engineers alert , "train alerters", require the locomotive engineer to push a button or toggle a lever when an intermittent light and sound alarm comes on. The alarm must be reset in a certain time period by pushing the button, using the train controls, or touching window frames; otherwise a penalty breaking or emergency stop will occur. This is the standard variety of alerter devices currently used in North American trains. Some locomotive engineers may be able to reset the alarm almost reflexively while in a hazardous state of awareness. Spouses of locomotive engineers have reported seeing the locomotive engineers make arm and hand movements to reset an "alerter" while in bed asleep. Although forms of these alerter devices have been in use for decades, there have been no studies that show that the alerters, themselves, make the locomotive engineer more alert.

Only in the past decade has there been considerable efforts to develop new technologies aimed at preventing fatigue/drowsiness related accidents. The technologies being developed can belong to one or more of four generic classes (Dinges, 1998). Because technological development is on going, there may be more than four classes, but only four will be discussed in this section.

1.2.1 Fitness-for-Duty Technologies

Fitness-for-duty technologies claim to provide some predictive behavioral or biological estimate, relative to the person's baseline or a group norm, of his capability for performing work. They give a prediction of a person's functional capability at the beginning of a work cycle. Many of theses technologies are aptitude and language-skill sensitive and have high learning curves, which makes them less ideal for use in a diverse population (Dinges, 1998). There are some biologically based technologies such as "FIT" by PMI, Inc. and "Pupilscan" by Fairville Medical Optics, Inc. (Dinges, 1998). Some of these devices have been used in industry as replacements for urine screens for drugs and alcohol and have been validated as effective predictors of drug and alcohol use. Manufacturers of these devices hope to expand the use to fatigue/alertness predictions. Many of these devices have not been validated to be sensitive to fatigue.

1.2.2 Mathematical Models of Alertness & Ambulatory Technologies

This class involves the development and application of mathematical models that predict a subject's alertness and performance at different times based on interactions of biological indicators of fatigue/drowsiness such as sleep, circadian rhythm and body temperature (Dinges, 1998). Companies developing these models seek to use their models on the biological sources of fatigue to predict performance capability and fatigue/drowsiness occurrences over a period of time. Samples of devices based on this approach are the Actiwatch by Minimitter, Inc. and the Motionlogger Sleepwatch by PMI, which combine mathematical models and wrist actigraphy.

1.2.3 Vehicle-based Performance Technologies

These technologies attempt to measure the behavior of the transportation systems hardware that the person controls. Proponents of this approach hypothesize that vehicle-based performances such as truck lane deviation and steering or speed variability can reflect a person's level of fatigue.

1.2.4 In-vehicle, On-line Technologies Monitoring Operator Status

This class of technologies seeks to record biobehavioral aspects, such as eyelid closure, heartbeat, facial expressions, and brain electrical activity of the person while he is operating the vehicle. This class of devices is the most common and diverse of the fatigue-monitoring approaches (Dinges, 1998). The table below shows examples of devices in this category. The table was adapted from Dinges, 1998.

Table 1 : Examples of biobehavioral measures and devices

Type of Measurement	Examples of Technologies
Video of the face (may include eyelid position, eye blinks, eye movements, pupillary activity, facial tone, direction of gaze, head movements)	• Oasis/Perclos • Ford Motor Co. (UK) & HUSAT Res. Inst. • Nissan Research & Development, Inc. • Toyota • Gaze Control System
Eye Trackers	• Eyegaze Systems by LC Technologies • Eye Tracking System by Applied Science

Wearable Eyelid Monitors	• Alertness Monitor by MTI Research, Inc. • Blinkometer by IM Systems, Inc. • Nightcap by Healthdyne Technologies • Eyelid Activity Measurement • Stay-Awake Eye-Com Biosensor
Head Movement Detector	• Proximity Array Sensing System by Advanced Safety Concepts, Inc.
EEG Algorithms	• Drowsiness Detection by Consolidated Research, Inc. • EEG Algorithm adjusted by CTT • EEG Spectral Analysis • Quantitative EEG Analysis
ECG Algorithms	• MAP Process by PALS Technology
EMG Algorithms (myo-motor sensing)	• NOVAlert by Atlas, Inc.
Actigraphs or Ambulatory Motion Monitors	• Actiwatch by MiniMitter, Inc. • Motionlogger Sleepwatch
Temperature Sensors	• CorTemp

Video of the face

Video of the face involves recording images of the face, which may include eyelid position, eye blinks, eye movements, pupillary activity, facial tone, direction of gaze, and head movements. Some technologies in this category are being developed by Carnegie Melon, Ford Motor Company, Nissan, and Toyota.

One type of measure that seems the most promising in previous studies by the Department of Transportation is PERCLOS. PERCLOS is the percentage of eyelid closure over the pupil over time. In other words, it is the measure of the portion of time the subject's eyes were closed at least some percentage (e.g. 80% eyelid closure) over a one minute period judged by a trained observer. It deals with slow eyelid closures, droops, instead of blinks. OASIS is a device under development that records PERCLOS values. OASIS was tested in this study and will be discussed in more detail in the Chapter 3.

Head Movement Detector

Developers in this category believe there may be head motion patterns that indicate fatigue or drowsiness such as micro-movements of the head that occur prior to nodding off. The Proximity Array Sensing System (PASS), developed by Advanced Safety Concepts, Inc. is a non-contact head-monitoring device. ASC believes that PASS may detect micro-sleeps based on head movement patterns. The head may begin to bob or roll when a person is fatigued and is starting to fall asleep. PASS records the x, y, and z coordinates of the head at electronic rates using three electromagnetic fields. Changes in the x, y, z coordinates of the head may indicate fatigue onset. The system consists of an array of three capacitive sensors that are contained in a foam-core module mounted above the person's head. These sensors create hemispheric sensing fields around a person's head position. The proximity of the head to each sensor is determined and gives a triangulated position of the head. The center of the head is the point of intersection of the three proximities. This center point is tracked over time to determine the patterns of head motion. PASS may be susceptible to electromagnetic interference from radios. Metal objects may also interfere with the field. (Advanced Safety Concepts, 1996)

Eye tracker

The eye tracker system follows and records or tracks the pupil's diameter and point of gaze. The eye tracker from Applied Science Laboratories uses the pupil to corneal reflection technique. It consists of an optics module (includes pupil camera, locating camera, illuminator, mirror), a camera positioned behind the driver's shoulder to provide a video image of the same seen the subject sees, and the eye tracker control unit and computer. A 2-axis servo-tracking mirror is directed by a computer to continually attempt to re-center the pupil image within the pupil camera's field of view. Eye closure is measured to get blink frequency and duration. Another eyetracker working on similar principles is the "Eyegaze Systems" developed by LC Technologies.

Wearable eyelid monitors

Wearable eyelid monitors are monitors that are worn by the subject. Such monitors include the Nightcap, the Alertness Monitor, and the Blinkometer. These monitors may remedy to problem of video of the face technology and eye trackers by continuously monitoring the eye; the later detectors may report false alarms if the eyes or head leave the line of sight of the detectors. However, they may also inconvenience or bother subjects who do not want to wear the monitors. The Nightcap system was created originally for medical use in sleep studies, but developers hope the device might also be effective in identifying drowsiness early enough to alert a driver. The Nightcap is a vigilance monitoring system that is being developed in the Laboratory of Neurophysiology at Harvard Medical School and Healthdyne Technologies. The Nightcap is a two channel recording device that can differentiate wake, REM sleep, and non-REM sleep, and is sensitive to the transition from wakefulness to sleep. One channel monitors eyelid movement and the other monitors body movements, specifically the movements of the head. The movements are recorded in quarter-second or one-minute epochs.

The eyelid sensor records movements in the eyelid that are caused by passive movements of the eyeballs as well as active movements of the eyelid resulting from the contraction of the levator palpebrae muscle. Eyelid movements (ELM) are deformations of the lid which produce voltages in the sensor in excess of 1mV for vigilance monitoring. ELM density decreases as drowsiness onsets. An indication of drowsiness is "the loss of voluntary control over the levator palpebrae muscle and a decrease in tonic activation of the muscle which normally holds the upper eyelid up" (Stickgold,1999).

The eyelid sensor is an adhesive-backed piezoelectric film (2.5 mm X 8mm). It is applied to the upper eyelid and attached to a sensor mount worn on the forehead. The mount is connected to a wallet-sized signal-processing and recording unit. The piezoelectric film has been worn for periods in excess of 10hrs without causing significant discomfort or vision interference. The body movement sensor is a multi-polar cylindrical mercury switch and is mounted on the forehead. It detects rotations of the head. The recorded data is transferred to a Macintosh computer for analysis.

The Alertness Monitor developed by MTI Research, is an eye blink device that is supposed to detect and track fatigue. It measures the ratio of eyelid closure to eyelid open. It is attached to an eyeglass frame. The optical electronics is mounted on the frame in a position such that an emitted infrared beam falls along the axis of the eye blink. The source of the infrared beam is transmitted from an emitter on the nosepiece of the eyeglasses to a sensor. The sensor is located on the arm of the eyeglasses. Care must be taken to minimize the risk that the infrared beam may shine on the subject's eye. The Alertness Monitor glasses must be fitted and calibrated for each subject. The glasses are connected to a PC to allow data collection.

The Blinkometer, developed by IM Systems Inc. is a blink recording device that uses an algorithm that is supposed to be capable of detecting drowsiness/sleep. It consists of a sensor that is placed at the outer canthus of one eye and a small recording device powered by lithium batteries. The sensor has a piezoelectric film that moves with eyelid activity. The Blinkometer has two possible modes: blinks per minute (approximately twenty per minute) or blink-to-blink interval.

EEG Algorithms

Electroencephalographic activity (EEG), recorded from the scalp, is composed of waveforms that can be placed in three main categories, beta, theta, and alpha waves. Each type of wave correlates with the level of arousal. Highly aroused individuals have greater beta activity and lower alpha and theta activity. As arousal decreases, beta activity decreases and alpha activity increases. Further declination in arousal results in alpha activity decrease and theta activity increase. Different EEG algorithms attempt to make this wave correlation with fatigue or drowsiness. The equipment, including electrodes, gel, wires, and monitor, can be messy, difficult to apply, and cumbersome to the driver, and thus make EEG monitoring devices an unlikely technology for in field use. However, research in the development of a reliable, dry electrode is underway.

Myo-Motor Sensors

The NOVAlert is a wrist sensor that is supposed to predict drowsiness and sleep. It is an apparatus developed by Atlas Researches Ltd. in Israel. The sensor can be attached to a wristwatch and can record data in real time with a lag of approximately sixty-four seconds. NOVAlert detects and processes high-resolution myo-motor and vaso-motor wrist signals. It monitors wrist surface EMG signals to detect muscle mass variations.

During the transition from wakefulness to sleep there is decreasing grip muscle activity and an un-tensing of the muscle. NOVAlert tracks the second-by-second variations of the forearm flexor muscles. The wrist sensor also emits a skin vibro-tactile stimulator at fixed or random intervals. The stimulator evokes a grip response, a grip in muscle tone. The quality of the grip response is related to the arousal level of the subject. When the subject is completely awake, the response is a quick and intense increase in grip muscle tone. As the subject becomes drowsy, the grip response becomes lower. The response is given a number according to an index that is computed with respect to a baseline. NOVAlert can also be tested in the non-alerting condition, in which no alerter or vibro-tactile simulator is activated.

Ambulatory Motion Monitor

These devices are supposed to assess mental fatigue by monitoring limb movements. The Actiwatch, made by the MiniMitter Company, is a cordless monitor that resembles the form of a wristwatch and attaches to the wrist. It measures micro-motions and force. The movement of the wrist may indicate sleep occurrences; little to no motion detected during sleep. Actiwatch does not allow evaluation and warning of drowsiness in real time. However it may still be useful in recording the sleep pattern of the subject one week before the in train simulator experiments. Since the amount of sleep a subject has had when she begins the experiment may affect performance, this data may be valuable in comparing experimental data between subjects.

Temperature Monitors

These devices measure internal body temperature over a period of time to record a person's circadian rhythm. Troughs in body temperature over a period of twenty-four hours indicate low points in a person's biological activity level and alertness. There are usually two troughs in a person, one during the early morning hours and one during the late afternoon hours. These devices are not for field tests, but rather are used as baseline data in conjunction with other devices in studies such as this one.

Most of these technologies are in the early stages of development, prototyping and testing. Most are proprietary and haven't been proven in scientific studies to be effective, reliable, practical, or valid. As new technologies are developed, independent studies are needed to ensure their effectiveness, reliability, practicality, and validity.

1.3 Objectives of the FRA

The FRA has contracted the John A. Volpe National Transportation Systems Center in Cambridge, MA to test some of the current technologies that claim to detect fatigue/drowsiness. The objective is to find the most reliable, effective, and practical technology that may be used in the railroad industry, with possible applications in other transportation fields. The project has been divided into six phases.

Table 2: Phases of Volpe Fatigue/Alertness Project

PHASE	DESCRIPTION	# of SUBJECTS to Be Used
Phase I	• Pilot Study • Develop protocols and design • Use Volpe Train Simulator • Collect and analyze initial data to refine future studies	4 Subjects MIT students
Phase II	• Short Pilot Study (Volpe Train Simulator) • Run-through refined design and protocols	1 Subject MIT student
Phase III	• Volpe Employee Study • Data Collection • Use Volpe Train Simulator	30 Subjects Volpe employees

Phase IV	• Locomotive Engineer Study • Data Collection • Use Volpe Train Simulator	# of Subjects to be determined Real locomotive engineers
Phase V	• Locomotive Engineer Study • Data Collection • Use Amtrak Acela Simulator in Delaware	# of Subjects to be determined Real locomotive engineers
Phase VI	• Field Experiments • Data Collection • Test technologies on trains, train stations	# of Subjects to be determined Real locomotive engineers

1.4 Objectives of this Study

This study focuses on Phase I of the project. Phase I is the pilot study stage in which initial experimental designs and protocols are tested on human subjects. The primary objective of Phase I is to refine experimental designs and protocols for future phases of the project. An example of a possible refinement in experimental design is to get a baseline of how long an experimental run on the train simulator is needed to observe fatigue/drowsiness in subjects. The secondary objective is to evaluate the effectiveness of some fatigue/alertness technologies. This is a secondary objective because the small subject pool for this pilot study will not yield enough data with which to conclusively determine the validity of the technologies.

The following are specific questions this pilot study hoped to answer:

1. Is there a difference in human performance on the Arithmetic, Train Sentry, LED, and Speed conformity tasks as the train simulation progressed?
2. Do the measurements from the PVT, FIT2000, and Waypoint devices detect any difference in human performance on the Arithmetic, Train Sentry, LED, and Speed conformity tasks as the train simulation progressed?

3. Is there any difference in human performance between the arithmetic task and the Train Sentry task? If so, can these differences indicate that one task is more effective than the other in keeping subjects awake and alert?
4. Is there a difference in human performance on the Arithmetic, Train Sentry, LED, and Speed conformity tasks between day and night runs?
5. Do the Oasis, FIT2000, PVT, and Waypoint devices detect any differences in human performance between day and night runs?
6. Are there differences in human performance on the Arithmetic, Train Sentry, LED, and Speed conformity tasks between 4hr and 8hr simulator runs?
7. Is the duration of the simulator run (4hr or 8hr) long enough to see degradations in human performance on the Arithmetic, Train Sentry, LED, and Speed conformity tasks?
8. Do any of the Oasis, PVT, FIT2000, and Waypoint devices correlate with each other?
9. Do the measurements from the Oasis, PVT, FIT2000, and Waypoint devices correlate with subjective measures (from subjective rating scales and questionnaires the subjects filled out)?
10. Do any of the subjects' responses to the subjective categories in the subjective ratings questionnaire correlate?

2. Fatigue, Alertness, Vigilance

The discussion of fatigue, alertness and vigilance in this section will lay the basis for some of the choices made in the experimental design and protocol described in the next section.

2.1 Definitions

First, what exactly is fatigue? Most people know it when they experience fatigue, but are not able to define it. I.D. Brown defined fatigue as a "disinclination to continue performing a task because of perceived reductions in efficiency" (Scerbo, 1998). Fatigue is a condition related to the amount of time spent working on a given task, duration of sleep, quality of sleep, shift work, work schedules, circadian rhythms, and time of day (National Transportation Safety Board, 1999).

Drowsiness is a state preceding sleep. Drowsiness and fatigue are not necessarily the same state. Studies have found that fatigue may be related more to time on task and drowsiness may be related to workload (Scerbo, 1998).

Vigilance is a state of readiness to detect infrequent, simple signals over prolonged periods of time (Boff, 1988). Vigilance involves sustained attention. In this study, alertness is used synonymously with vigilance.

2.2 Contributors of Fatigue

External factors such as work schedules and work environment and biological factors contribute to fatigue. Many drivers recognize the problems of fatigue, sleepiness, and inattentiveness. They cite irregular and unpredictable work schedules, especially those involving late night and early morning shifts, and in cab conditions such as noise, vibration, and draftiness as contributors to these symptoms (Buck 1992).

Time of day also contributes to fatigue. Higher levels of fatigue and inattentiveness occur in early morning, approx. 5-6am and mid-afternoon, and approx. 2-3pm. The cycle of work, sleep, and rest around a twenty-four hour period is called the circadian rhythm. There are phases in the 24-hour period where there are decrements in performance ability. Because of the nature of current scheduling policies, many locomotive engineers must work against their normal circadian rhythms. In addition to possibly not getting enough rest prior to an unanticipated work call, some locomotive engineers have to work during low performance periods of their circadian rhythm.

2.3 Vigilance as a Measure of Fatigue/Drowsiness

Fatigue, drowsiness and alertness levels are difficult to measure because there are no known chemical or physical tests to identify them as there are for identifying alcohol or drug presence. How then, are the various "fatigue/drowsiness-monitoring" devices described in the previous chapter to be tested?

Studies have shown that the ability to be vigilant and to react quickly degrade as fatigue and drowsiness increase (Dinges, 1992). Deficits in performance on vigilance tasks include performance lapses, increased periods of non-responding or delay in responding, and increased reaction times. Therefore, we may be able to indirectly measure a subject's level of fatigue or drowsiness by measuring their performance on vigilance tasks.

2.4 Locomotive Engineer Task Likened to Vigilance Task

Vigilance tasks are characterized by the following conditions:

- Subject has to exercise continuous vigilance over an extended period of time.
- Signals to be detected occur at irregular intervals and without advance warning
- Signals are of low intensity
- Frequency of critical events, which are unexpected events or emergency situations, is low with a maximum of 60 critical stimuli per hour. (Schuhfried, 1996)

The overall task of the locomotive engineer is to maintain the train speed within a range corresponding to restrictions of each track segment at the correct position. The locomotive engineer must also respond to unexpected tasks or emergency situations. Locomotive engineers may fail this task by forgetting temporary speed restrictions, missing or misinterpreting track signals, forgetting the presence of maintenance of way workers, and having to make emergency break applications or actions (Lamonde, 1992). Thus, operating a locomotive may be likened to a vigilance task.

3. Experiment

The focus of this study was to refine experimental designs and protocols for future phases of the project and to evaluate some fatigue/alertness monitoring devices.

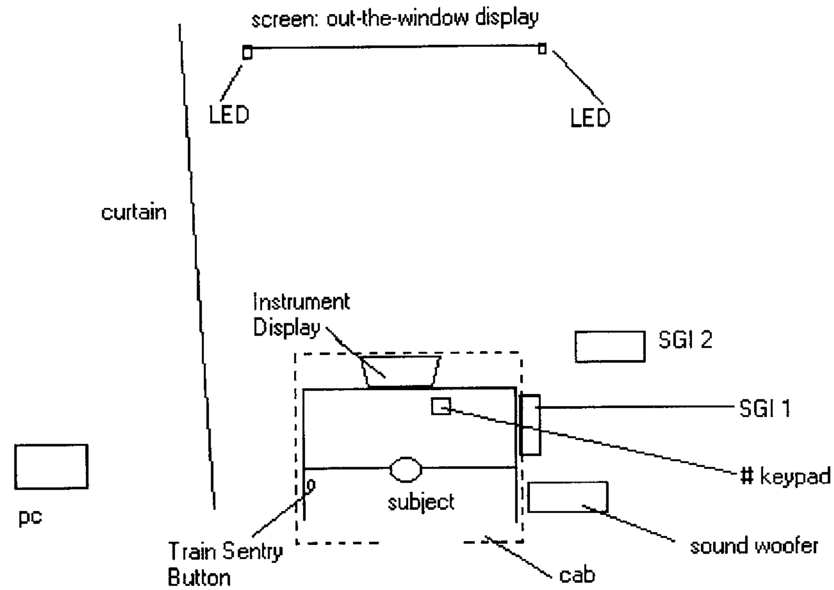
3.1 Apparatus

The experiment took place at the Volpe National Transportation Systems Center in Cambridge, MA. The equipment used can be divided into two categories, train simulator equipment and fatigue/alertness monitoring devices.

3.1.1 Volpe Train Simulator

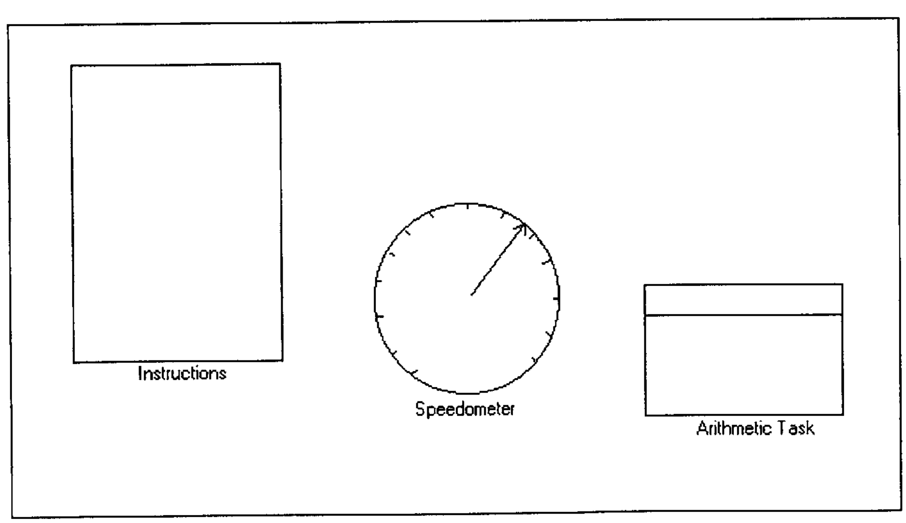
The High Speed Train Simulator at the Volpe Center was modified to allow for fatigue/alertness testing. The cab was stripped of its console control boxes and throttle. A joystick, which allowed static one-push input, replaced the throttle to avoid learning curve effects, which would result from training non-locomotive engineer subjects to control vehicle dynamics with the throttle. A numeric keypad was used for the subject to input arithmetic answers and to press the <ENTER> key to start the simulation. The simulator consists of two Silicon Graphics Indigo2 computers (SGIs), a Barco Projector, a 6ft X 8ft projector screen, a PC, and a sound woofer. The Projector screen showed the out-the-window view (OTW). One of the SGIs showed the instrument panel. The PC generated train sound. A drop cloth blocked the rest of the room from the subject's view. The simulator setup is shown below.

Figure 1: Train Simulator System Setup



The simulator instrument panel was stripped of all gauges and dials, except for the speedometer and arithmetic task box. An instruction box appeared at the beginning of the simulation and at the end of breaks. The OTW showed a night display because of the outdated graphics capabilities. The night view also decreases the number of possible stimuli for the subject and aid in getting the subject fatigued and drowsy. The figure below shows the instrument panel .

Figure 2: Train Simulator Instrument Panel



3.1.2 Devices Tested

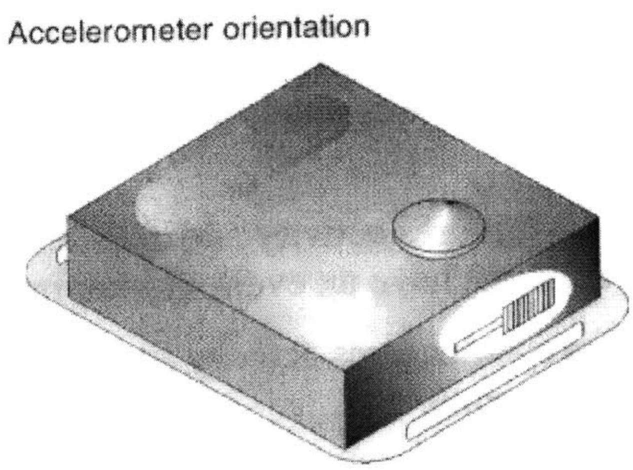
The devices tested in this study were the FIT2000, Waypoint, OASIS, Actiwatch, Motionlogger Sleepwatch, NOVAlert, CorTemp, PVT, Train Sentry Alerter, and the Arithmetic Alerter. The Actiwatch and Motionlogger Sleepwatch were used for baseline data collection during the baseline phase of this experiment. The PVT, FIT2000, and Waypoint were tested during the baseline phase and the breaks between the train simulator sessions. OASIS, CorTemp, and NOVAlert collected data on the subject while he was in the train simulator cab. The Train Sentry Alerter and Arithmetic Alerter were also used during the simulation. The devices are described below.

Devices tested during baseline data collection

Actiwatch-AW64

The Actiwatch is an activity monitor designed for long term monitoring of gross motor activity in human subjects. It contains an accelerometer that is capable of sensing any motion with a minimal resultant force of 0.01g. The MiniMitter Company, which developed the Actiwatch, has created an algorithm to analyze sleep/wake cycles according to data stored in the watch. The watch can store several days of data. (See figure below.)

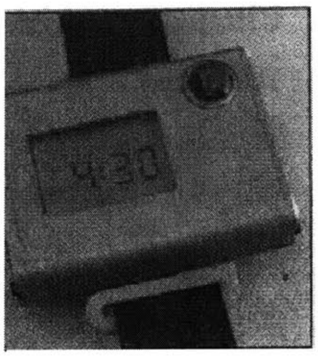
Figure 3: Actiwatch-AW64



Motionlogger Actigraph Sleepwatch-S Model

The Sleepwatch is also an activity monitor designed for long term monitoring of gross motor activity in human subjects. The Sleepwatch utilizes a precision piezoelectric bimorph-ceramic cantilevered beam, which generates a voltage each time the Actigraph is moved. The voltage is passed to the analog circuitry where the original signal is amplified and filtered. The Sleepwatch scores sleep using an algorithm called the Cole-Kripke algorithm. It also keeps track of the amount and duration of light the watch is exposed to. The Sleepwatch also has a time display on its face of the local time.

Figure 4: Motionlogger Actigraph Sleepwatch-S Model

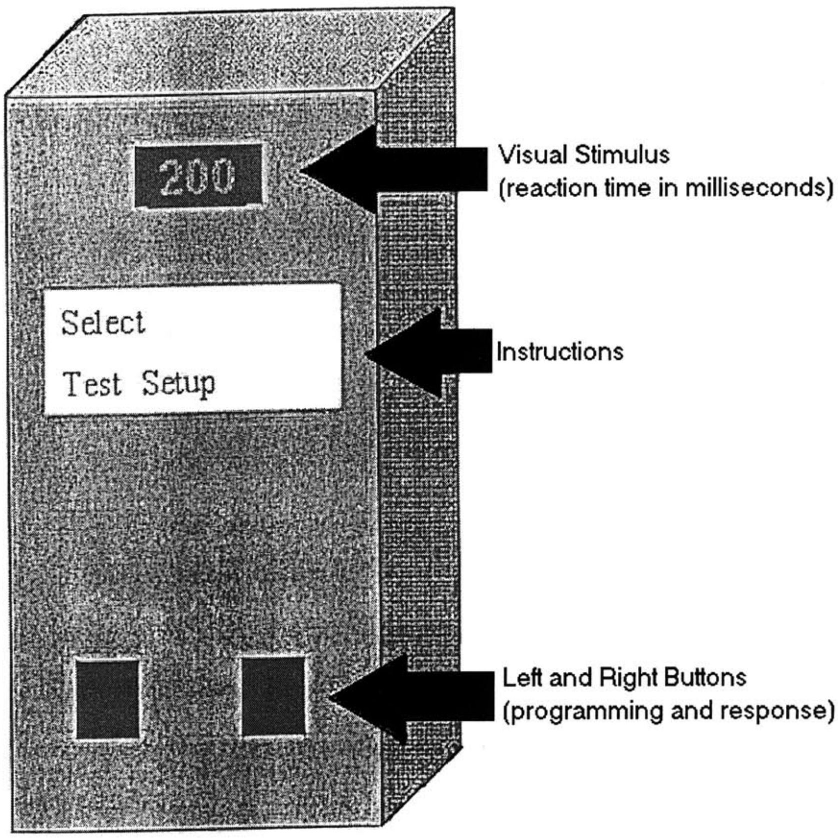


Devices tested during baseline data collection and simulator session breaks

PVT

The PVT-192 is a computerized test-presentation and data capture system to measure a subject's reaction time to stimuli. Human reaction time (RT) is used as an index of motor performance. The figure below is a picture of a PVT-192 unit. The unit has two push buttons, one on the Right and one on the Left, and two displays. The smaller display is a 4-digit LED numeric display. A series of numbers used to test a subject's reaction time and his performance feedback will show in this display. The larger display, labeled "Instructions" in the figure below, is a 16 character LCD alphanumeric display. The larger display is used for programming the PVT. The subject's task is to push the left or right button with his dominant finger or hand as quickly as possible when he sees numbers in the "Visual Stimulus" display. The numbers represent milliseconds passed until the subject pushes a button. The subject must push the button that corresponds to his dominant hand. For example, if the subject is right-handed, he must push the right button.

Figure 5: PVT



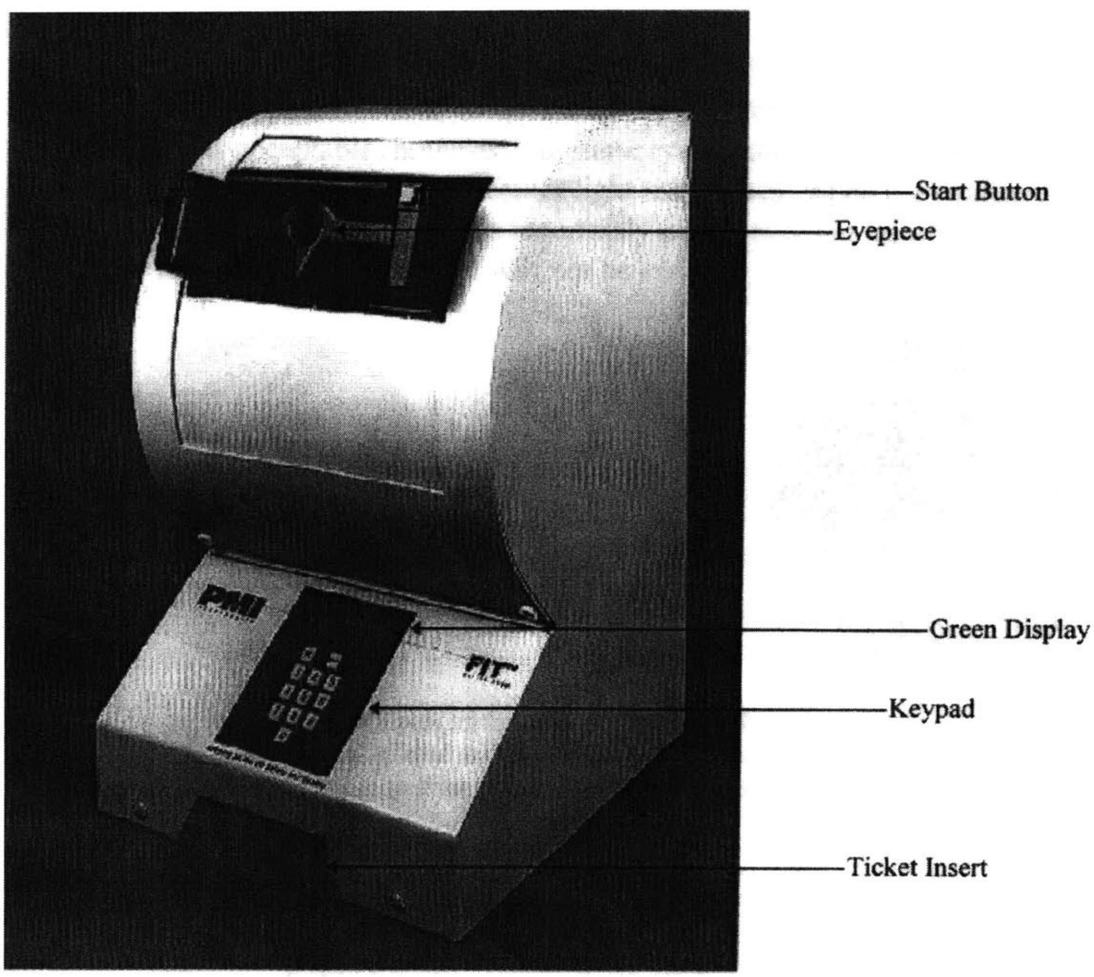
Waypoint

Waypoint is a computerized test presentation and data collection system that tests a subject's awareness of important events, such as events seen while driving. The goal of Waypoint is to predict how safe a driver a person is by computing a high-risk odds ratio for his performance on the test. Simple instructions on the computer screen guide the subject through the test. The task is to touch letters and numbers in order, a number first followed by a letter. The number and letter buttons will be scrambled on the screen and you are to touch them according to the following sequence: 1 – A – 2 – B – 3 – C – 4 – D – 5 – E, etc. The subject should do this as quickly as possible without making a mistake. Once the test is completed, a message will appear that tells the subject what his high-risk odds ratio is. The lower the high risks odds ratio, the safer a driver he is predicted to be. The odds ratio is calculated according to a proprietary algorithm that was unavailable at the time of this report.

FIT2000

The FIT 2000 is a test that claims to reduce the risk of human error and accidents in the workplace by screening for the current effects of factors that may cause a person to be at "high risk". FIT2000 defines "High risk" as the active presence of a factor(s) that will cause a person's motor skills, decision-making ability or alertness to decrease. The main testing unit of FIT2000 is the Screener. (See figure below.) The screener looks like an eye-examining machine often used in the optometrist's office. The FIT2000 takes eye measurements such as pupil diameter and saccadic velocity.

Figure 6: FIT2000 Screener



Devices tested during the train simulation

Train Sentry Alerter

The Train Sentry III is an electronic device designed and currently widely used to monitor the alertness of the locomotive engineer. It belongs to a class of standard alerter devices used in North American trains. After a predetermined period of time, the system requests acknowledgement by the means of visual and auditory alarms. First, the light on the alerter response button will illuminate. If the subject does not respond to this light, the auditory alarm will start and another set of lights in the front corner of the train cabin will flash red. To respond to the alarms, the subject must press the response button. Once the subject responds, the alarms will stop and reset themselves. In a real locomotive, failure to respond to the alarms results in the system de-energizing a magnet valve in the locomotive brake system. This results in a power-down sequence, which will bring the locomotive to a safe and complete stop. If subjects don't respond to the alarms during the simulation, the simulation will go into an emergency pause state.

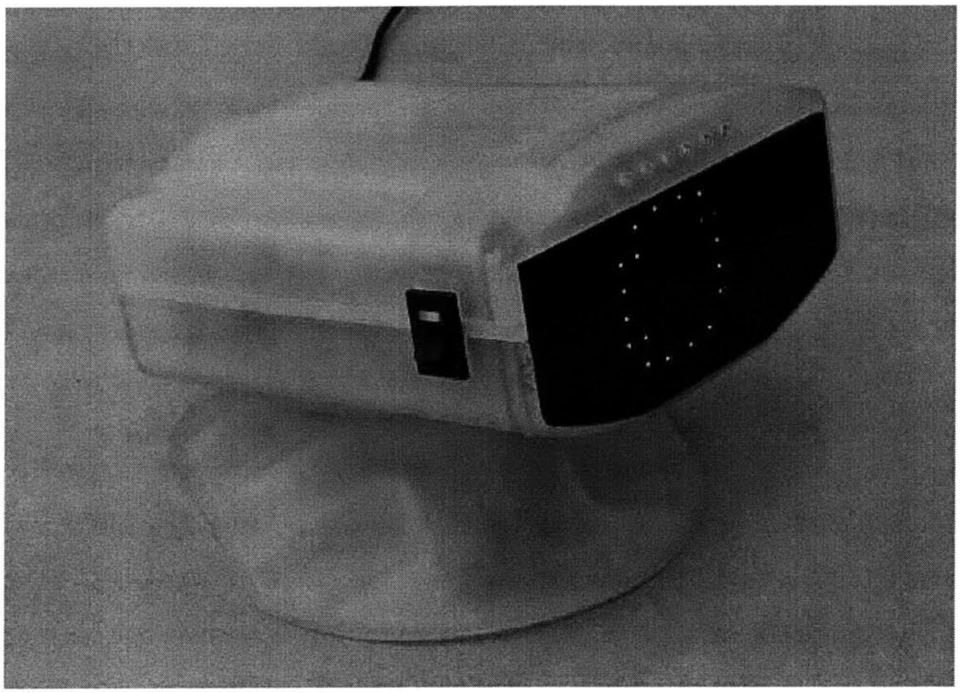
Arithmetic Alerter

The Arithmetic Alerter is currently being developed and works in conjunction with the Train Sentry Alerter. The arithmetic alerter imposes a cognitive task, a simple addition or subtraction problem, in addition to the sequence of alarm events imposed by the Train Sentry Alerter. When the alerter first starts, an addition or subtraction problem will appear on the instrument panel. The subject should enter the correct answer to the problem on a numeric keypad. The subject should just press the number once. If the answer is correct, the problem will disappear and the alarms will turn off and reset. If the answer was incorrect, the problem will remain on the instrument panel until you enter the correct answer. If subjects do not enter the correct answer in a predetermined time, the auditory alarm will start and the lights in the upper corner of the cab will start flashing red. Again, if subjects do not respond to these alarms during the simulation, the simulation will go into an emergency pause state.

OASIS/Copilot

The Copilot is a device that claims to automatically track and detect fatigue from eye position and eyelid closure (PERCLOS). PERCLOS is the percentage of eyelid closure over the pupil over time. In other words, it is the measure of the portion of time the subject's eyes were closed at least some percentage (e.g. 80% eyelid closure) over a one-minute period. The measurements involve slow eyelid closures and droops, rather than blinks. The monitor takes two simultaneous images of the driver at two wavelengths of light. The monitor then measures the reflection of light from the eyes to determine eye position and eyelid closure.

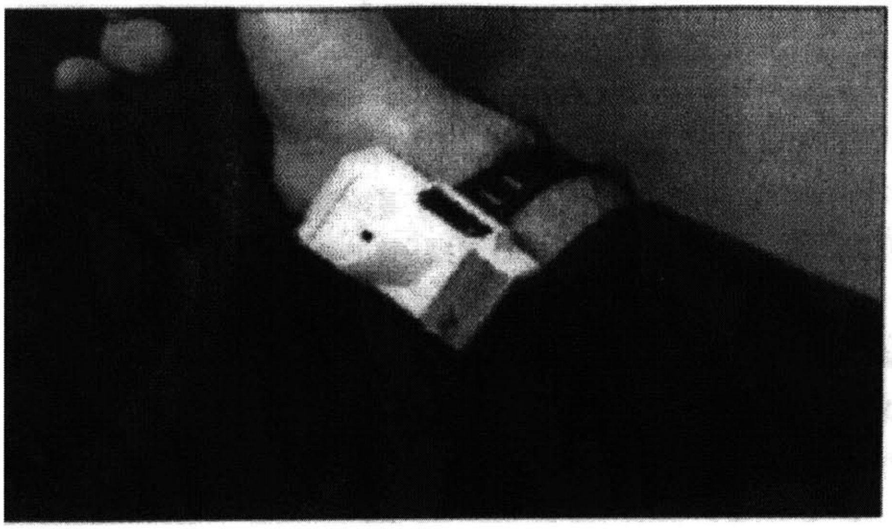
Figure 7: OASIS



NOVAlert

NOVAlert is a wrist-worn sensor/monitor/transmitter for broad monitoring and alerting tasks. Atlas Interactive Technologies, the company which developed NOVAlert claims that the device identifies signs of performance decrement, memory impairment, distorted perception, inattention, drowsiness and increasing propensity of impending sleep by recording and analyzing micro muscle activity.

Figure 8: NOVAlert



During the simulation, the subject wore the NOVAlert wrist unit on his dominant wrist and thumb while operating the train simulator.

CorTemp

CorTemp is a wireless core body temperature monitoring system. It is a clinical electronic thermometer system that records temperature measurements of the internal body. The CorTemp consists of the CorTemp Temperature Sensor pill and the CorTemp2000 (CT2000) Ambulatory Receiver. The CorTemp Temperature Sensor pill takes internal body temperature readings at specified intervals and transmits those readings to the CT2000 Ambulatory Receiver. The first figure below shows the CT2000 Ambulatory Receiver. The Receiver is battery-powered. The next figure shows the CorTemp sensor pill to scale.

Figure 9: CorTemp CT2000 Ambulatory Receiver

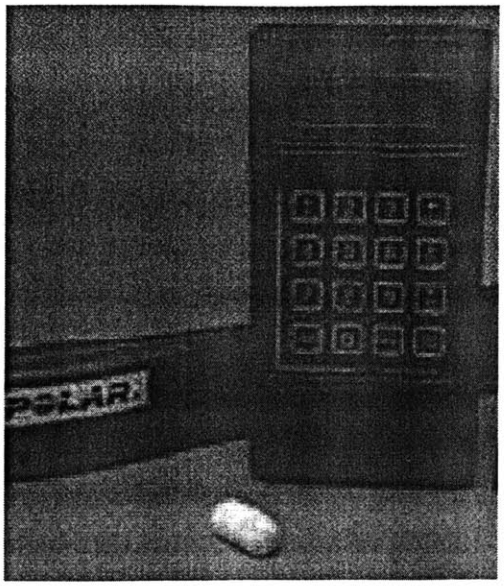
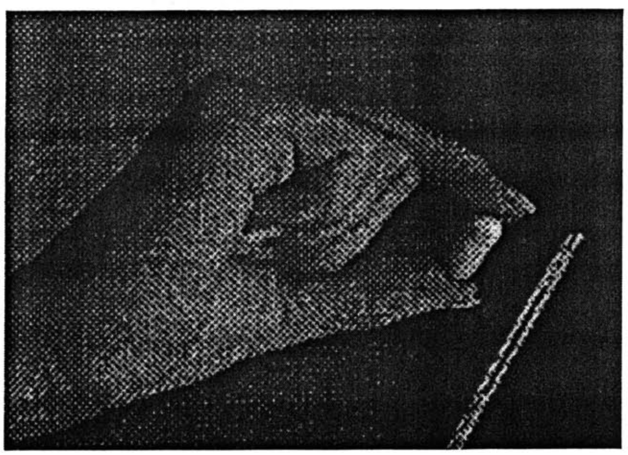
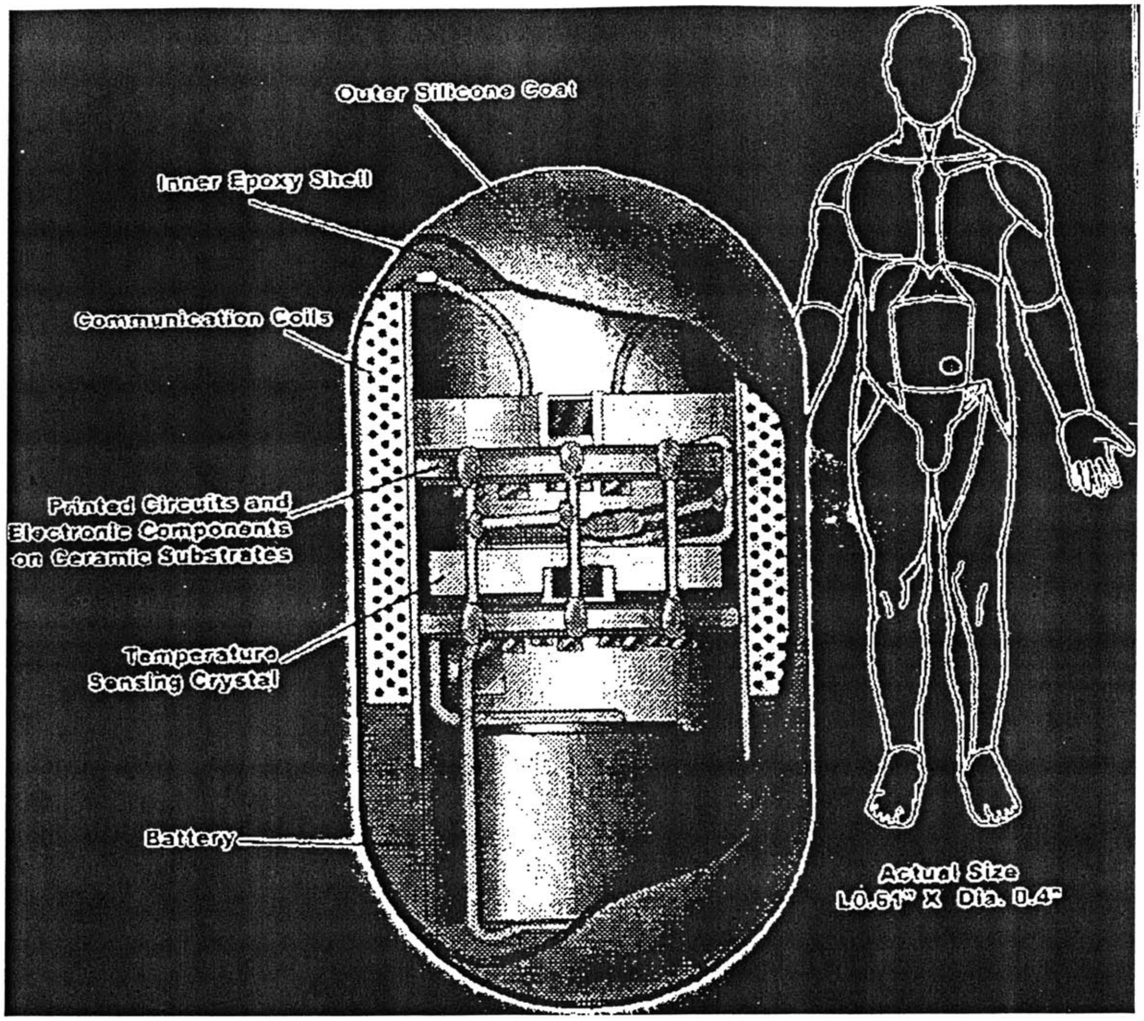


Figure 10: CorTemp Pill to Scale



The CorTemp Sensor pill is powered by a non-rechargeable Silver-Oxide battery and is encapsulated in epoxy resin, which is then coated with silicone rubber. The Sensor utilizes a temperature sensitive crystal, which vibrates in direct proportion of the temperature of the substance surrounding it. This vibration creates an electromagnetic flux, which transmits harmlessly through the surrounding substance. A diagram of the interior of a CorTemp Sensor pill is shown below. The CT2000 Receiver receives this signal and translates it to digital temperature information, which is displayed on the unit and stored to memory.

Figure 11: Interior of a CorTemp Pill



Before each run on the 4hr or 8hr train simulation, the subject was given the CorTemp Sensor pill to swallow. The subject was also given a waist pouch or belt to carry the CT2000 Receiver unit. The CorTemp Sensor pill is disposable and passes through the subject's system according to his metabolism. The CorTemp Sensor pill has been proven to be safe and has been approved by the FDA.

3.2 Experimental Design

The experiment can be divided into two parts, the baseline data collection and the simulator runs. Baseline data were collected to get the measurements of the subject under "normal" conditions. More detail on the baseline data phase will be discussed in the Experimental Protocol section.

The simulator part of the experiment was designed to create an environment that would foster fatigue and drowsiness in subjects during the simulation. The lights of the simulator room were turned off and minimal lighting came from a small light to illuminate the numeric keypad. A rumbling train sound that was approximately 80dB continuously filled the room.

Subjects had to participate in two 4-hour simulator runs or two 8-hour simulator runs. Previous studies show that fatigue and diminishing alertness increases in the early morning hours and mid-afternoon, corresponding to the human circadian rhythm. Thus, each subject worked on a night run and day run on the simulator. The runs consisted of 110-minute simulator sessions followed by a 10-20minute break. The 4-hour simulator run had two sessions and one break, and the 8-hour simulator run had four sessions and three breaks. During the 110-minute simulator session, OASIS, NOVAlert, and CorTemp collected data while the subject completed three types of tasks on the simulator: alerter, LED, and speed conformity. During the breaks, subjects were given a battery of tests, which included tests on the PVT, FIT2000, Waypoint, and a subjective rating questionnaire.

3.2.1 Train Simulator Tasks

Subjects had to complete three different types of tasks during each 110-minute simulator session. session. They were the alerter task (a standard alerter or the arithmetic alerter), the LED response task, and the speed conformity task. Although the Train Sentry Alerter and Arithmetic Alerter are devices, they do not collect their own data. The train simulation was programmed to record response times to these two alerters. The alerters also served a role as a train task since one of the tasks of real locomotive engineers is to respond to an alerter button. Thus, while we are testing the Train Sentry and Arithmetic Alerter, we are also imposing a task on the subject during the simulation. The Speed conformity and LED tasks, on the other hand, serve solely as tasks. The tasks required during the train simulation are described below.

Train Sentry Alerter Task

The subject had to respond to a lighted button followed by sound alarms and flashing lights. The actual mechanical device was described in more detail in the previous section.

Arithmetic Alerter

The arithmetic alerter imposed a cognitive task, a simple addition or subtraction problem, in addition to the sequence of alarm events imposed by the Train Sentry Alerter. This task was described in more detail in the previous section.

LED Task

The LED task was a split attention task to ensure that the subject looked up, outside the train cab. Red and green LEDs were set alongside the out-the-window view of the simulator (the projector screen). If a red LED illuminated, the subject had to pull the joystick. If a green LED illuminated, the subject had to push the joystick.

The subjects were told that the LED task was actually a cruise control task. The following is what the subjects were told:

"This is a new technology for this industry, but one that still remains under development. Volpe is trying to expedite the development in addition to testing the aforementioned alerter technologies. During the simulation, you will be asked to monitor locomotive speed and to make corrections if it falls outside the acceptable range. If the speed too high, you will pull the speed control joystick towards your body to decrease the speed. If the speed is too low, you will push the joystick forward, away from your body to increase the speed. You will also be asked from time to time to make corrective movements based on LED output. Red and green LEDs are provided alongside the out-the-window view of the simulator (the projector screen). When the speed control algorithm detects a fault between internal speed values and speed values displayed on the speedometer, it will light up a red LED for you to slow the train down, or a green LED for you to increase speed. Again to decrease speed, you will pull the speed joystick towards your body, and to increase speed, you will push the speed joystick away from your body."

The subjects were told the truth about the LED task in the debriefing session at the end of the experiment.

Speed Conformity

The speed conformity task was a vigilance task. The subject had to maintain the vehicle speed within an allowed range (between 60mph and 70mph) by pushing a joystick whenever the speed went out of range. If the speed exceeded the allowable range, the subject had to push the joystick towards the slower position. If the speed was below the range, the subject had to push the joystick to the faster position. The speed control was "static" rather than dynamic, i.e. a one-push or one-pull joystick was used instead of a throttle to avoid learning curve problems.

3.2.2 Task Occurrence & Frequency

The tasks occurred at random time intervals but the total number of occurrences of each task remained constant within each 110-minute train simulator session. The table below shows the breakdown of the tasks, their rate of occurrence, and the total number of occurrences per 110-minute train simulator session.

Table 3: Train Simulator Task Frequency in a 110 minute Session

Task	Frequency	Total Tasks in 110 min session	Total Tasks in 4hr (2 sessions)	Total Tasks in 8hr (4 sessions)
Alerter (standard alerter or Arithmetic)	Every 9-13mins	10	20	40
LED	Every 20-25mins	5	10	20
Speed Conformity	Every 20-25mins	5	10	20

3.2.3 Measurements

The following table shows the types of measurements taken for this study. When a device takes more than one type of measurement, the measurement used for analysis is listed.

Table 4: Measurements Taken

DEVICES & TRAIN SIMULATOR TASKS	MEASUREMENT
Fit2000	Saccadic velocity
Waypoint	Odds Ratio
Oasis	Perclos
Actiwatch	Micromovements in the wrist
Motionlogger Sleepwatch	Micromovements in the wrist, light luminance
PVT	Reaction Time
NOVAlert	EMG of the wrist and thumb muscles
CorTemp	Internal Body Temperature
Train Sentry Alerter	Reaction Time, # of Correct, Wrong, and Missed Responses
Arithmetic Alerter	Reaction Time, # of Correct, Wrong, and Missed Responses
LED Task	Reaction Time, # of Correct, Wrong, and Missed Responses
Speed Conformity Task	Reaction Time, # of Correct, Wrong, and Missed Responses
Subjective Rating Questionnaires	Subjective rating scales (mm)

3.3 Procedure

3.3.1 Protocol

The experiment consisted of two parts:

1) Experiment Part I, baseline data collection
2) Experiment Part II, first simulator and second simulator runs.

In Experiment Part I, the subject visited the lab twice prior to the start of the first experimental run. Data were collected from the subject's performance in various psychometric tasks, the subject's sleep-wake logs, and the various vigilance monitoring devices. The subject was asked to wear the Actiwatch and Motionlogger Sleepwatch for five consecutive days and to complete daily sleep/wake logs.

In Experiment Part II, the subject came to the lab for two runs on the train simulation. The length of each run was 4 or 8 hours. One of the simulation runs took place during daytime hours and the other run occurred during the late night/early morning hours. The subject performed simulation-based tasks for 110 minutes at a stretch, followed by time for a brief food and rest break and non-simulation based performance and subjective testing. The second simulator run occurred several days after the initial run. If the first simulator run occurred during the day, the second run occurred a minimum of two days afterwards. If the first simulator run occurred during the night, the second simulator run occurred a minimum of three days afterwards. The differences in minimum days between phases were to ensure the subjects had returned to their normal sleep/wake cycles before completing the second simulator run. Studies have shown that it takes longer for a subject to return to his sleep/wake cycle after staying up during the night than during the day (Buck, 1993). The subject was asked to continue completing the sleep log until the completion of the second simulator run. Below is a general outline of the experimental days comprising Experiment Parts I and II. A more detailed breakdown the N days of an experiment is described in the Appendix.

Table 5: Day-by-Day Experimental Procedure Breakdown

Exp Day	Exp Part	Events	Measurements Taken
1	Part I Intro & Baseline Data Collection	• Subject came to Volpe Center for Introduction • Subject given 6min practice run on the simulator • Subject completed First Set of Baseline Tests • Subject given Actiwatch and Motionlogger Sleepwatch and daily log	• Psychometric testing (digit cancellation task, subjective rating scales) • FIT2000 (5 baseline points) • PVT • Waypoint • Actiwatch & Sleepwatch • Daily log
2	Part I	• Subject continued wearing wrist monitors and filling in daily log forms	• Actiwatch & Sleepwatch • Daily log
3	Part I Second Set of Baseline Data Collection	• Subject came to Volpe for Second Set of Baseline Tests • Subject given 6min practice run on the simulator • Subject brought with them the Actiwatch, Sleepwatch, and completed daily log • Actiwatch, Sleepwatch, and daily log forms were checked to ensure data was being recorded correctly	• Psychometric testing (digit cancellation task, subjective rating scales) • FIT2000 (10 baseline points) • PVT • Waypoint • Actiwatch & Sleepwatch • Daily log
4	Part II	• Subject continued wearing wrist monitors and filling in daily log forms	• Actiwatch & Sleepwatch • Daily log
5	Part II First simulation Run	• Subject came to Volpe for the first 4hr or 8hr Train Simulator run • Subject brought the Actiwatch, Sleepwatch, and the completed daily logs • Subject returns Actiwatch and Sleepwatch • If the simulation run occurred during the night, the subject was given a ride home	• Psychometric testing (digit cancellation task, subjective rating scales) • FIT2000 (5 baseline points, and 2-4 data points) • PVT • Waypoint • Actiwatch & Sleepwatch • Daily log

Exp Day	Exp Part	Events	Measurements Taken
5	Part II First simulation Run		• Train Simulator (Alerter, LED, Speed Conformity) • Oasis • NOVAlert • CorTemp
6 to (N-1)	Part II	• Subject continues filling in daily log forms up to day N.	• Daily log
N	Part II Second simulation Run Part II	• Subject came to Volpe for the second 4hr or 8hr Train Simulator test • Subject brought all his daily log forms • Subject completed a debriefing survey and was debriefed about the study • If the simulation run occurred during the night, the subject was given a ride home	• Psychometric testing (digit cancellation task, subjective rating scales) • FIT2000 (5 baseline points, and 2-4 data points) • PVT • Waypoint • Actiwatch • Daily log • Train Simulator (Alerter, LED, Speed Conformity) • Oasis • NOVAlert • CorTemp • Debriefing forms

3.3.2 Subject Selection

Four subjects were used in the study. They were all students between the ages of nineteen and thirty-one. Subjects were chosen on the basis of four criteria, which were determined from their answers to the preliminary Subject Survey. The Subject Survey can be found in the Appendix. The selection criteria were

1. The subject must not have sleep disorders.
2. The subject must not smoke.

3. The subject must not be overweight. Standard height/weight charts were used to ensure subjects were not obese.

4. The subject must have an acceptable Epworth Sleepiness Score (a score of 9 or less).

The Epworth Sleepiness Test is a paper test in which the subject gives numerically rated responses to questions such as "Do you often fall asleep watching TV?". The ratings are then summed to get the Epworth Sleepiness Score. A score of 9 or higher may indicate that the subject has sleep problems. The Epworth Sleepiness Test can be found on the last page of the Subject Survey in the Appendix.

3.3.3 Subject Training

Subjects were given instruction packets during their introductory meeting. The instruction packet is in Appendix B. During the introduction meeting, the subject was also shown the testing devices and took tests on the FIT2000, PVT, and Waypoint. They were also exposed to the subjective rating tests. The subjects were also given a six-minute practice session on the train simulation during the introductory meeting and the second set of baseline tests (i.e. during Experiment Day 1 and 3). During the train simulator demo, the subject was exposed to the alerter task, arithmetic task, LED task, and speedometer task. The subject was instructed to try to not talk, sing, or fidget during the simulator runs.

3.3.4 Counterbalancing

Factors that needed to be counterbalanced were the order of Day vs. Night runs and the order of the Arithmetic vs. Standard Alerter Task per simulation run. Due to the small number of subjects, the experiment could not counterbalance all possible combinations of conditions. The table below shows the counterbalancing that was done. Subjects were numbered according to the ID # on the Subject Survey they completed in order to maintain their anonymity during the experiments.

Table 6: Counterbalancing for the 4-Hour Simulator Run

	Day	Night
Subject 1	2, A	1, SA
Subject 2	1, A	2, SA

Note: A=Arithmetic Task, SA=StandardAlerter Task

Table 7: Counterbalancing for the 8-Hour Simulator Run

	Day	Night
Subject 3	2, SA	1, A
Subject 4	1, SA	2, A

Note: A=Arithmetic Task, SA=StandardAlerter Task

The elements in the cells represent the order in which the Day or night run took and the type of alerter condition (Standard Alerter or Arithmetic Alerter) used. For example, for Subject 1, the cell containing "2, A" means the subject did the 4hr day run second and that the day run had the Arithmetic condition.

3.3.5 Payment Incentives

Subjects were paid $40 for completing the baseline data collection phase of the experiment. They were paid an additional $100 dollars for completing one 4hr simulation run or an additional $200 for completing one 8hr simulation run. Subjects could also earn bonus money based on their performance on the simulator tasks. The table below shows the payment breakdown.

Table 8: Subject Payment Breakdown

PHASE	4 HOUR CONDITION	8 HOUR CONDITION
I (baseline data)	$40	$40
II (initial simulation)	$100	$200
III (final simulation)	$100	$200
Performance Bonus	Up to $80	Up to $160
Total	$240-$320	$440-$600

To encourage subjects to try to stay awake and alert during the simulation run, subjects were awarded bonus money for correct and timely responses or bonus money was deducted for incorrect responses or for the lack of any response. The breakdown of the bonus system is shown below.

Table 9: Performance Bonus System

Response Type	Alerter/Arithmetic Task	LED Task	Speedometer Task
Correct within 5secs	$1	$1	$1
Correct between 6-20secs*	$0.50	$0.50	$0.50
Correct between 20-30secs	-$0.50	-$0.25	-$0.25
Wrong	-$0.50	-$0.50	-$0.50
No Response	-$0.50	-$0.50	-$0.50

*For the Alerter or Arithmetic Task, subjects receive $0.50 for each correct response between 6-18 seconds. After 18secs, the sound alarm comes on and $0.50 is deducted from the bonus money.

4. Results & Discussion

There were several goals in this study. The primary goal was to run a test bed study to prepare for future phases of the Volpe Study. The secondary goals were to provide preliminary answers the following questions:

1. Is there a noticeable difference in human performance on the Arithmetic, Train Sentry, LED, and Speed conformity tasks between day and night runs?

2. Do the measurements from the PVT, FIT2000, and Waypoint devices correlate with known indicators of fatigue such as response time?

3. Is there any difference in human performance between the arithmetic task and the Train Sentry task? If so, can these differences indicate that one task is more effective than the other in keeping subjects awake and alert?

4. Is there any difference in human performance on the Arithmetic, Train Sentry, LED, and Speed conformity tasks between day and night runs?

5. Do the Oasis, FIT2000, PVT, and Waypoint devices detect any differences in human performance between day and night runs?

6. Is there a difference in human performance on the Arithmetic, Train Sentry, LED, and Speed conformity tasks between 4hr and 8hr simulator runs?

7. Is the duration of the simulator run (4hr or 8hr) long enough to see degradations in human performance on the Arithmetic, Train Sentry, LED, and Speed conformity tasks?

8. Do the measurements from the PVT, FIT2000, and Waypoint correlate with each other?

9. Do the measurements from the devices correlate with subjective measures (from subjective rating scales and questionnaires the subjects filled out)?

10. Do any of the subjects' responses to the subjective categories in the subjective ratings questionnaire correlate?

We were not able to consistently test all the technologies as discussed in the previous chapter for several reasons:

- The NOVAlert device malfunctioned during the third simulator run. The device was used for Subject 13's 4hr night run, Subject 5's 8hr night run, and the first 2hrs of Subject 13's 4hr day run. The wiring of the wrist unit to the recorder unit broke. The wiring connected to the interior of the unit and could not be replaced. It was a prototype unit and removable wiring had not been implemented yet. The unit was then held by Israeli Customs when we tried to send it back to the manufacture in Israel for repair. Except for the first two and a half simulation runs, no other data was collected from the NOVAlert. As a result, NOVAlert was not evaluated in this study.

- The CorTemp also malfunctioned several times. In the first three simulations, the CorTemp did not record due to battery/battery contact-related problems. The problem was fixed, but then the CorTemp stopped working again in the fifth simulation run. The CorTemp was repaired and available for the next three simulations. However, due to the inconsistency in CorTemp data available for each subject and the goal of evaluating the CorTemp's effectiveness, the CorTemp was not evaluated here.

- The Motionlogger Sleepwatch and Actiwatch was used only for baseline data collection and not for the simulation runs. The original plan was to use the Sleepwatch in conjunction with the subject's sleep/wake logs to determine what periods of the day would capture the subject's trough in energy and alertness. The subject's simulation run would then include these periods. The original plan was changed. Instead, the subjects' simulation runs were prescribed. The night runs started at approx. 10pm for all subjects and ended at 2am for 4hr runs and at 6am for 8hr runs. The day runs started at approx. 9am and ended at 1pm for 4hr runs and 5pm for 8hr runs. This was done because some of the Actigraph software was not working at the beginning of the study. Another motivating factor was the complicated protocols for the study. We decided to concentrate on the main protocol as described in the previous chapter and wait until Phase II of the Volpe study to try to match simulation run schedules with the subject's biological clock. Therefore, there are no a detailed analyses of the Actiwatch and Sleepwatch in this report.

- Since this is a pilot study, various subjective tests, which asked the subject to rate his level of alertness, were tested and improved throughout the experiment. As result, there was an inconsistency between the types of subjective tests each subject took. Only the subjective test that was used consistently, the Subjective Rating Scale, was statistically analyzed.

- Irregularities in the data may have been caused by sound cues, clicks, from the Arithmetic and Train Sentry Alerters, the LEDs, and the camera monitoring equipment. The problem with the alerters and LED clicks were fixed after the first 4 experiments. The problem with the camera monitoring equipment could not be fixed. Every time the subject went out of camera range and experimenters had to adjust the camera angle from the proctor room. The camera made clicking sounds each time experimenters had to adjust the camera to the left.

4.1 Objective Results

4.1.1 Question 1: Was there a noticeable difference in human performance on the Arithmetic, Train Sentry, LED, and Speed conformity tasks between day and night runs?

The reaction times to the various train simulator tasks are the metrics we used to evaluate human performance. We expected the reaction times to be longer when the subject was drowsy or less alert. For each subject, the reaction times for each task was graphed over time in the simulation. The tasks occurred randomly but the number of each task in each 110minute session remained constant. There were five LED tasks, five Speed conformity tasks, and ten alerter tasks during each 110minute session. We hoped to observe patterns such as greater reaction times with increasing simulation time in the graphs.

For each subject, there are six graphs:

1) Alerter Task- Day run,
2) LED Task- Day run,
3) Speed Conformity Task- Day run,
4) Alerter Task- Night run,
5) LED Task-Night run, and
6) Speed Conformity Task- Night run.

Some selected graphs from some subjects are shown here. The graphs shown are not representative of or show significant differences from the other graphs. All the graphs can be found in the Appendix.

Figure 12: Arithmetic Task Reaction Time vs. Time, Subject 1, 4hr Day

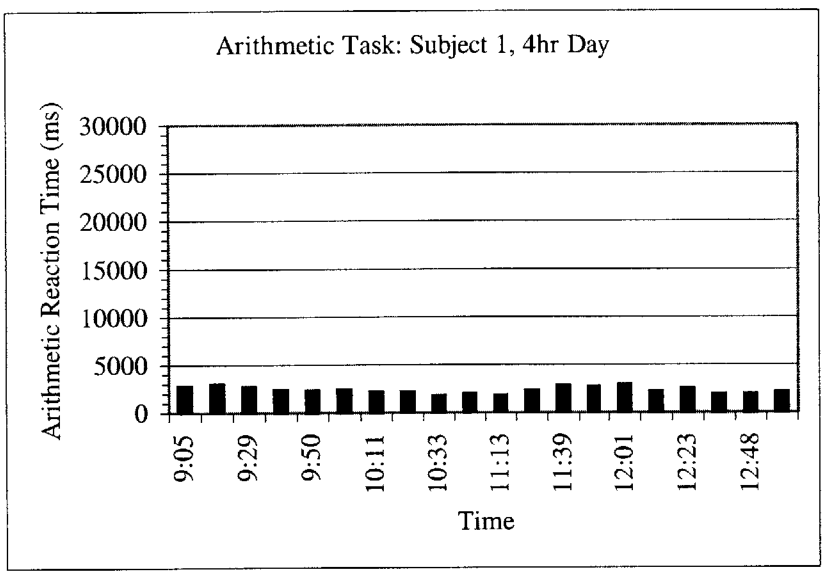


Figure 13: LED Task Reaction Time vs. Time, Subject 13, 4hr Day

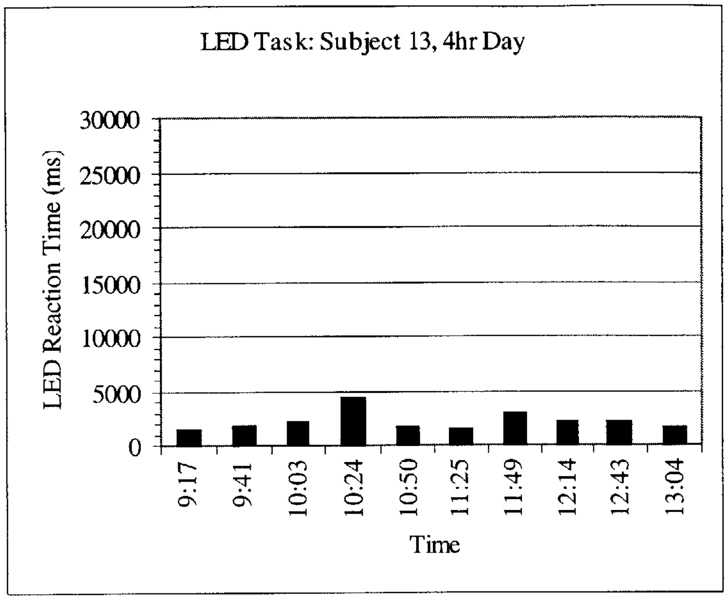


Figure 14: Speed Task Reaction Time vs. Time, Subject 1, 4hr Day

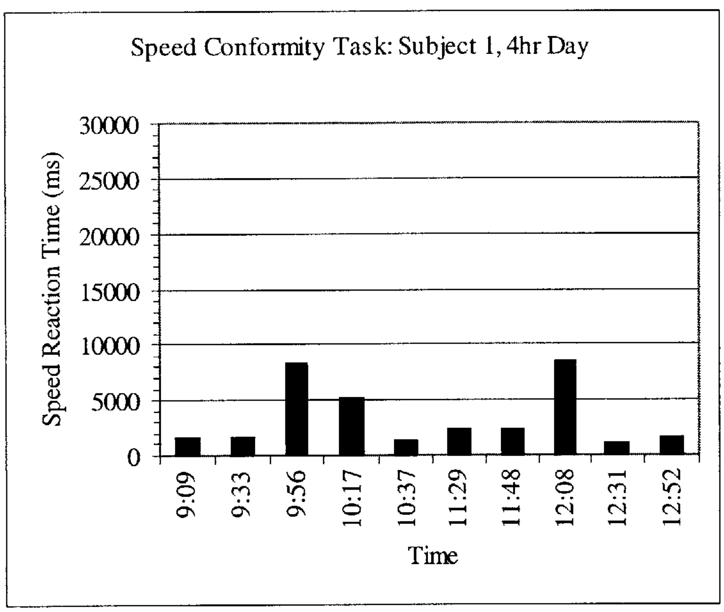


Figure 15: Train Sentry Reaction Time vs. time, Subject 5, 8hr Day

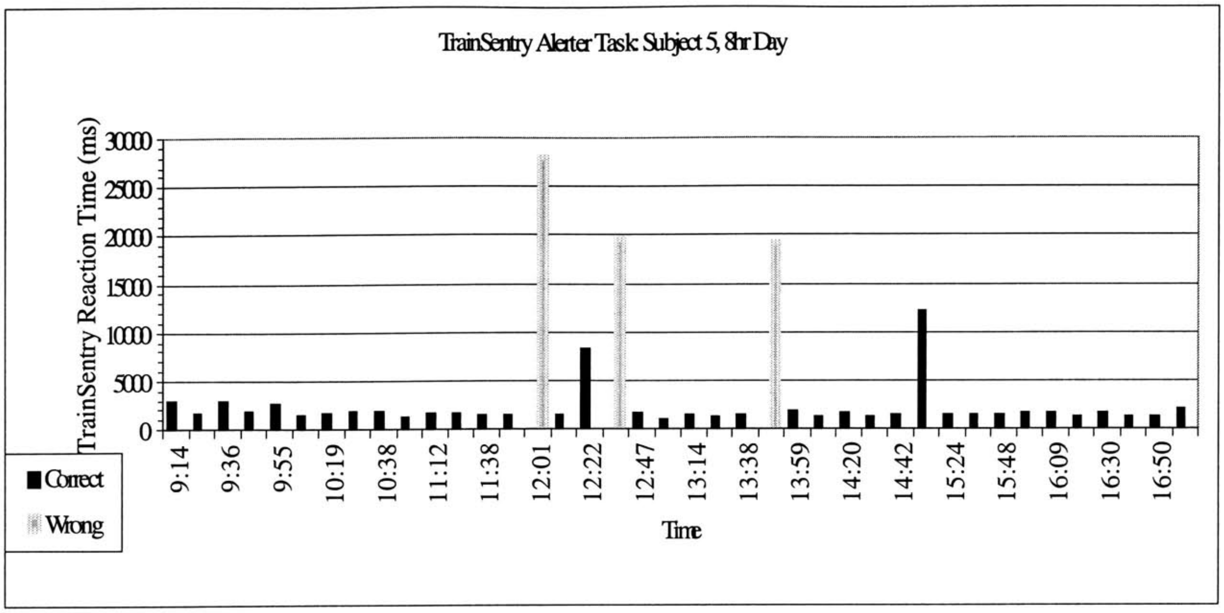


Figure 16: LED Task Reaction Time vs. time, Subject 6, 8hr Day

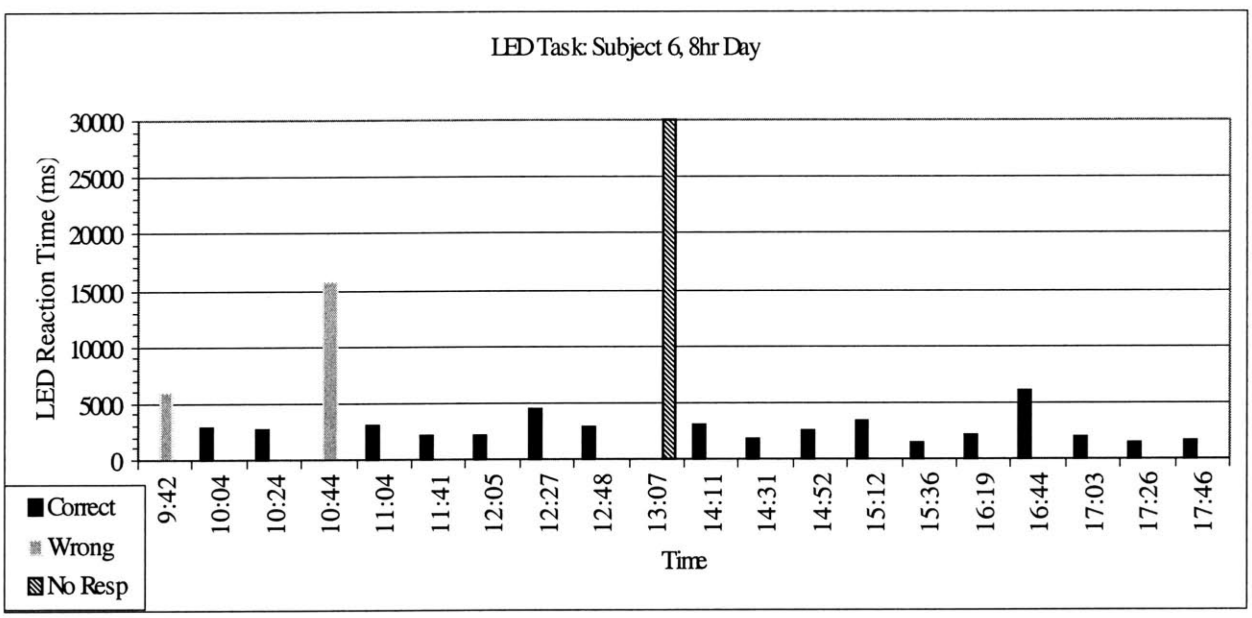
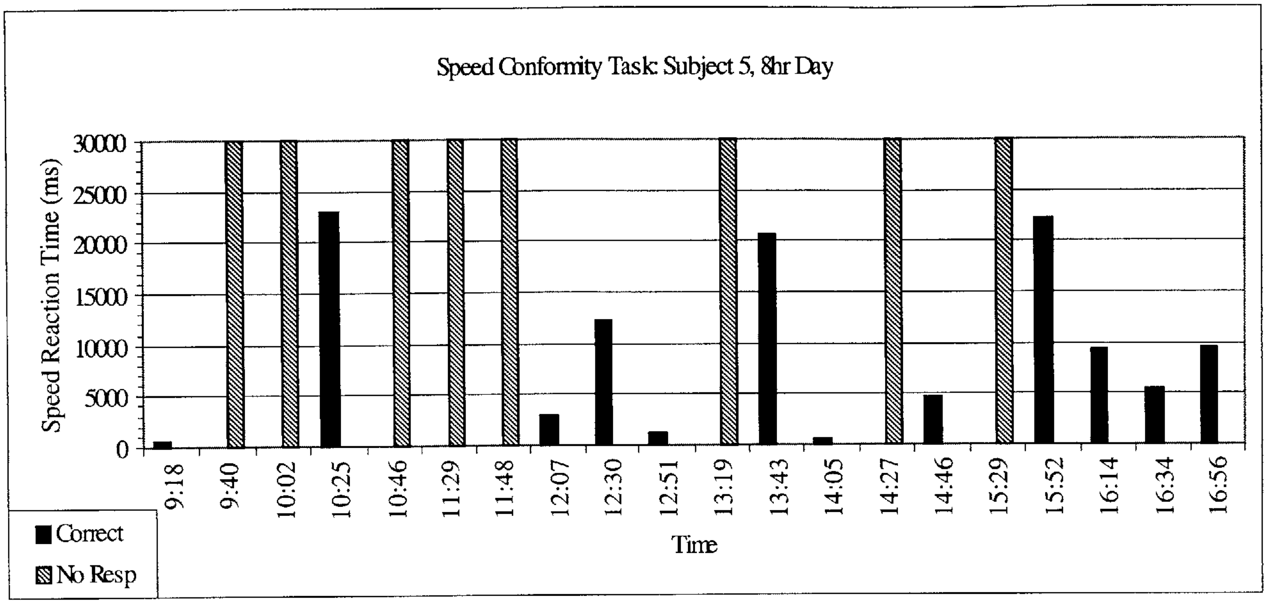


Figure 17: Speed Task Reaction Time vs. time, Subject 5, 8hr Day



In general, the graphs show no observable patterns in reaction times. Graphs with legends indicate that the subject did not respond or had some wrong responses to the task and shows the corresponding reaction time. A long, striped bar that goes up to 30,000 ms is shown on the graph if the subject failed to respond to a task that occurred at that time. Otherwise, the graphs by default show response times for correct answers.

Except for the case of Subject 5, 8hr Day Run, Speed Conformity, there were very few no responses and even fewer wrong responses. Subject 5 fell asleep several times during the day run and missed many speed conformity tasks during the middle of the run. The speed conformity tasks that he missed at the beginning of the run are mainly due to inattention. His eyes were open, but he did not look at the speedometer to see if the speed had gone out of range. This inattention occurred a few times with the other subjects, and usually occurred with the speed conformity task.

The peaks in some reaction times for the LED and Speed Tasks for Subjects 1, 13, and 6 could not be accounted for in the experimental logs taken by proctors during the simulation run. Some of the peaks in reaction times in Subject 5, however could be accounted for. Subject 5 had many episodes of micro sleeps throughout his day run and during the last 4hours of his night run. The experimental logs may not be reliable because there were two proctors and there was no methodology in the way the experimental logs were taken. This issue will be discussed later in this chapter. Video recordings of the simulations must instead be reviewed and a rating scale for the observations must be developed in order to account for the possible peaks in reaction times. This is a step that will be taken in future studies.

The absence of any patterns may be due, in part, to our student subject population. Many of these subjects reported irregular sleep/wake schedules in their sleep logs. Only one Subject 13, kept a close to regular sleep/wake schedule, but no observable patterns in his response times were found. This may be due in part to that fact that he had the 4hr simulation runs, and the 4hr runs may not have been long enough to observe possible fatigue/drowsiness effects in the reaction times. Each Subject's specific sleep/wake times during experiment are tabulated in the Appendix.

4.1.2 Question 2: Do the measurements from the OASIS, PVT, FIT2000, and Waypoint devices detect any difference in human performance on the Arithmetic, Train Sentry, LED, and Speed conformity tasks as the train simulation progressed?

The relevant devices we tested were the OASIS, FIT2000, Waypoint, and PVT. OASIS collected continuous data while the other three devices collected discrete data.

Continuous Data: OASIS

The OASIS device records Perclos values, which are measurements of the percentage of eye-lid closure in a one-minute period. The more tired or drowsy a person is, the more his eyes would be closed or drooping and the higher the Perclos values would be.

The following graphs show the Perclos values for each minute of the simulation run for each subject. Oasis collected data throughout the simulation run, even during the breaks. The values of Perclos were set at 100 for all data points within the break period. The clusters of Perclos values of 100 in the graph represent break periods and were ignored in the data analysis. Sample data sets are shown. Graphs for all the subjects are in the Appendix.

Figure 18: Perclos Graph for Subject 1 (4hr Day)

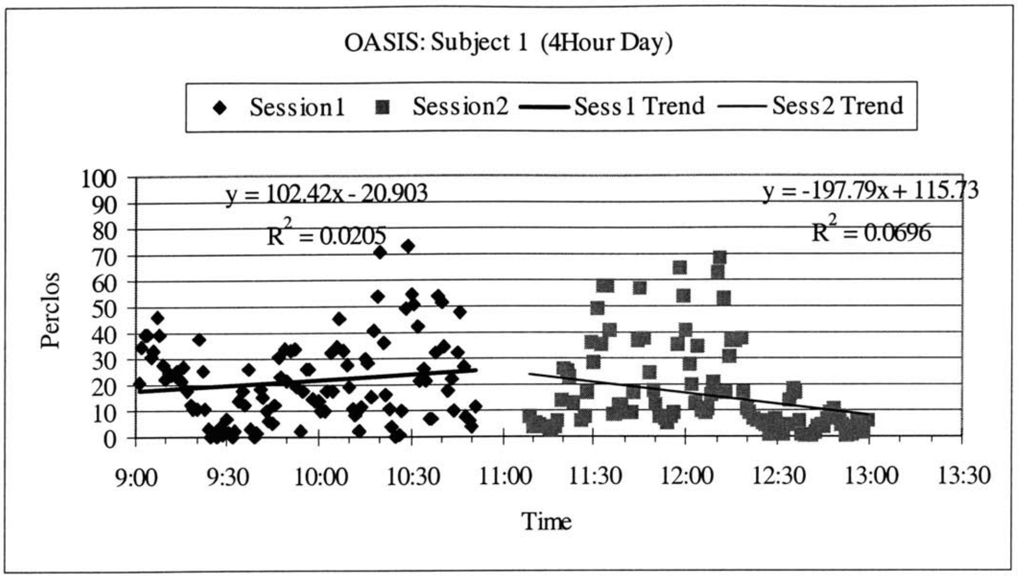


Figure 19: Perclos Graph for Subject 1 (4Hr Night)

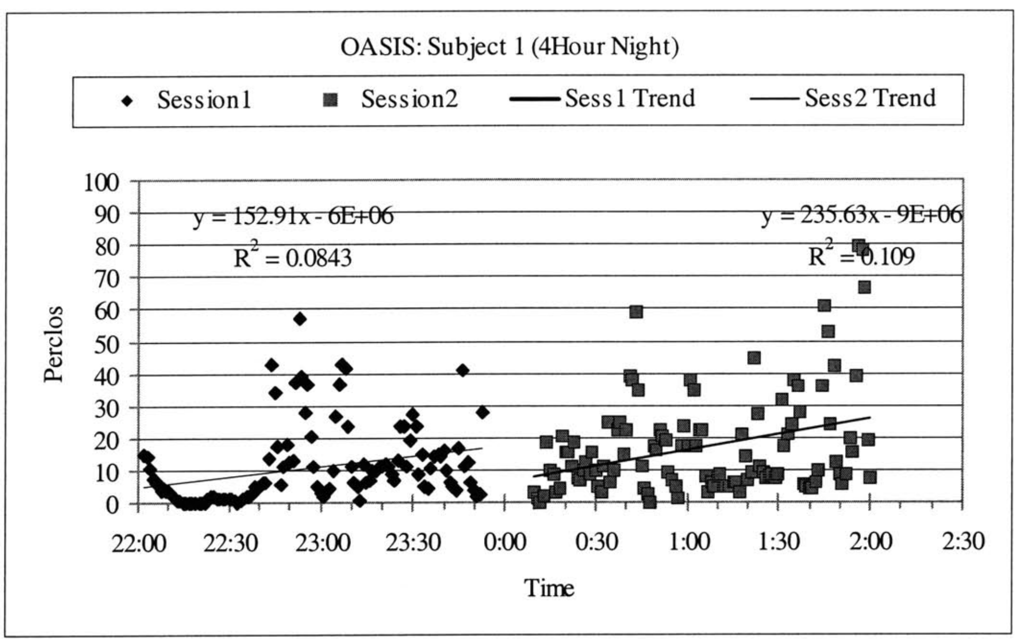


Figure 20: Perclos Graph for Subject 5 (8hr Day)

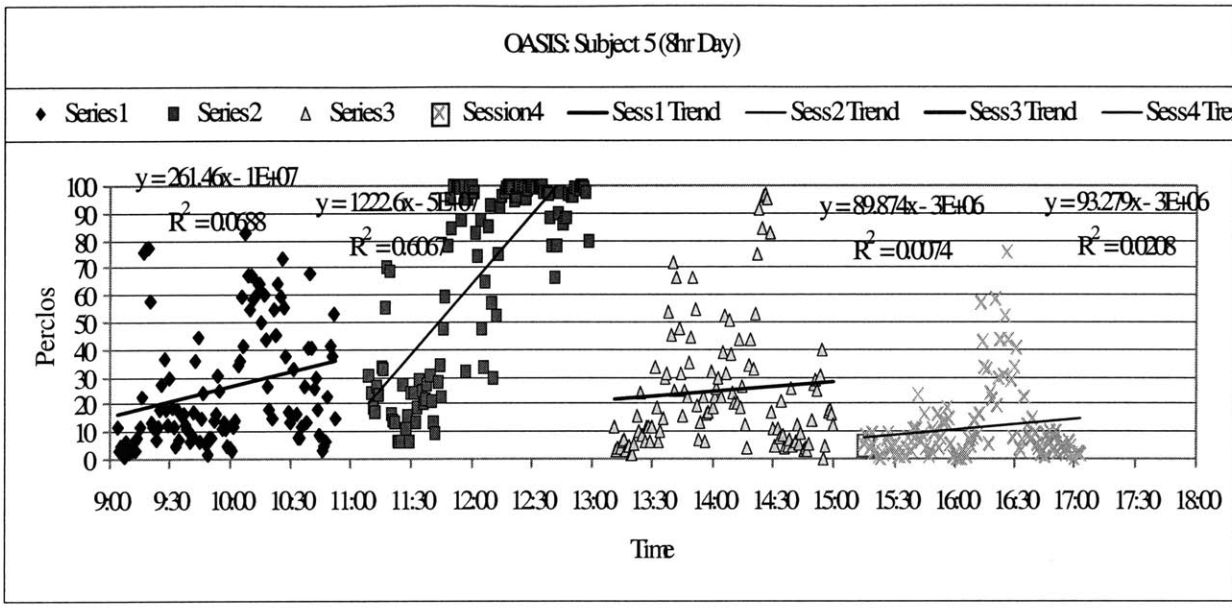
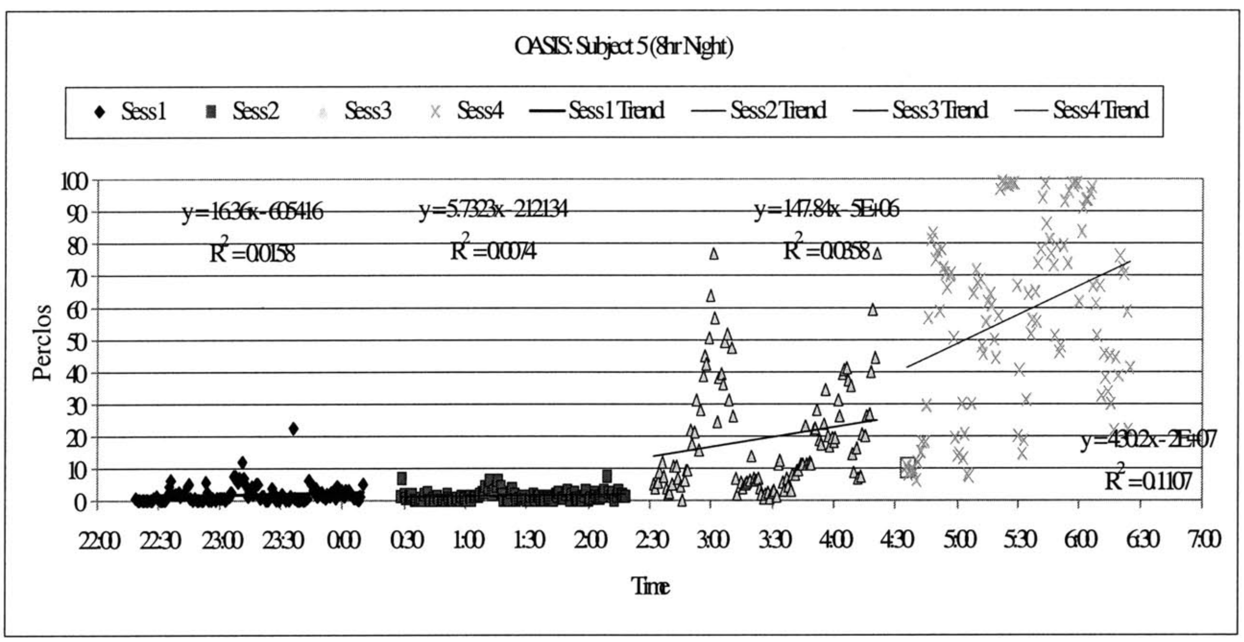


Figure 21: Perclos Graph for Subject 5 (8hr night)



Best-fit lines were drawn on the graphs to see if there were possible patterns such as increasing Perclos values with increasing time for each 110-minute session. In other words, the Perclos values would generally increase in the first 110-minute session, then return to low levels at the beginning of the next 110-minute session because the subject just had a break, and then start increasing again as the new session progressed. The regression value or the square of the correlation value, r^2 for all the subjects were below 0.2, which indicates that there is little relation between Perclos values and time in the simulation. An r^2 of 0.2 means the correlation value is roughly 0.4. Correlation parameter r measures the strength of the linear relationship between two variables. A correlation value of less than 0.5 indicates there is very little linear relationship between Perclos and time. The r^2 value of 0.6 in session of the 8hr day run for Subject 5 must be discarded because there were problems with camera positioning during that session. The camera was picking up reflections from the subject's golden necklace and had also been knocked out of view of the subject.

To examine the relationship between Perclos values and the reactions times to various train tasks, regressions were done. Regressions were chosen as the form of analysis in order to examine how well Perclos predicts reaction times. For each task event that the subject responded to, the Perclos values two minutes before the event were averaged and the Perclos values two minutes after the event were averaged. We took the two-minute averages before and after the event to examine the immediate Perclos values around the event. The Perclos averages before and after the event were then separately regressed with the simulation reaction times. For example, for Subject 1's night run, we did a correlation between the LED reaction times and the average Perclos values two minutes before the LED tasks. Then we found the correlation value between the LED reaction times and the average Perclos values two minutes after the LED tasks. The tables below show the correlation values for each subject and task condition. The regression value is the square of the correlation value.

Table 10: Subject 1, Correlation of Average Perclos 2 Minutes Before and After Task

	Arithmetic (Day)	TrainSentry (Night)	LED (Day)	LED (Night)	Speed (Day)	Speed (Night)
Avg Perclos 2mins Before Task	0.0833	0.0202	0.3081	0.4376	0.0767	0.0468
Avg Perclos 2mins After Task	0.0223	0.2016	0.1494	0.4040	0.3999	0.1876

Table 11: Subject 13, Correlation of Average Perclos 2 Minutes Before & After Task

	Arithmetic (Day)	TrainSentry (Night)	LED (Day)	LED (Night)	Speed (Day)	Speed (Night)
Avg Perclos 2mins Before Task	0.1588	0.4403	0.2309	0.5781	0.8263	0.2199
Avg Perclos 2mins After Task	0.0774	0.2058	0.2818	0.3674	0.1086	0.2000

Table 12: Subject 5, Correlation of Average Perclos 2 Minutes Before & After Task

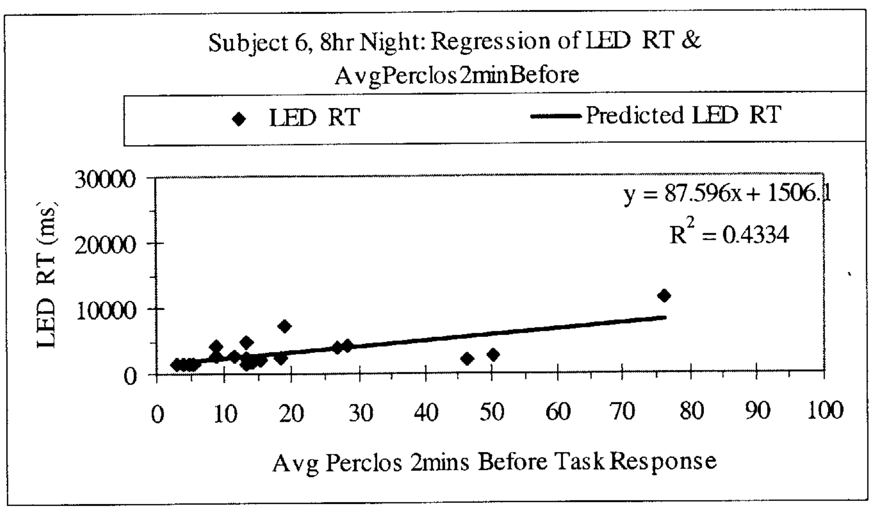
	Arithmetic (Night)	TrainSentry (Day)	LED (Day)	LED (Night)	Speed (Day)	Speed (Night)
Avg Perclos 2mins Before Task	0.2912	0.4980	0.2620	0.1749	0.1208	0.1340
Avg Perclos 2mins After Task	0.4992	0.2797	0.0203	0.0596	0.0004	0.1969

Table 13: Subject 6, Correlation of Average Perclos 2 Minutes Before & After Task

	Arithmetic (Night)	TrainSentry Task (Day)	LED (Day)	LED (Night)	Speed (Day)	Speed (Night)
Avg Perclos 2mins Before Task	0.5811	0.1151	0.2966	0.6583	0.2276	0.5607
Avg Perclos 2mins After Task	0.1882	0.1085	0.0818	0.1111	0.0467	0.1142

Most of the correlation values were less than 0.5 and the corresponding r^2 values were less than 0.2. This indicates that Perclos does not have a linear relationship with the reaction times if there is any relationship at all. Only the data of Subject 6 for the 8hr night for all 3 tasks (arithmetic, LED, and speed) consistently shows a possible relationship with the train task reaction times, but the relationships are small at less than 0.7. Subject 13 had two correlation values greater than 0.5, but the values were for tasks on different day/night conditions. For both subjects 6 and 13, the correlations greater than 0.5 were for the Perclos average before an event. This was what was expected, since Perclos values might predict the reaction time before an event occurs, but after the event occurs, Perclos values taken right after the event have no effect on the event that occurred before. The figure below is a regression plot with the highest correlation value of 0.6583. The graph is of Subject 6's 8hr night run and shows the regression between the LED RT and the Perclos average two minutes before the LED task. Graphs of the regressions for each subject are shown in the appendix.

Figure 22: Regression for Subject 6, 8hr Night Run (LED & Perclos Avg Before)



Each diamond-shaped data point on the graph represents the LED reaction time and the average Perclos value two minutes before the LED reaction occurred. The straight line is the regression line, which predicts the "best-fit" line for the data points. The line slants upwards to the right, which means that the higher the Perclos values before an LED task comes on, the higher the subject's reaction time will be. So the more closed the subject's eyelids are, the slower he'll react to the LED task.

The question remains on what definitive Perclos value indicates fatigue, drowsiness, or vigilance decrement thresholds. A study by Wierwille and colleagues in 1994 established a drowsiness criterion of a Perclos value of 80% or greater. Is that 80% cutoff consistent with the data in this study? The table below shows the number of 80% Perclos values each subject had.

Table 14: # of Occurrences of Perclos Values >80 for each subject

session	d1	d2	d3	d4	n1	n2	n3	n4
Subject5, #P>=80	1	57	6	0	0	0	0	26
Subject6, #P>=80	0	1	0	0	0	0	0	8
Subject1, #P>=80	0	0			0	0		
Subject13, #P>=80	0	0			0	0		

The second session during the day run for Subject 5 should be disregarded. The high # of Perclos values over 57 were due to OASIS camera problems. The camera fell out of place and did not get a direct view of the subject's eyes. The problem was fixed during the break after session 2.

Not many subjects had Perclos values of 80% or greater. However, subjects 5 and 1 were observed to fall asleep or "nod off" several times through their simulation runs. The other two subjects were observed to close their eyes repeatedly, but only for seconds at a time. Subject 5 fell asleep in the fourth session of his night run and had the most incidences of Perclos values greater than 80. The small subject size and counterbalancing precludes us from examining the 80% cutoff more thoroughly.

Discrete Data: PVT, FIT2000, Waypoint

These devices were designed to be predictive; their advocates claim the devices can predict human performance based on a measure. Each test was performed at least twice before the day of the simulation run and then once just before the simulation run, once during each simulation break, and at the end of the simulation. The following graphs show the values or mean values from each test. The codes on the x-axes of the graphs represent the baseline or simulation run, the day or night condition and the test number. For example, subject 1 did a PVT test during the break in the 4hr day simulation, which would be coded as sd2 (simulator, day, test #2).

PVT

The unit of measurement of the PVT is reaction time. As the subject tires or becomes drowsy and less alert, his response time should increase. Therefore, we would expect to see PVT reaction time data points that increased or sloped upwards for each day and night run. The last PVT data point for each day and night condition might be lower because the subject realized he had finished the testing and was excited at being able to leave the lab.

Figure 23: PVT data for Subject 1

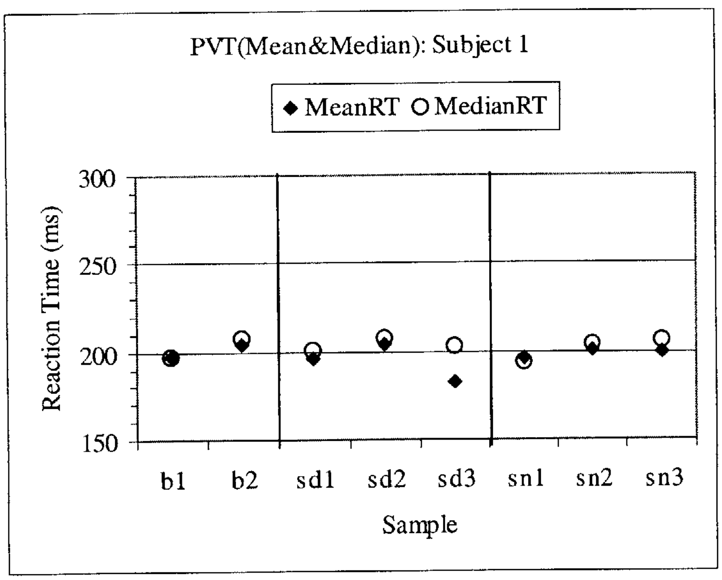


Figure 24: PVT data for Subject 13

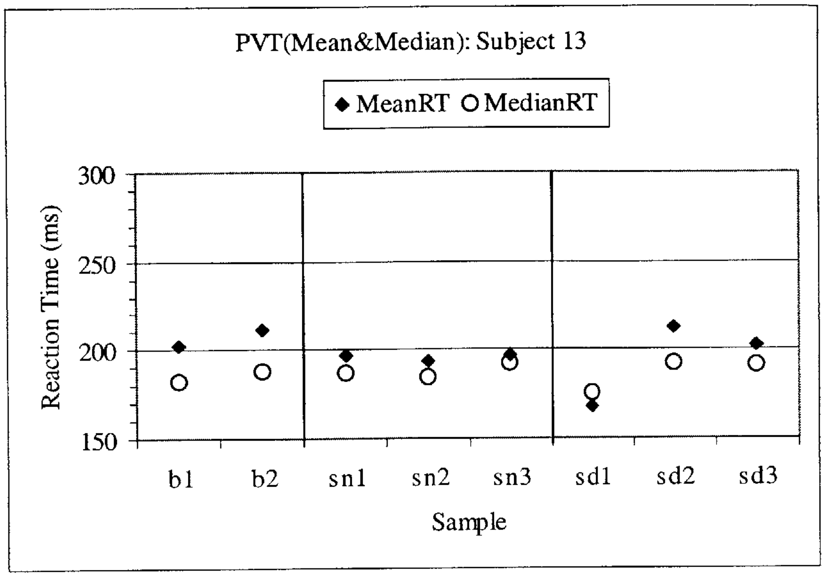


Figure 25: PVT data for Subject 5

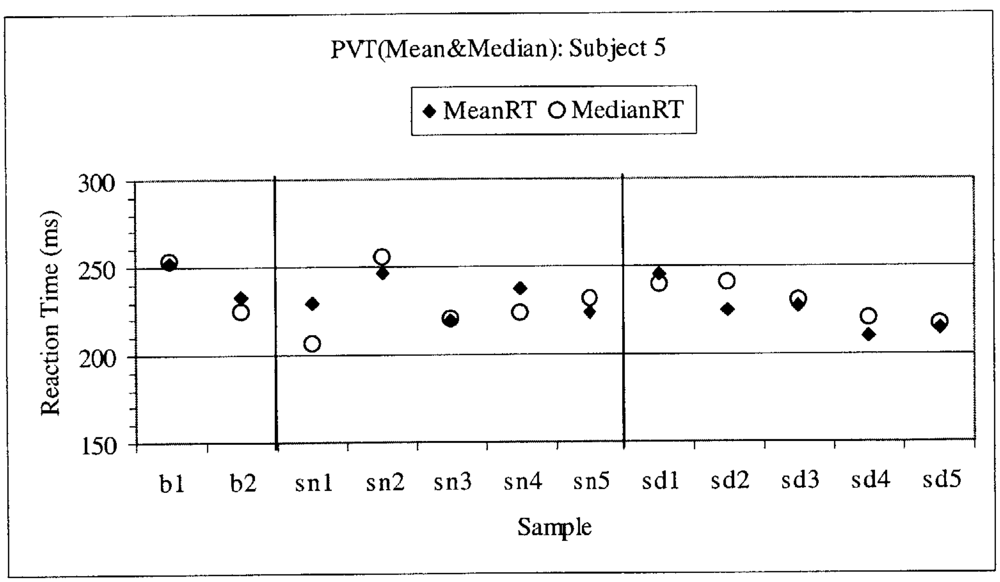
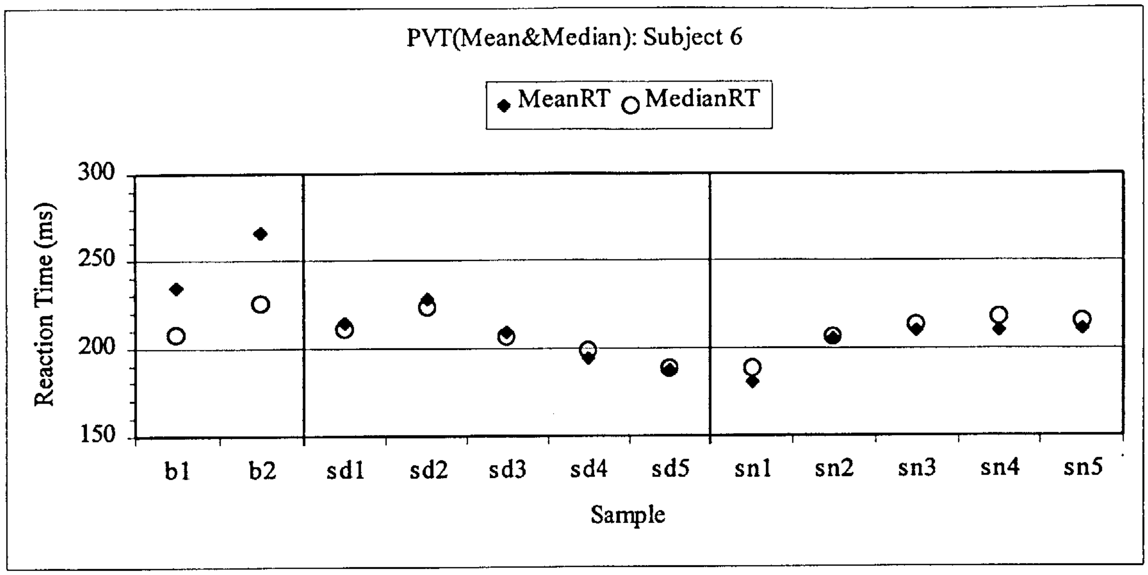


Figure 26: PVT data for Subject 6



Subject 6 had slightly increasing mean reaction times in his night run, which is what we expected. Subject 13 had increasing mean reaction times during the night simulation run, but right after the simulation, his mean reaction time decreased (data point sd3), which is again a possibility we expected. Subject 1 also had a slight increase in mean reaction times that decreased right after his simulation during the day. The rest of the data show no patterns that we expected and are analyzed later in this section.

FIT2000

The unit of measurement is saccadic velocity. We would expect the saccadic velocity to decrease as subjects became fatigued or less alert. We would therefore expect to see negatively sloped patterns in graphs with increasing test sample per night or day. The last FIT2000 data point for each day and night condition might be higher for similar reasons to the PVT aforementioned.

Figure 27: FIT2000 Data for Subject 1

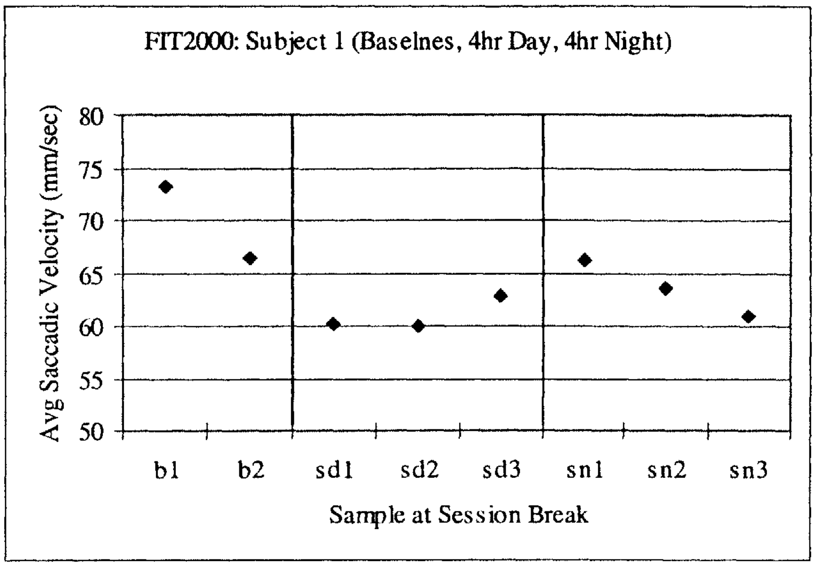


Figure 28: FIT2000 Data for Subject 13

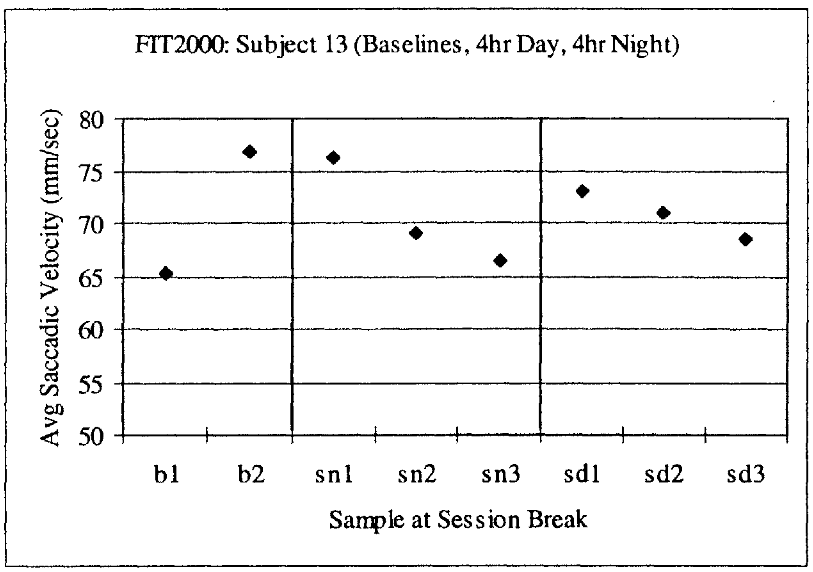


Figure 29: FIT2000 Data for Subject 5

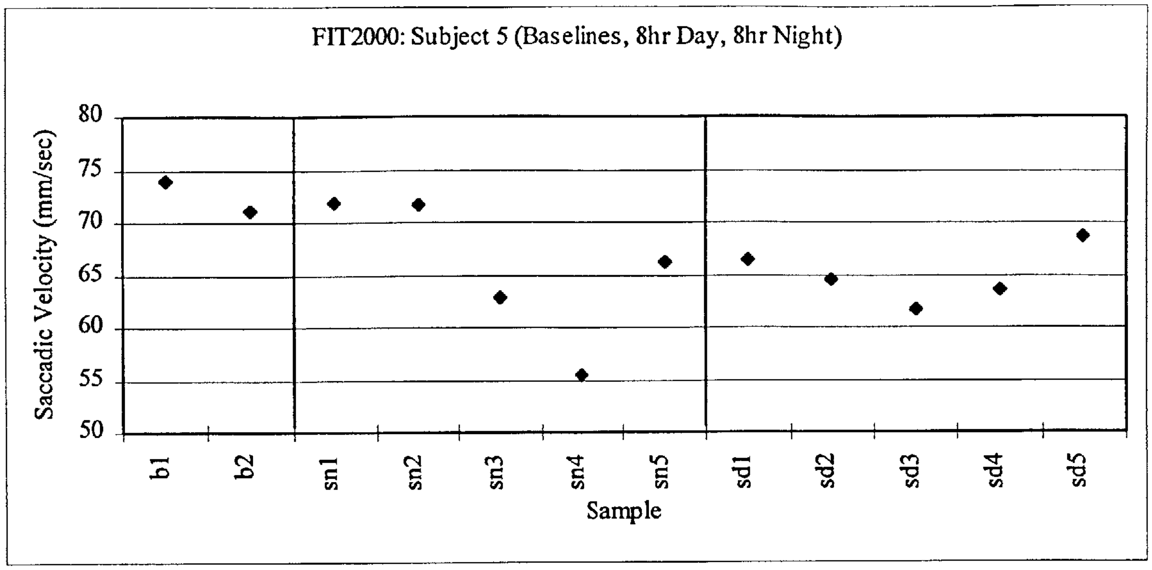
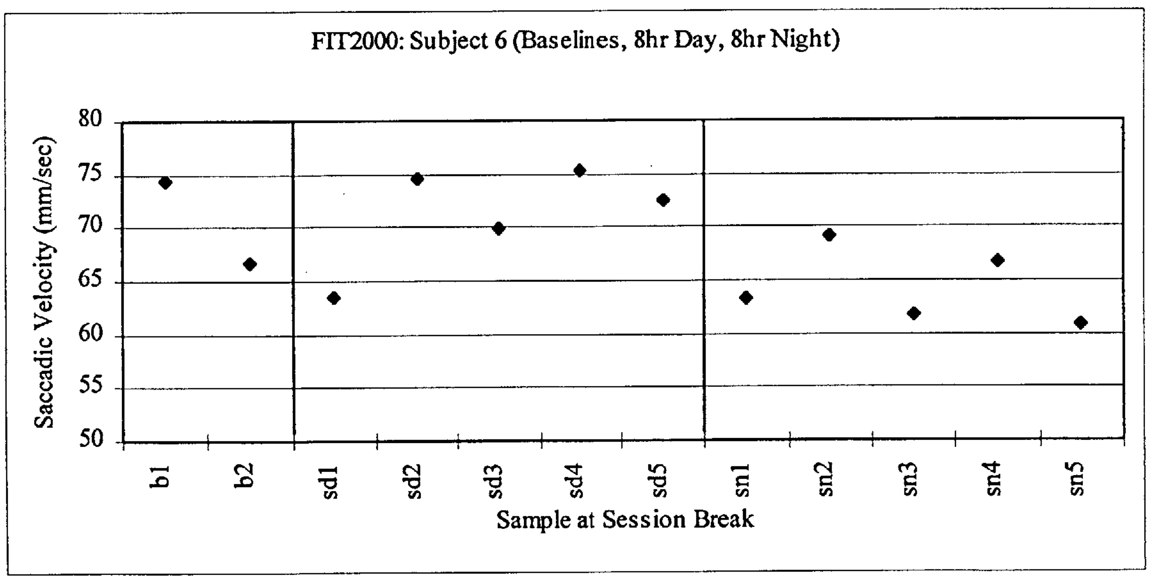


Figure 30: FIT2000 Data for Subject 6



Subjects 1 and 13 had decreasing average saccadic velocities over their night runs, which is what we expected. Subject 13 also had decreasing average saccadic velocities over his day run. Subject 1, however had increasing average saccadic velocities over his day run, which may be due to his sleep/wake tendencies. His sleep/wake logs indicate that he usually doesn't wake up until the late morning, early afternoon hours, whereas the day run started at 9am and ended at 1pm. Subject 5 had "U" shaped average saccadic velocities over both day and night runs. This

"U" shape was another possibility that we expected; the subject becomes tired and drowsy over the run but then starts to become more alert again as they realize the run is coming to an end. The graphs of Subject 6 show no pattern that we expected or can explain.

Waypoint

The unit of measurement is the high-risk odds ratio. We would expect the odds ratio to increase as the subjects became tired and fatigued.

Figure 31: Waypoint Data for Subject 1

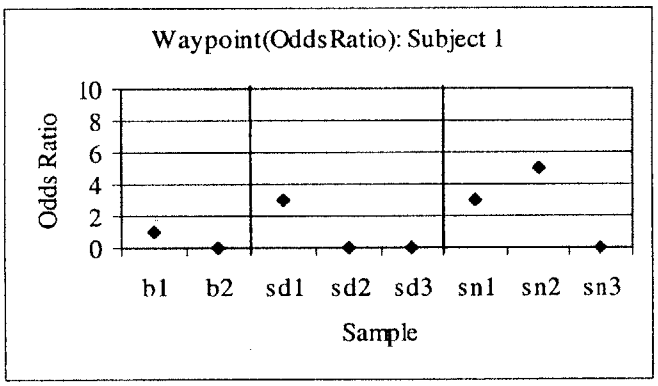


Figure 32: Waypoint Data for Subject 13

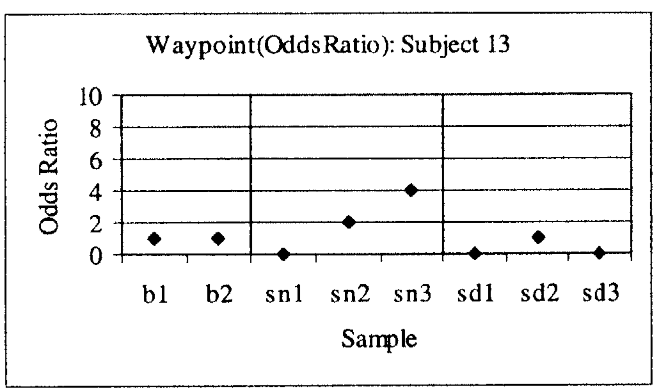


Figure 33: Waypoint Data for Subject 5

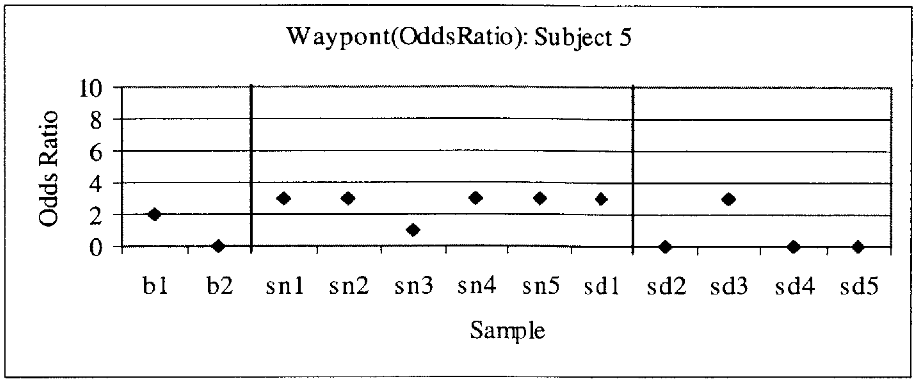
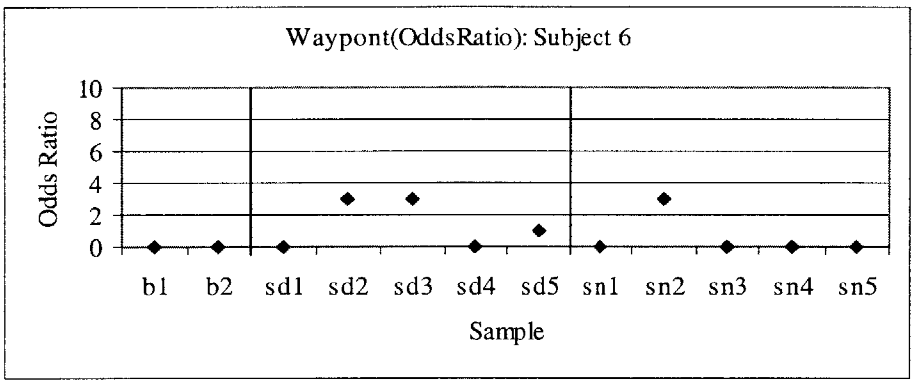


Figure 34: Waypoint Data for Subject 6



Subject 13 had increasing odds ratios during his night run. Subjects 13 and 5 had increasing odds ratios that decreased right after their day and night runs, respectively. The rest of the data show no expected patterns.

For all the devices, the baseline values gave us an indication of the subject's performance on the test when not under simulator conditions. The graphs show no consistently observable difference between the baseline data points and the test measures for the PVT, FIT2000, and Waypoint. This may be due to the small number of tests we ran on each device.

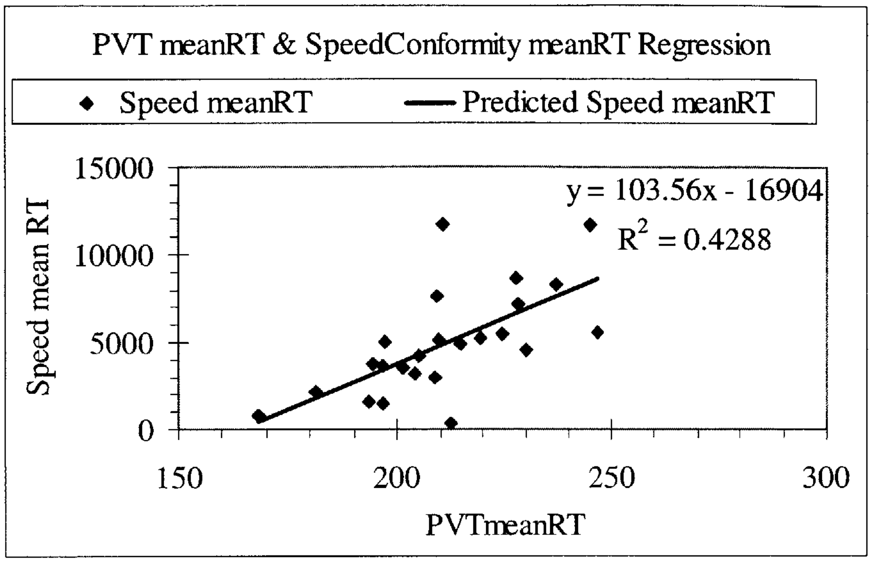
To determine whether there were possible relationships between the devices and the train task reaction times, a set of regressions was done. We wanted to examine how well the devices predicted reaction times. So for each 110-minute simulator session, the average reaction time for each train task was calculated. These train task reaction time averages were compared with the measurements from the devices. There weren't enough data points to do regressions for each subject. So for each task, the subjects' average reaction times were combined and a set of regressions was done between these average reaction times and the corresponding FIT2000, Waypoint, or PVT values. This increases the power of the test so that even small differences in the data may be significant. The table below shows the correlation values, r. The corresponding regression values are just the square of the correlation, r^2.

Table 15: Correlations between Train Task RTs & FIT, PVT, Waypoint

	TrainSentry	Arithmetic	LED	Speed
PVTmeanRT	0.3993	-0.0304	0.2136	0.6549
FITmeanSaccadicVelocity	-0.4268	-0.0520	-0.4311	-0.2909
WaypointOddsRatio	-0.1023	-0.3998	-0.0102	0.0776

The correlation values are less than 0.7 or greater than -0.7, which indicates there are no strong linear relationships between the train tasks and the devices. A negative correlation value between two variables means that there is an inverse relationship between them. The FIT2000 and Waypoint generally have negative correlations; this means that as saccadic velocity or odds ratio increases, the reaction times decrease. The PVT and Arithmetic Task had a negative correlation value and the Waypoint and Speed Task had a positive correlation, which is the opposite of what we would expect. However, since the correlations are so small, close to zero, we can simply say the data shows there is no linear relationship between the PVT and arithmetic task reaction time and that there is no relationship between the Waypoint and the speed task reaction time. Only the PVT and speed task have a correlation that nears 0.7. The regression for this relationship is shown in the plot below. Although r = 0.655, the regression value is only 0.4288. Regression plots for the other combinations of device and train task are in the Appendix.

Figure 35: Regression of PVT mean RT and Speed Conformity Task Mean RT



4.1.3 Question 3: Is there any difference in human performance between the arithmetic task and the Train Sentry task? If so, can these differences indicate that one task is more effective than the other in keeping subjects awake and alert?

The FRA recommended adding a cognitive task to a vigilance device such as the standard alerter. The reasoning is that a cognitive device requires some mental process by the subject and so the subject will be more alert or vigilant under the cognitive-related task. This study tested whether such reasoning could be validated in experiments. Questions asked in conjunction with this goal are whether the arithmetic task required more time to respond to than the standard alerter. If so, how much more time, by what factor (e.g. Factor of 2), do the arithmetic tasks take. In addition, does the arithmetic task put too much workload or mental demand on the locomotive engineer such that it takes the engineer's attention from the main task of driving the train.)

The Student t-test was done on the reaction times to the standard alerter and arithmetic tasks for each subject. The table below shows the two-tailed t-statistic and corresponding p-values for a 95% acceptance region. The hypothesis was that there was no significant difference in the alerter and arithmetic response times. A p-value of 0.05 or less means the hypothesis is rejected.

Table 16: P values for T-test Between Train Sentry RT & Arithmetic RT

	Subject 1	Subject 13	Subject 5	Subject 6
T Stat	3.6795	4.9974	1.5128	-2.6324
Pvalue	0.0008	0.0001	0.1378	0.0114

The p-values show that there was a statistically significant difference in the mean value of the Standard Alerter task and the Arithmetic task for Subjects 1, 13, and 6. The p-value for Subject 5 indicates that there was no statistically significant difference in his reaction times to the Arithmetic task and Train Sentry Alerter task. Subject 5 slept for several minutes at time during the train simulations and awoke to the Arithmetic or TrainSentry alarm ringing more than once, which may account for the non-significant p-value. The p-values across the subjects indicate that there probably is a significant difference in the amount of time needed for a subject to react to Arithmetic problem and TrainSentry Alerter. The table below of mean reaction times shows that overall, the Arithmetic task took longer to respond to.

Table 17: Mean & Variance of Arithmetic RT & Train Sentry RT

	Subject 1	Subject 13	Subject 5	Subject 6
Arithmetic Mean RT	2345	2570	2175	1510
TrainSentry Mean RT	1855	1310	3608	3043
Arithmetic RT Variance	140500	1251593	1499872	12268528
TrainSentry RT Variance	214184	19895	34366865	1289128

The mean reaction times to the arithmetic task were generally greater than those for the Train Sentry task. Again the data for Subject 5 is the exception; the data shows that the mean reaction time to the arithmetic task is greater than that for the Train Sentry task. A possible reason for Subject 5's result is that he was more tired and sluggish on the simulator run testing the Train Sentry task. His sleep logs indicate that he slept at approximately 5am and then had to come to lab to do the experiment at 8:30am. His Arithmetic simulator run occurred at night, several days before the day run and he was much more awake for the first half of the night run.

To increase the power of the t-test, all the subjects' response time data points were grouped so that the only differences between two groups were arithmetic or standard alerter task conditions, and the t-test was run on the means of the overall arithmetic or standard alerter task.

Table 18: P Values for T-test on Arithmetic & TrainSentry -Combined Subject RTs

	with all data points		without some Subject 5 data points	
	Arithrithmetic RT	TrainSentry RT	Arithrithmetic RT	TrainSentry RT
Mean	2558.36	2233.33	2594.90	1718.80
Variance	4870476.64	12700896.36	4925963.42	1912746.83
t Stat	0.85		3.62	
P-value	0.40		0.00	

The first p-value was calculated from combining data from all the subjects and indicates that there was no significant difference in reaction times between the Arithmetic and Train Sentry task. This result does not seem reasonable since three of the four subjects independently had p-values that indicated there was a difference in reaction times. The data of Subject 5 must be so different that it causes the p-value to be statistically insignificant. Three of the reaction times for Subject 5 were much greater than the values of the rest of the data. These reaction times were approximately 19000 ms or greater and were due to the subject falling asleep and being awakened by the sound alarms. The three reaction times were removed from the data set, and a new t-test was run that resulted in a p-value of 0.0004, indicating a significant difference in reaction times between the Arithmetic and Train Sentry tasks. The corresponding mean values show what overall, the Arithmetic Task took approximately 1.5 times longer to respond to than the Train Sentry Task.

To evaluate the immediate affects of the Standard Alerter and the Arithmetic task on the subject, regressions were run on the subject's arithmetic or standard alerter reaction times and the corresponding Perclos values two minutes after the alerter or arithmetic event. (See the discussion in the previous section for more details on how the two-minute Perclos average values were calculated.) For each subject, we would expect to see repeatedly lower Perclos values with the arithmetic or alerter task that was more "effective" in keeping the subject alert. Some results from the previous section on Perclos are shown in the table below. Re-examining these results, we found that there was no correlation between response times and the Perclos values immediately after the response to an Arithmetic or Train Sentry task.

Table 19: Correlation of Avg Perclos 2Mins After Arithmetic & Train Sentry Task

	Subject 1	Subject 13	Subject 5	Subject 6
Arithmetic Task	0.0223	0.0774	0.4992	0.1882
TrainSentry Task	0.2016	0.2058	0.2797	0.1085

Further, a t-test between the Arithmetic and Train Sentry Perclos values (2mins after the task) was done to see if there was a significant difference between them. The p-values are shown in the table below. The p-value was only significant for Subject 5, indicating that there was a significant difference in Subject 5's eye closure between completing a Train Sentry task and Arithmetic task. Possible reasons for the differences in Subject 5's data and the rest of the subjects were discussed above.

Table 20: P values for T-test on Avg Perclos 2Mins After Arithmetic & TrainSentry Task

	Subject 1	Subject 13	Subject 5	Subject 6
T statistic	-0.3194	-1.0486	2.1821	-1.3326
P value	0.7512	0.3020	0.0324	0.1867

The table of means and variances for the average Perclos two-minutes after a task response (Table below) shows that Subject 5's eyelids were more open (smaller Perclos value) on average after responding to an Arithmetic task than after responding to a Train Sentry task. Subject 1 and 13 also had eyelids more open after responding to an arithmetic task. We expected that subjects would have smaller Perclos values after responding to an arithmetic task because they would have to look for the correct number to enter on the numeric keypad rather than just pushing a lighted button on the side of the cab. However, since the average Perclos values two-minutes after the Arithmetic and Train Sentry tasks are not significantly different (as indicated in the p-values) for Subject 1 and 13, we cannot conclusively say that the Arithmetic task generally makes subjects open their eyes more. Instead, more experiments must be run on more subjects.

Table 21: Mean & Variance of Avg Perclos 2Mins After Arithmetic & TrainSentry Task

	Subject 1	Subject 13	Subject 5	Subject 6
Arithmetic Mean Perclos	15.83	12.56	18.92	23.09
TrainSentry Mean Perclos	17.17	16.89	32.83	18.07
Arithmetic Perclos Variance	163.20	232.57	571.70	348.89
TrainSentry Perclos Variance	186.20	107.48	1054.04	218.57

In general, the arithmetic cognitive task does not seem to increase the subject's level of alertness but rather adds additional response time to the task of responding to an alerter. This doesn't eliminate the arithmetic task as a possible alteration to existing standard alerter devices, but rather prompts us to try, in later studies, slightly more difficult arithmetic problems, possibly problems requiring two digit rather than one digit responses.

4.1.4 Question 4: Are there differences in human performance on the Arithmetic, Train Sentry, LED, and Speed conformity tasks between day and night runs?

In order to determine whether it is necessary to run future subjects in both a day and night condition or whether running them only during the night or only during the day was sufficient to capture their decrements in performance due to fatigue, drowsiness or lack of alertness, the reaction times to the various tasks between night and day runs were evaluated.

Comparing the day and night run graphs in section 4.1.1 showed no general trends in reaction times. The alerter task graphs may look like they are showing a difference between day and night runs but the difference may be due to the difference the alerter type, Train Sentry standard alerter or Arithmetic alerter, rather than time of day.

To quantitatively see if there were possible differences in the time of day and reaction times, the Student t-test was run on the reaction times between day and night conditions for each task for each subject. Due to the small sample sizes throughout this study, analysis of variance tests were not run. Since each subject did one run under the arithmetic task condition and one run under the

Train Sentry alerter condition, the difference between day and night condition for the arithmetic task and Train Sentry conditions could not be determined for an individual subject. The hypothesis for each task was that there were no significant differences in the means of the reaction times. The acceptance region was 95%, so p-values less than 0.05 would mean there was a significant difference between day and night runs. The tables below show the results of the two-tailed t-tests.

Table 22: P values for T-test between LED RT in Day & Night Runs

	Subject 1	Subject 13	Subject 5	Subject 6
T statistic	0.3087	0.1442	-1.5067	0.1586
P value	0.7611	0.8872	0.1468	0.8749

Table 23: P values for T-test between Speed RT in Day & Night Runs

	Subject 1	Subject 13	Subject 5	Subject 6
T statistic	0.6701	-1.2049	0.0377	-0.1420
P value	0.5113	0.2590	0.9701	0.8878

We expected reaction times to be longer during night runs than during day runs. However, p-values show that there was no difference in the reaction times to the Speed Conformity task or the LED task between day and night runs. This result may be due to our subject population of students. The students did not follow regular sleep/wake schedules, so their performance on the train tasks during the day and night showed no differences. Since none of the p-values were significant, we didn't combine the subject's data to run one t-test between day and night reaction times for the LED or Speed Task.

Although there were no significant differences, the means and variances of the Day vs. Night reaction times were compared to see whether there might be a general trend of longer reaction times at night. Looking at the tables below, only Subject 5 had longer response times during the night for the LED task. For the Speed task, Subjects 13 and 6 had higher mean reaction times during the night run.

Table 24: Mean & Variances of LED RT for Day & Night Runs

	Subject 1	Subject 13	Subject 5	Subject 6
Day Run, Mean	3480	2200	2615	3380
Night Run, Mean	2990	2150	5150	3235
Day Run, Variance	14230667	797778	2581342	10725895
Night Run, Variance	10956556	405000	54035263	5997132

Table 25: Mean & Variance of Speed RT for Day & Night Runs

	Subject 1	Subject 13	Subject 5	Subject 6
Day Run, Mean	3400	560	5615	4530
Night Run, Mean	2460	3290	5525	4790
Day Run, Variance	8295556	109333	63622395	37863263
Night Run, Variance	11382667	51223222	50381974	29142000

Thus these experiments indicate no differences in the effects of day vs. night runs on the subjects' performances on the train tasks. We reiterate that this result may not be indicative of the locomotive engineer population and that experiments on a population that more closely resembles locomotive engineers is needed.

4.1.5 Question 5: Do the Oasis, FIT2000, PVT, and Waypoint devices detect any differences in human performance between day and night runs?

To answer this question, the subjects' measurements were combined for each device and t-tests were run comparing the day and night data. For example, all the mean reaction times to the PVT were combined so there was no distinction between subjects. This data was then divided into two groups, day and night, and a t-test was run comparing the day and night mean reaction times. The table below shows the t-statistics and their corresponding p-values.

Table 26: P values for Day vs. Night Comparisons of PVT, FIT2000, and Waypoint

	PVT MeanRT	FIT MeanSaccadicVelocity	Waypoint OddsRatio
T Statistic	-0.3513	0.8363	-1.4764
P value	0.7278	0.4096	0.1506

Table 27: Mean & Variance of PVT, FIT2000, Waypoint between Day & Night Runs

	PVT MeanRT	FIT SaccadicVelocity	Waypoint OddsRatio
Mean Day	207.58	67.27	1.06
Mean Night	209.87	65.76	1.88
Variance Day	376.13	26.04	1.93
Variance Night	307.88	26.26	2.92

None of the p-values indicate a significant difference between day and night runs. This was expected because the subjects performance on the train tasks also did not show a significant difference between day and night runs.

4.1.6 Question 6: Are there differences in human performance on the Arithmetic, Train Sentry, LED, and Speed conformity tasks between 4hr and 8hr simulator runs?

To answer this question, the problem was broken into two parts. First, we compared the first four hours of the 8hr simulator run with the 4hr simulator run. Then we compared the first four hours of the 8hr runs to the last four hours of the 8hr runs.

The train task reaction time graphs in section 4.1.1 do not show any trends between the first four hours of the 8hr run and the 4hr run. T-tests were done comparing the train task reaction times from the first four hours of the 8hr run and the reaction times in the 4hr run. The table below shows the results of this set of t-tests. For each task, the first 4hours of Subject 6's data was compared with the 4hr runs of Subjects 1 and 13. The same was done for the first 4hours of Subject 5's data with the 4hr runs of Subjects 1 and 13.

Table 28: P values for T-tests between the first four hours of 8hr run and 4hr run

	Sub 6 (0-4hr) & 1	Sub 6 (0-4hr) & 13	Sub 5 (0-4hr) & 1	Sub 5 (0-4hr) & 13
ArithmeticRT	0.0001	0.7757	0.0134	0.0610
TrainSentryRT	0.0002	0.0191	0.1320	0.0693
LED RT (Day)	0.6856	0.1797	0.5962	0.4681
LED RT (Night)	0.5293	0.0603	0.5687	0.4867
SpeedRT (Day)	0.3546	0.0603	0.8290	0.1922
SpeedRT (Night)	0.6481	0.9788	0.2734	0.5625

We hypothesized that there would be a significant difference in the first four hours of the 8hr run and the 4hr run because subjects who came in knowing they have to last eight hours in the simulation probably came in with a different mindset than a person who only had to stay in the simulation for half the time. However, the p-values show that there were no significant differences between reaction times in the first four hours of the 8hr run and the 4hr run. Only the Arithmetic and TrainSentry tasks have significant p-values between the first 4hrs of an 8hr run and the 4hr runs. This may be due to the variability in reaction times between subjects to the Arithmetic and TrainSentry tasks. Another possible reason is that the Arithmetic and TrainSentry reaction times were compared across day and night runs. In other words, while the LED and Speed reaction time data were separated by day and night runs, the alerter tasks (Arithmetic and TrainSentry) did not distinguish between day and night runs. For example, the t-test between Subject 6 and 1 for the arithmetic task compared Subject 6's night run with Subject 1's Day run. This was an effect of the counterbalancing of conditions and subjects. Therefore, it is best to disregard the data p-values for the Train Sentry and Arithmetic tasks.

We also looked at the 8hr runs and ran t-tests to find possible significance differences in train task reaction times between the first four hours and the last four hours of the simulation. The table below shows the results of these tests.

Table 29: P values for t-tests between first four and second four hours of 8hr run

	Sub 6 (0-4hr) & (4-8hr)	Sub 5 (0-4hr) & (4-8hr)
ArithmeticRT	0.0479	0.5457
TrainSentryRT	0.2316	0.4500
LED RT (Day)	0.2659	0.7395
LED RT (Night)	0.0853	0.1064
SpeedRT (Day)	0.3045	0.3705
SpeedRT (Night)	0.2046	0.7925

Most of the p-values indicate that there are no statistically significant differences between the first four hours of an 8hr run and the last 4 hours of the run. Only the p-value for comparisons of the arithmetic reaction times for Subject 6 showed was statistically significant. It means that for Subject 6, there was a difference in the mean reaction times to the Arithmetic task between the first four hours and last four hours of the run. Experiments on more subjects would have to be conducted to determine whether this significant p-value holds across subjects.

4.1.7 Question 7: Is the duration of the simulator run (4hr or 8hr) long enough to see degradations in human performance on the Arithmetic, Train Sentry, LED, and Speed conformity tasks?

From the results of Question 6, we were unable to answer this question. In general, the p-values found in the discussion of Question 6 show no significant differences between 4hr and 8hr runs. Also, in earlier discussions, no temporal trends in the reaction times to the various train tasks were found. This would indicate that 4hr and 8hr runs are not long enough to see degradations in human performance. However subjective data from the subject and experimenters indicate that subjects do tire and become drowsy through both 4hr and 8hr runs. The subjective data is discussed in later sections of this chapter. The inconsistency between objective data and subjective data further prompt us to run more experiments.

4.1.8 Question 8: Do any of the Oasis, PVT, FIT2000, and Waypoint devices correlate with each other?

Correlation values were found for the combinations of PVT, FIT2000, and Waypoint data. Oasis was excluded from these correlations because it collected continuous data rather than discrete points. The correlation values are shown in the table below.

Table 30: Correlation values between PVT, FIT2000, and Waypoint

	PVTmeanRT	FITmeanSaccadicVelocity	WaypointOddsRatio
PVTmeanRT	1.0000		
FITmeanSaccadicVelocity	-0.1530	1.0000	
WaypointOddsRatio	0.3801	-0.0565	1.0000

None of the correlations had values greater than 0.70, which means there were no strong linear relationships between the different devices. The highest correlation, $r = 0.381$, was between the PVT and Waypoint.

4.2 Subjective Results

How well do the devices predict the subjects' own subjective measures of their fatigue and alertness as indicated by their responses to the Subjective Rating Scales Questionnaire? They filled out the questionnaire before the simulator run, during each simulator break, and after the simulator run. In the questionnaire, the subject rated seven qualities: level of boredom, mental demand (MD), time pressure (TP), level of effort (LE), overall workload (OW), fatigue, and stress level (SL), on a scale of 0 to 100. The subject filled out the scales by placing a tick mark somewhere on or between the 0-100 range. The distance of the tick from 0 was measured in millimeters using a ruler.

4.2.1 Question 9: Do the measurements from the Oasis, PVT, FIT2000, and Waypoint devices correlate with subjective measures (from subjective rating scales and questionnaires the subjects filled out)?

Correlations of each subjective category and each device (FIT2000, PVT, and Waypoint) for each subject were calculated and are shown in the Appendix. The subjective ratings varied highly between subjects and their correlation values differed significantly between subjects. To see if there was an overall relationship between the subjective categories and the FIT2000, PVT, and Waypoint, the individual subject ratings for each category were combined and correlations were done on the overall subjective ratings and the device measurements. The resulting correlation values are tabulated below.

Table 31: Correlation Values between PVT, FIT2000, Waypoint & Subjective Ratings

	PVT	FIT2000	Waypoint
PVT	1.0000		
FIT2000	-0.1240	1.0000	
Waypoint	0.3668	0.0070	1.0000
Boredom	0.3361	-0.2149	0.0626
MD	-0.3182	0.1701	0.1645
TP	-0.3149	-0.1720	0.1032
LE	-0.3555	-0.0048	0.0699
OW	0.0658	0.0296	0.3265
Fatigue	0.2634	-0.3532	0.2537
SL	-0.2857	-0.0837	0.0564

All of the correlation values are much less than 0.70, which indicates that there was little to no linear relationship between the device measurements and the subjects' own measure of his levels of boredom, mental demand, time pressure, level of effort, overall workload, fatigue and stress level. Another set of correlations was done separating the day and night conditions, which also had no correlation values greater than 0.70. Thus, the measurements of the devices did not correlate with the subject's own subjective measures.

4.2.2 Question 10: How well do the subjective measures correlate with each other?

As discussed in chapter 2, many people have trouble defining exactly what fatigue or alertness is. How then do we develop subjective rating scales to capture their measures of these qualities? The seven qualities in the subjective ratings questionnaire were chosen because we believed they would be qualities the subject would experience during the train simulation and be able to rate. How closely do these qualities relate to each other? The table below shows the correlations of the subjective measures when data from the subjects are combined.

Table 32: Correlation Values between the Subjective Ratings Categories

	BOREDOM	MD	TP	LE	OW	FATIGUE	SL
BOREDOM	1.0000						
MD	-0.6911	1.0000					
TP	-0.5169	0.7133	1.0000				
LE	-0.5143	0.7691	0.8708	1.0000			
OW	-0.5664	0.7725	0.7175	0.7049	1.0000		
FATIGUE	0.6768	-0.5693	-0.3333	-0.3335	-0.2952	1.0000	
SL	-0.3121	0.6254	0.8446	0.7836	0.5371	-0.2275	1.0000

The correlation values between the subjective ratings were much higher than the correlation values between the devices and subjective ratings. Cells in the table that have significant correlations, those that show a strong relationship between the different rating qualities are shadowed. The correlations indicate that mental demand (MD) and time pressure (TP) have a strong positively linear relationship. As time pressure increases, mental demand increases. Mental Demand also correlated with the subject's level of effort (LE) and the subject's overall workload (OW). Time pressure positively correlated with the subject's level of effort, overall workload and stress level. The level of effort positively correlated with overall workload and stress level. These results were expected. What was unexpected was the lack of strong linear relationships between fatigue and the other qualities. Fatigue had a more linear relationship with boredom, with a correlation value of 0.677, which is very close to 0.70. Fatigue and mental demand had a correlation value of -0.525, which indicates a slight negative or inverse relationship; as fatigue increases, mental demand decreases. For the most part, correlations were 0.50 or above which shows some presence of linearity between the subjective qualities.

4.2.3 Subject feedback in the debriefing forms

After the last simulator run, each subject was given a debriefing form to complete. We wanted to get the subjects comments about their experiences during the experiment in order to enhance and refine the final version of the protocol for future phases of the project. A sample of a debriefing form is included in the appendix. Some questions in the debriefing form were:

1. What parts of the experiment/protocol the subject found objectionable or a hardship?
2. What defects in the simulation did the subject notice?
3. How aware of time was the subject?

The following are some of the subjects' answers to the questions.

1. Some subjects commented on how uncomfortable the chair was.
2. Subjects 13 and 5 noticed flashing lights and clicking sounds during the simulations. The clicks came from the alerter, LED, and camera movements. The flashing lights came from small LEDs on a box that connected some computers to the network. As a result, the noise and light sources were removed or dimmed before Subjects 1 and 6 started the experiment.
Other comments were that the railroad tracks in the simulation were sometimes jittery. The railroad tracks will be fixed for the next experiments. A couple of subjects noticed lights above the projector screen. The experiments were run in a warehouse that had two large slits in the ceiling, which allowed light to enter from the outside. This will be corrected in future experiments.
3. All subjects stated that they were aware of time. They generally knew when a simulation session would be over. The subjects can get rough idea of what time of day or night it was from knowing that the sessions lasted 110 minutes each and breaks would last about 15-20mins. We are looking at other possible ways of decreasing the subject's awareness of time in the next experiments.

5. Conclusion

Many of the results in this study were negative or inconclusive. We found that there were no temporal patterns in the response times to the Arithmetic, Train Sentry, LED, and Speed conformity tasks among the subjects. None of the measurements from the Oasis, PVT, FIT2000, or Waypoint showed detected differences in the reaction times to the Arithmetic, Train Sentry, LED, and Speed conformity tasks. The devices did not have strong linear correlations with the task reaction times. The addition of a cognitive task, the Arithmetic task, to the Train Sentry Alerter did not conclusively increase a subject's alertness level. The Arithmetic task did yield longer response times by a factor of approximately 1.5. However, the mean Train Sentry response times were so short, slightly over 1.5 seconds that we could not determine whether the Arithmetic task would negatively detract from a locomotive engineer's main task of operating the train. There were no differences in the subject's day and night response times to the Arithmetic, Train Sentry, LED, and Speed conformity tasks. The Oasis, PVT, FIT2000, and Waypoint did not detect differences between day and night simulation runs. There were no differences in response times between the 4hr and 8hr simulation runs. Whether a 4hour or 8hr run was long enough to observe degradations in human performance could not be determined. None of the measurements of the PVT, FIT2000, and Waypoint correlated with each other. The measurements from the PVT, FIT2000, and Waypoint did not correlate with the subjects' own subjective ratings. Some of the subjective rating categories, Mental Demand, Time Pressure, Overall Workload, Stress Level, and Level of Effort, had high correlations.

Although we had many negative or inconclusive results, we gained invaluable knowledge and experience in this study that will aid in our design and implementation of future phases of the project.

6. Recommendations for Further Study

The knowledge gained and discussed in the conclusion section will be carefully considered to improve experimental protocols and the train simulation for Phase II of the Volpe Study. Some changes to the test environment conditions we will make are to improve the train simulation with a better out-window-display and to will ensure there are no extraneous light sources or noises in the simulation room to detract the subject's attention. Some aspects of the protocol that will be changed are the way we select subjects and determine their simulation start/end times. For future studies, we will select subjects who more closely resemble the population of rail-road engineers. We will also select subjects with more regular sleep/wake schedules. The CorTemp, Actiwatch, and Sleepwatch will be used to customize the simulation start/end times for each subject, so that we can assure that a simulation run will catch the trough in the subject's circadian rhythm. We will take more tests on the PVT, FIT2000, and Waypoint to get more data points. We will run experiments on enough subjects to fully counterbalance all the test conditions.

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Appendix A: Experimental Data

A1. Subject Sleep/Wake Schedules

Subject Sleep/Wake Times As Recorded in their Sleep/Wake Logs

Subject 1

Exp Day	1	2	3	4	5	6	7
Wake	------	10:00am	11:37am	12:50pm	7:20am	10:35am	11:25am
DaySchedule	Regular	Regular	Regular	Regular	Regular	Regular	Regular
Sleep	4:05am	3:30am	4:35am	1:00pm	6:00am	3:45am	------
Tests	Baseline1	------	Baseline 2	------	Day Run	------	Night Run

Subject 13

Exp Day	1	2	3	4	5	6	7	8	9
Wake	------	8:45am	7:40am	7:15am	7:15am	7:45am	7:15am	7:00am	7:15am
DaySchedule	Regular	Regular	Regular	Regular	Regular	Regular	Regular	Regular	Regular
Sleep	1:00am	1:20am	1:40am	1:10am	3:00am	1:00am	1:00am	1:00am	------
Tests	Baseline1	------	Baseline 2	------	Night Run	------	------	------	Day Run

Subject 5

Exp Day	1	2	3	4	5	6	7	8	9
Wake	------	1:00pm	12:00pm	10am	12:00pm	9:00am	11:00am	2:00pm	12:00pm
DaySchedule	Regular	Regular	Regular	Regular	Regular	Regular	Regular	Regular	Regular
Sleep	5am	3:30am	3:00am	2:30am	7:00am	3:00am	4:00am	1:00am	12:00am
Tests	Baseline1	------	Baseline 2	------	Night Run	------	------	------	------

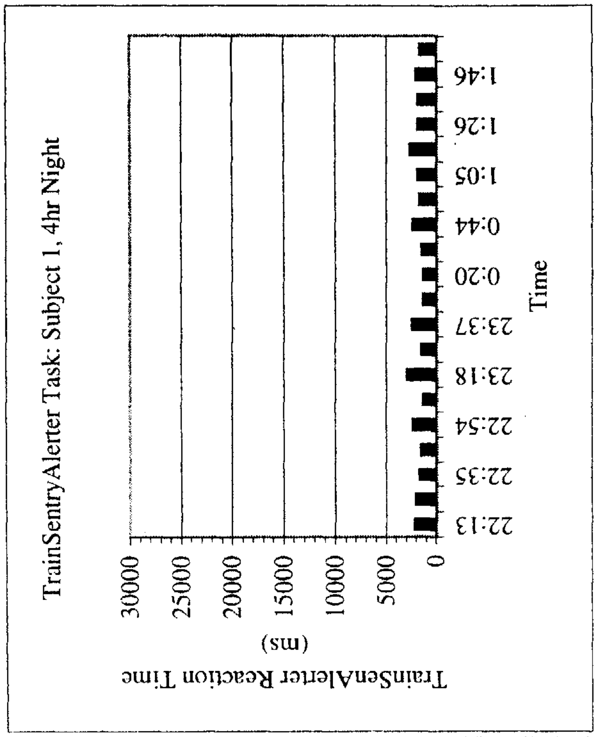
Subject 5 continued

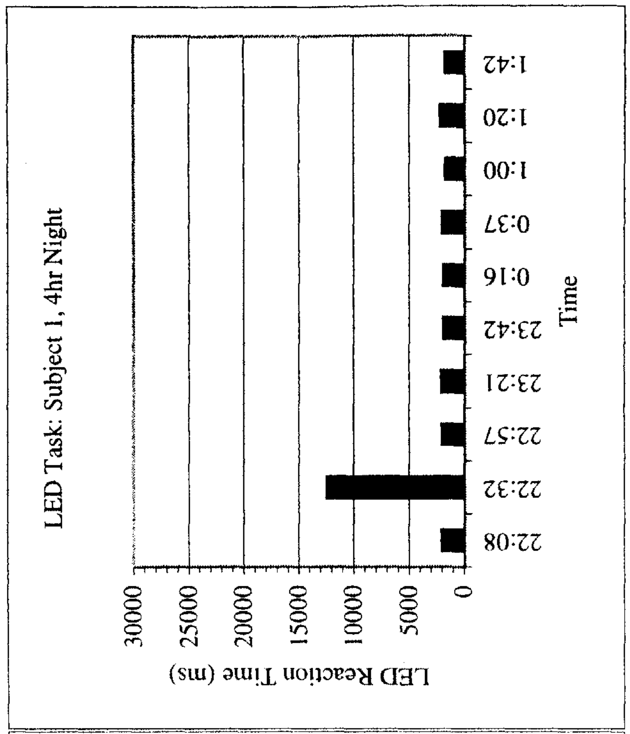
Exp Day	10	11	12	13	14
Wake	10:30am	9:00am	11:00am	9:30am	8:10am
DaySchedule	Regular	Regular	Regular	Regular	Regular
Sleep	2:00am	2:00am	1:00am	5:00am	------
Tests	------	------	------	------	Day Run

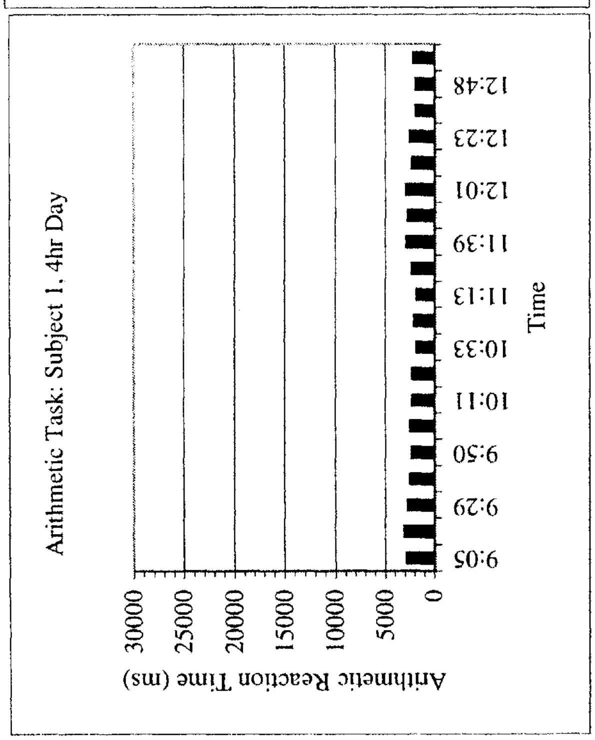
Subject 6

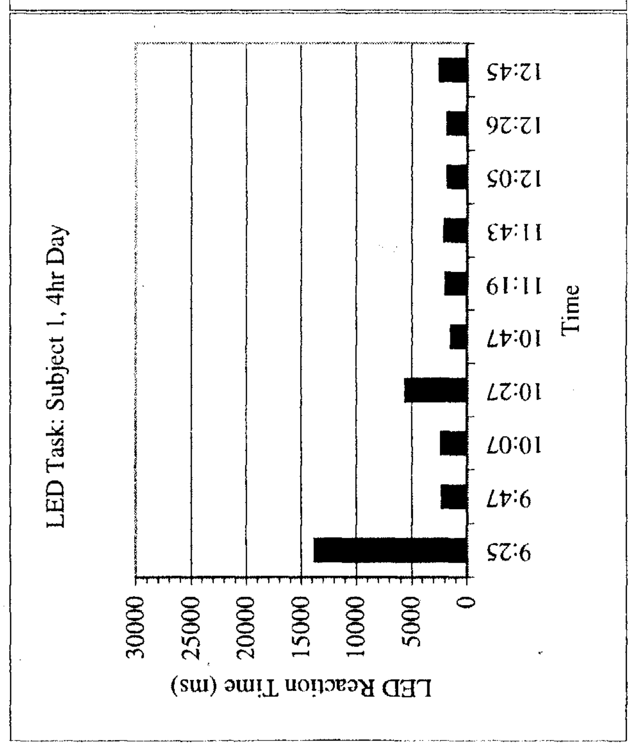
Exp Day	1	2	3	4	5	6	7
Wake	------	10:45am	10:12am	10:15am	7:45am	10:58am	12:10pm
DaySchedule	Regular	Regular	Regular	Regular	Regular	Regular	Regular
Sleep	4:00am	4:26am	4:00am	4:22am	12:50am	3:40am	------
Tests	Baseline1	------	Baseline 2	------	Day Run	------	Night Run

A2. Graphs of Reaction Times to Each Train Task (Train Sentry Alerter, Arithmetic, LED, Speed) for Each Subject

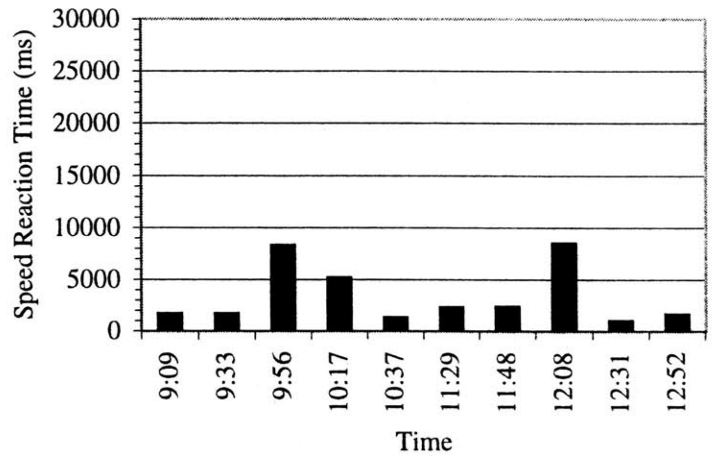




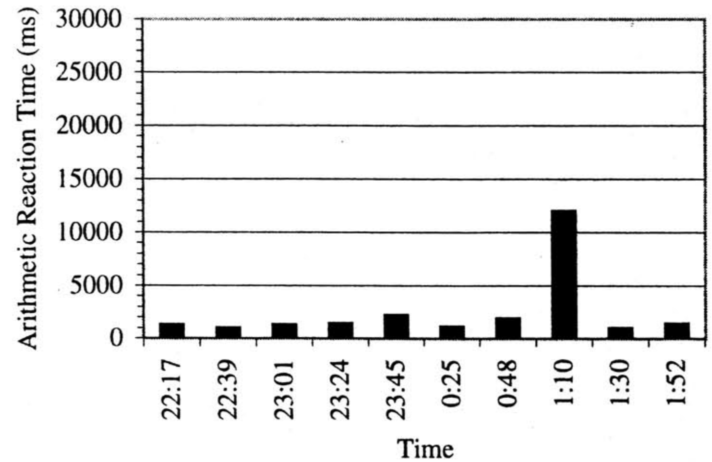




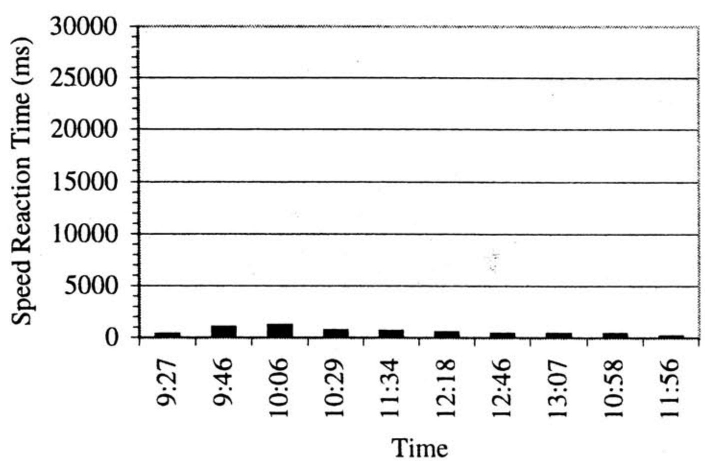
Speed Conformity Task: Subject 1, 4hr Day



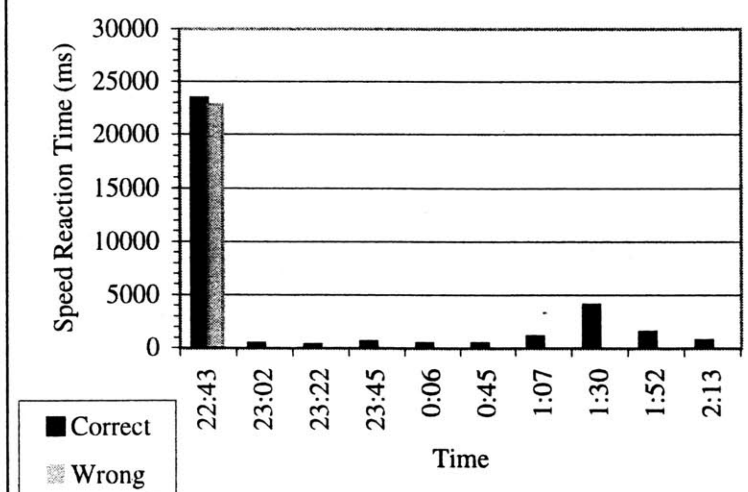
Speed Conformity Task: Subject 1, 4hr Night

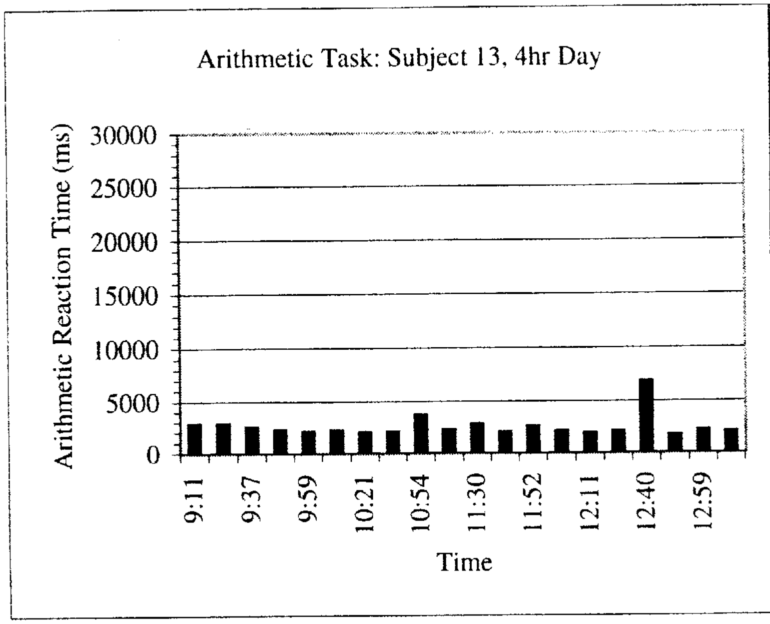


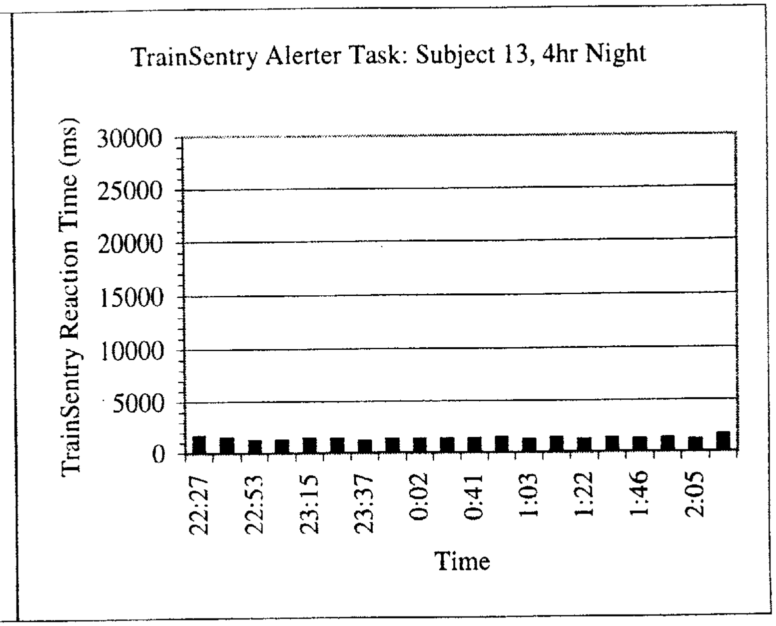
Speed Conformity Task: Subject 13, 4hr Day

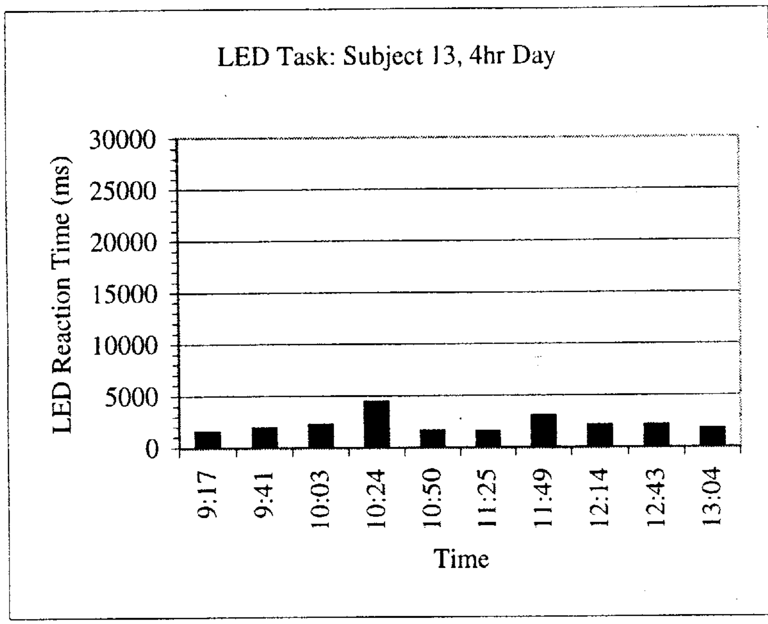


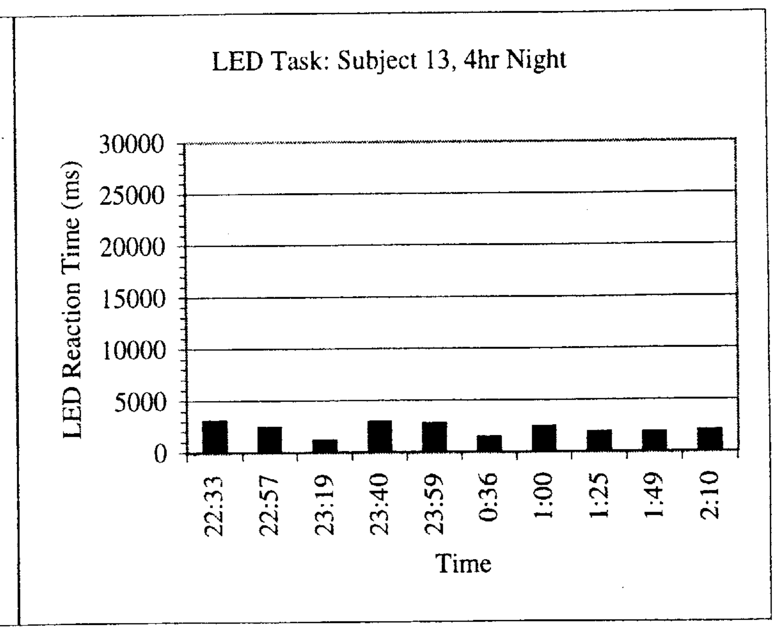
Speed Conformity Task: Subject 13, 4hr Night

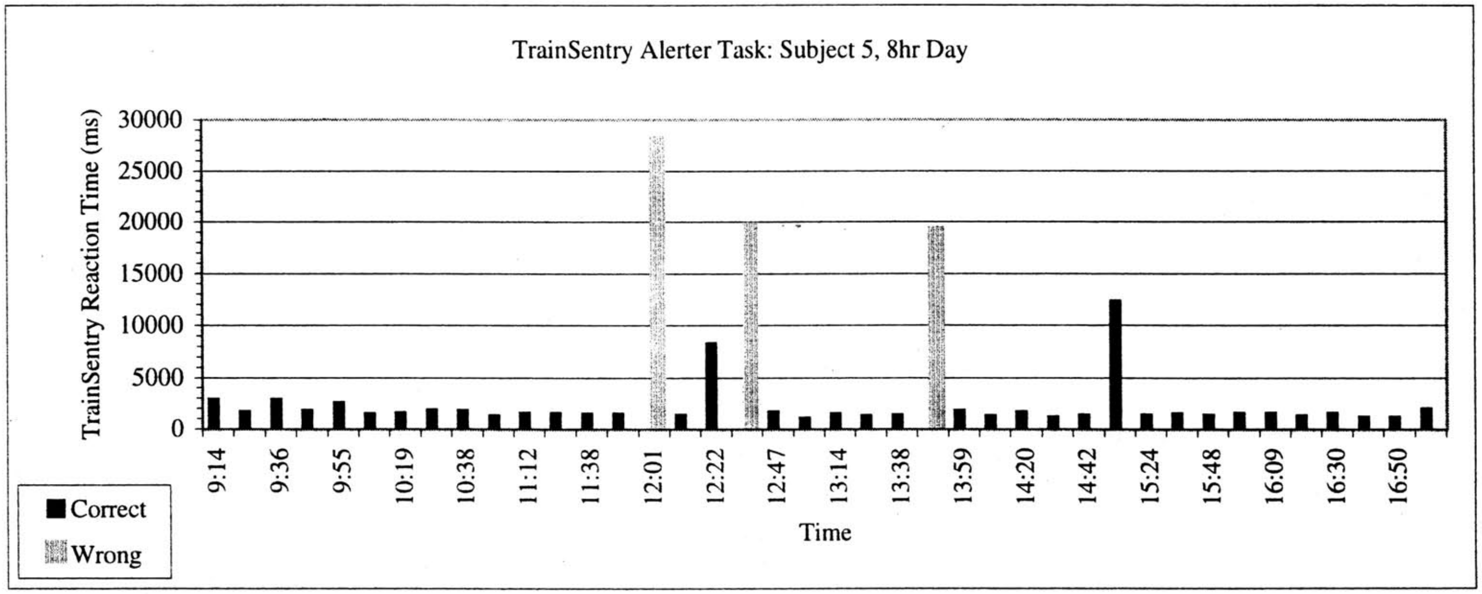


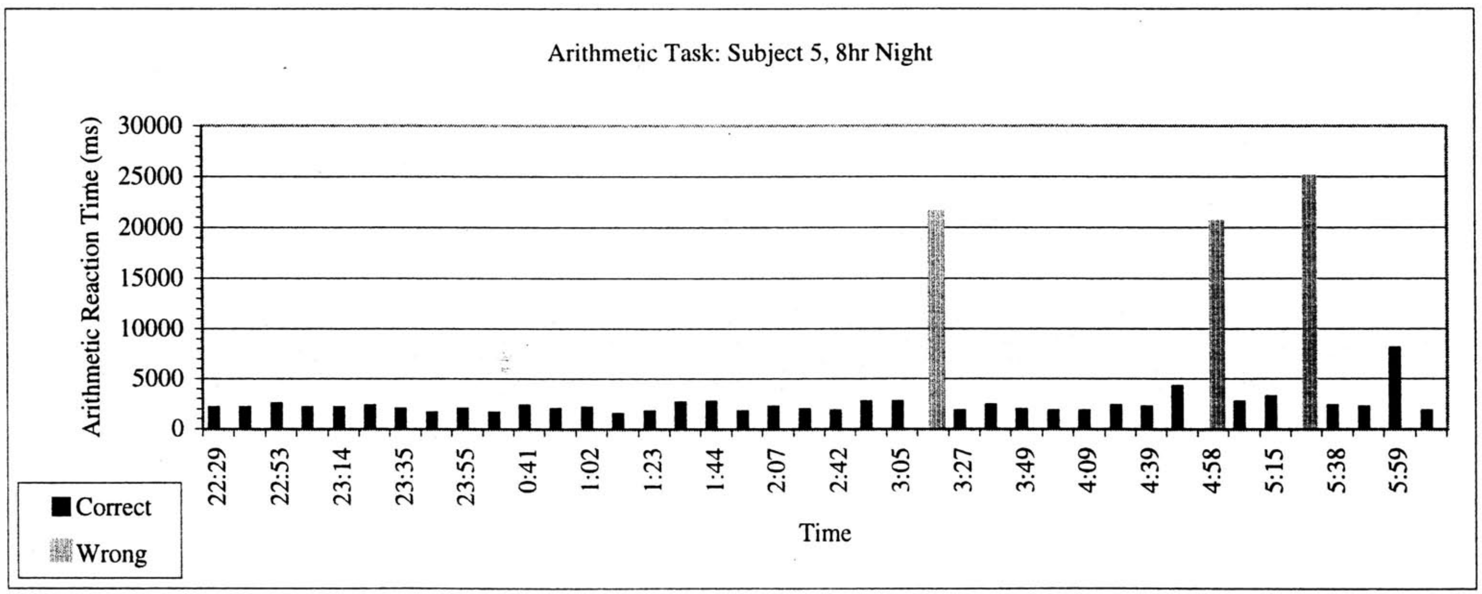

Arithmetic Task: Subject 13, 4hr Day
Arithmetic Reaction Time (ms)
30000
25000
20000
15000
10000
5000
0
9:11
9:37
9:59
10:21
10:54
11:30
11:52
12:11
12:40
12:59
Time

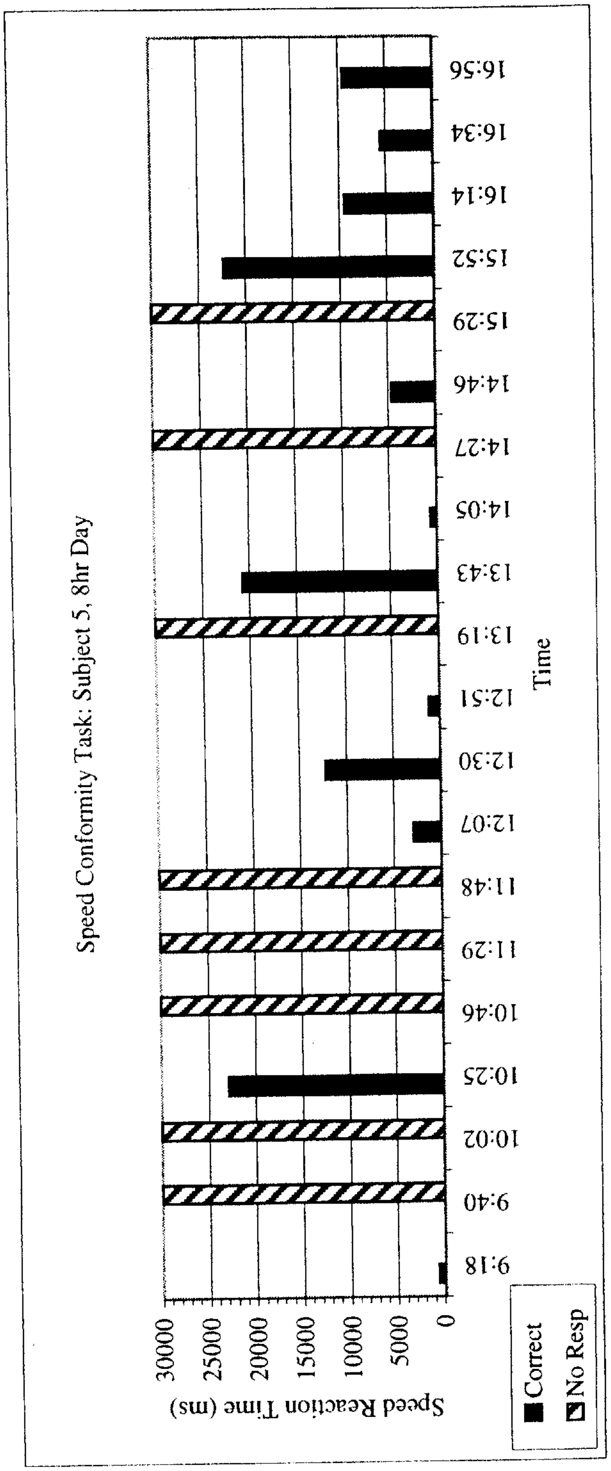

TrainSentry Alerter Task: Subject 13, 4hr Night
TrainSentry Reaction Time (ms)
30000
25000
20000
15000
10000
5000
0
22:27
22:53
23:15
23:37
0:02
0:41
1:03
1:22
1:46
2:05
Time

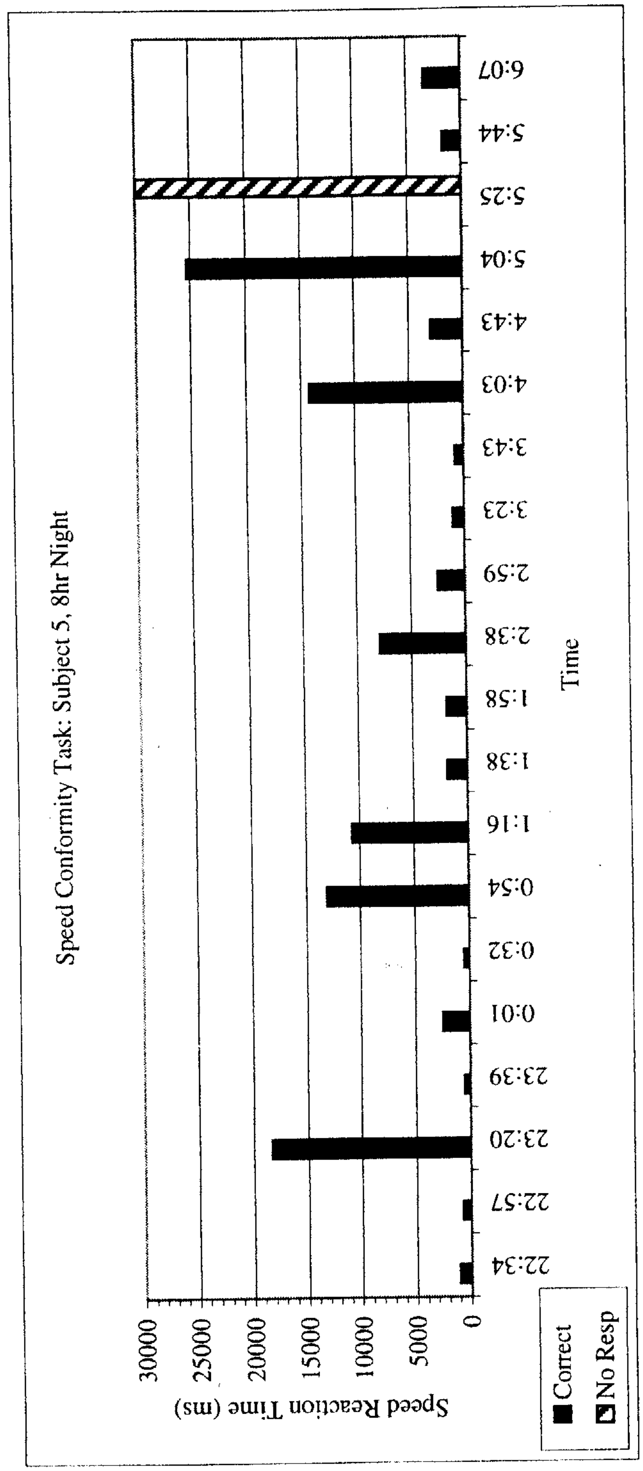

LED Task: Subject 13, 4hr Day
LED Reaction Time (ms)
30000
25000
20000
15000
10000
5000
0
9:17
9:41
10:03
10:24
10:50
11:25
11:49
12:14
12:43
13:04
Time

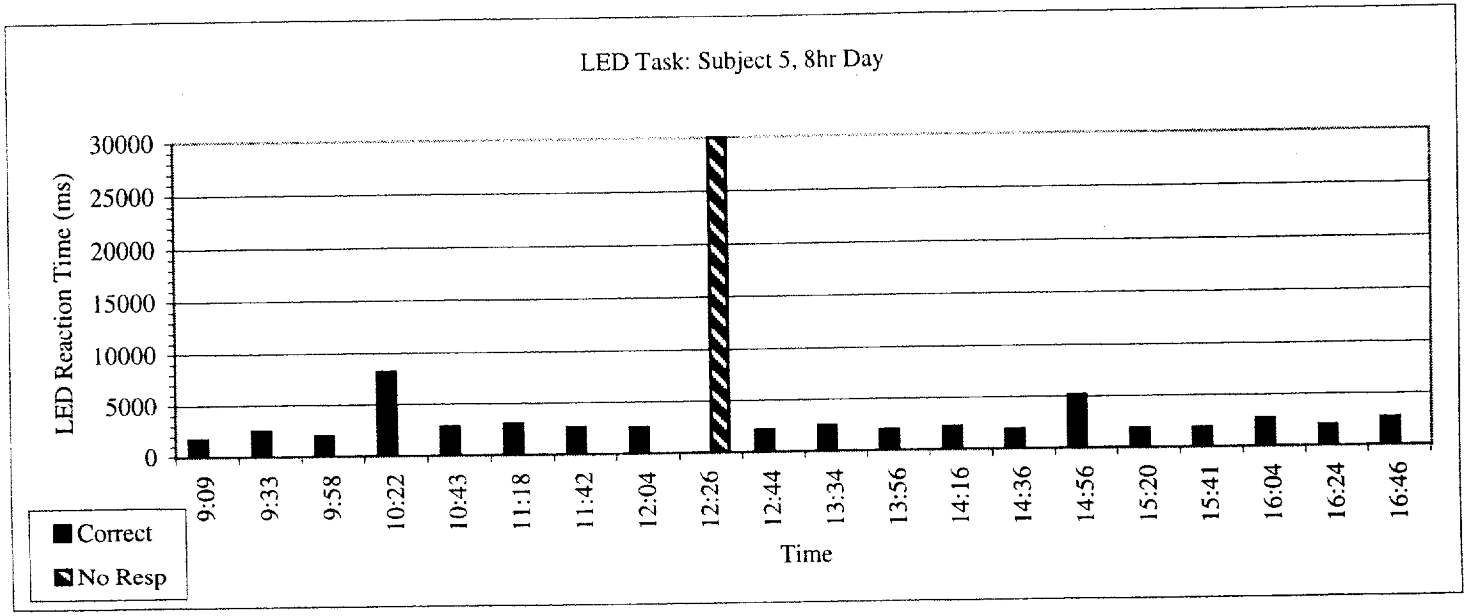

LED Task: Subject 13, 4hr Night
LED Reaction Time (ms)
30000
25000
20000
15000
10000
5000
0
22:33
22:57
23:19
23:40
23:59
0:36
1:00
1:25
1:49
2:10
Time

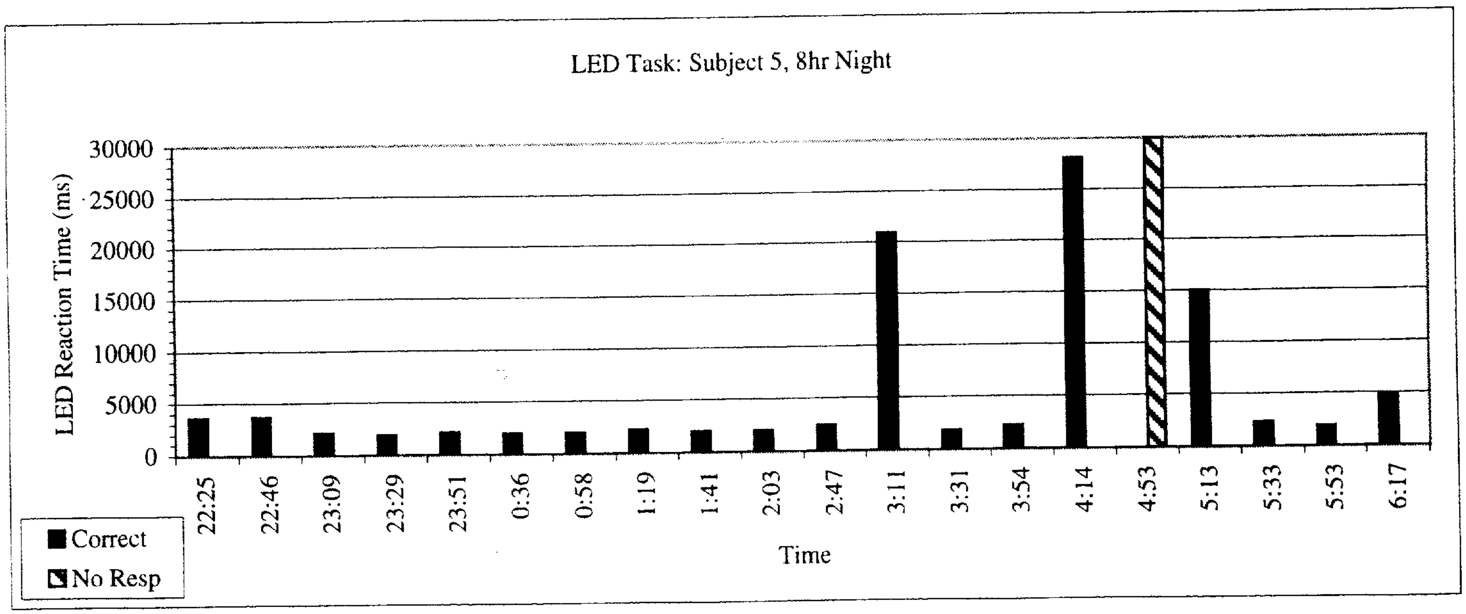

TrainSentry Alerter Task: Subject 5, 8hr Day
TrainSentry Reaction Time (ms)
30000
25000
20000
15000
10000
5000
0
9:14
9:36
9:55
10:19
10:38
11:12
11:38
12:01
12:22
12:47
13:14
13:38
13:59
14:20
14:42
15:24
15:48
16:09
16:30
16:50
Time
Correct
Wrong

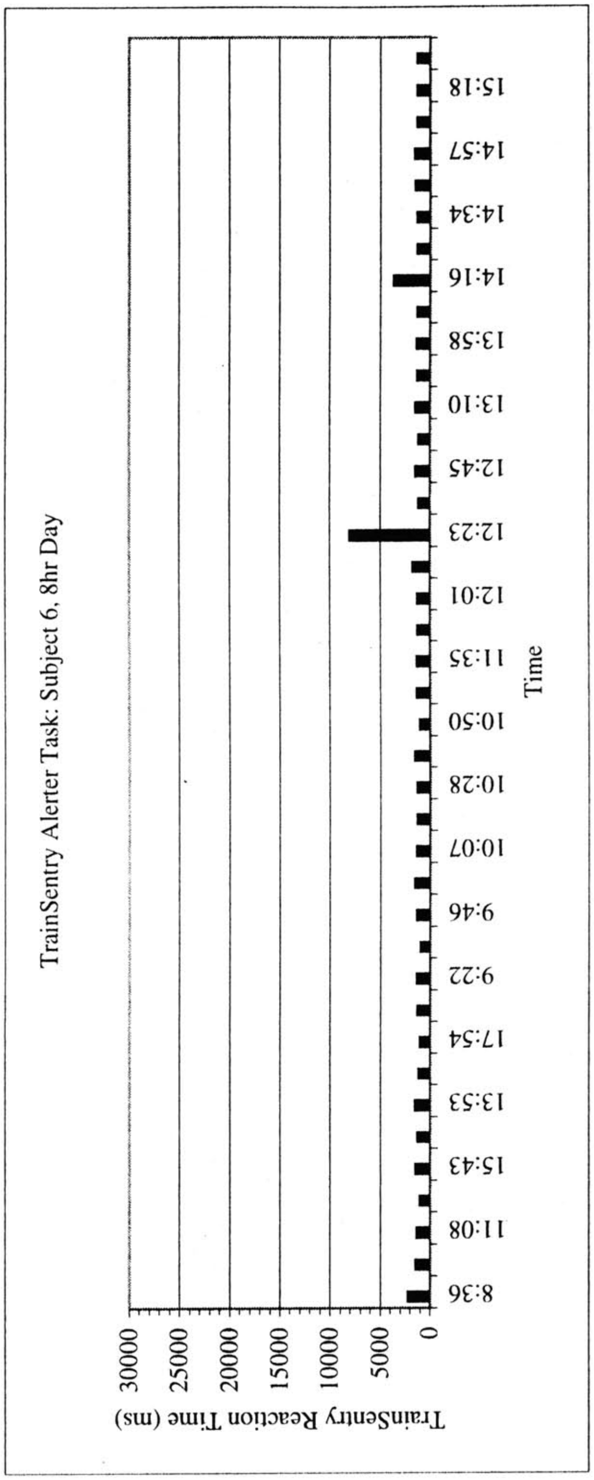

Arithmetic Task: Subject 5, 8hr Night
Arithmetic Reaction Time (ms)
30000
25000
20000
15000
10000
5000
0
22:29
22:53
23:14
23:35
23:55
0:41
1:02
1:23
1:44
2:07
2:42
3:05
3:27
3:49
4:09
4:39
4:58
5:15
5:38
5:59
Time
Correct
Wrong

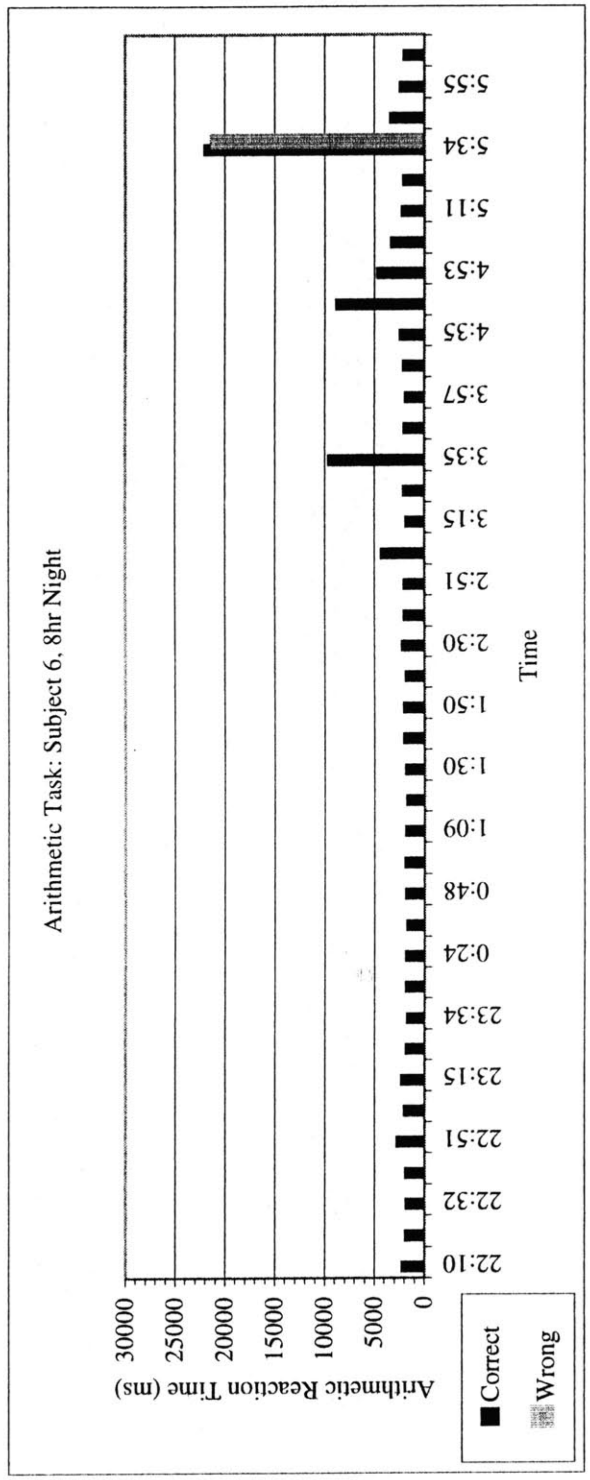

Speed Conformity Task: Subject 5, 8hr Day
Speed Reaction Time (ms)
30000
25000
20000
15000
10000
5000
0
Time
9:18
9:40
10:02
10:25
10:46
11:29
11:48
12:07
12:30
12:51
13:19
13:43
14:05
14:27
14:46
15:29
15:52
16:14
16:34
16:56
Correct
No Resp

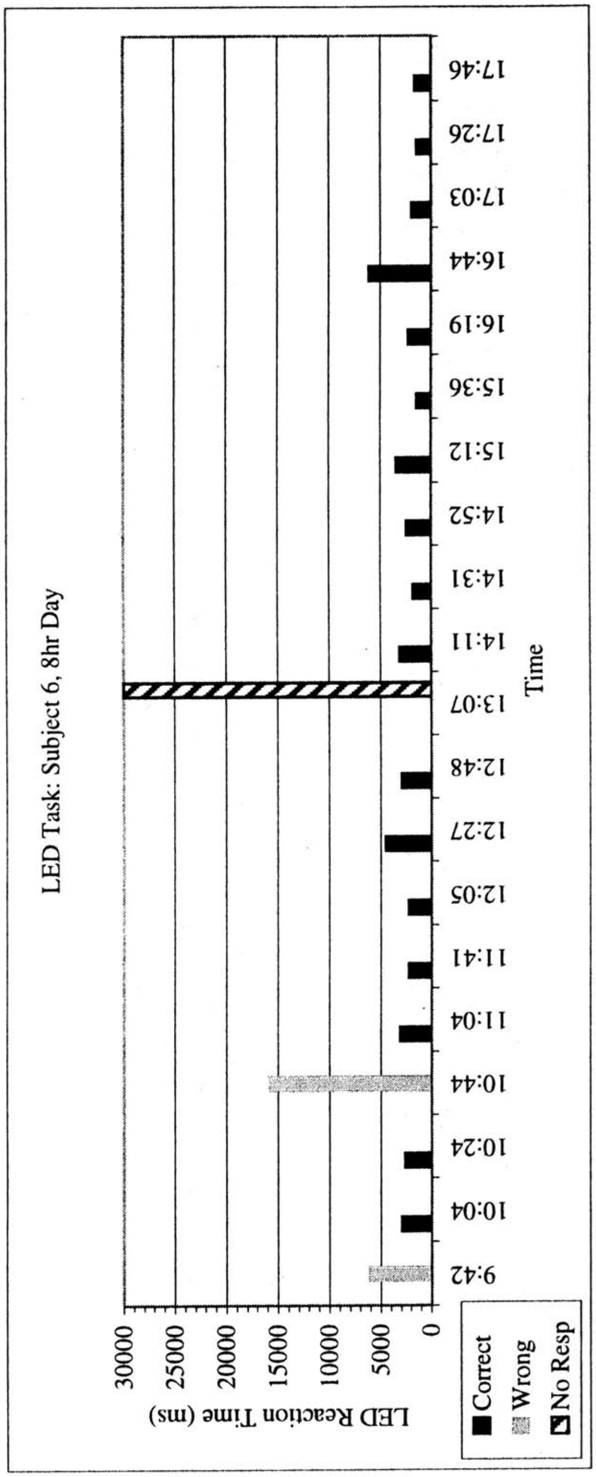

Speed Conformity Task: Subject 5, 8hr Night
Speed Reaction Time (ms)
30000
25000
20000
15000
10000
5000
0
Time
22:34
22:57
23:20
23:39
0:01
0:32
0:54
1:16
1:38
1:58
2:38
2:59
3:23
3:43
4:03
4:43
5:04
5:25
5:44
6:07
Correct
No Resp

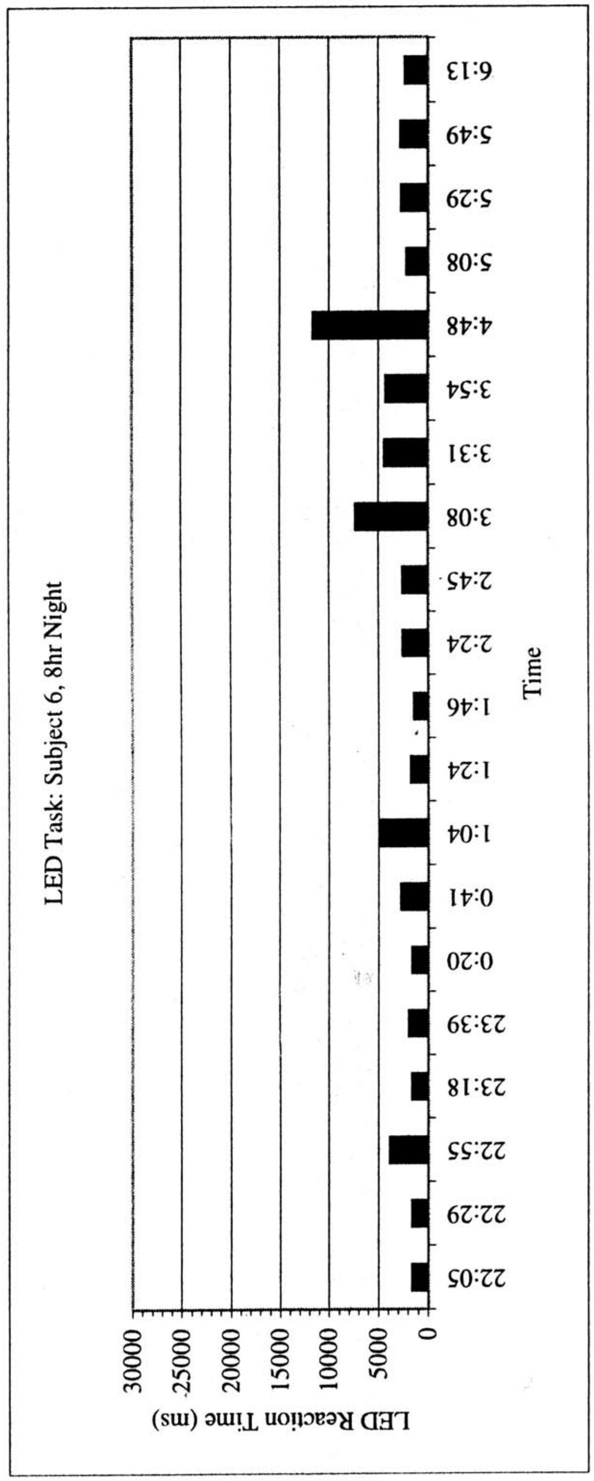

LED Task: Subject 5, 8hr Day
LED Reaction Time (ms)
30000
25000
20000
15000
10000
5000
0
9:09
9:33
9:58
10:22
10:43
11:18
11:42
12:04
12:26
12:44
13:34
13:56
14:16
14:36
14:56
15:20
15:41
16:04
16:24
16:46
Time
Correct
No Resp

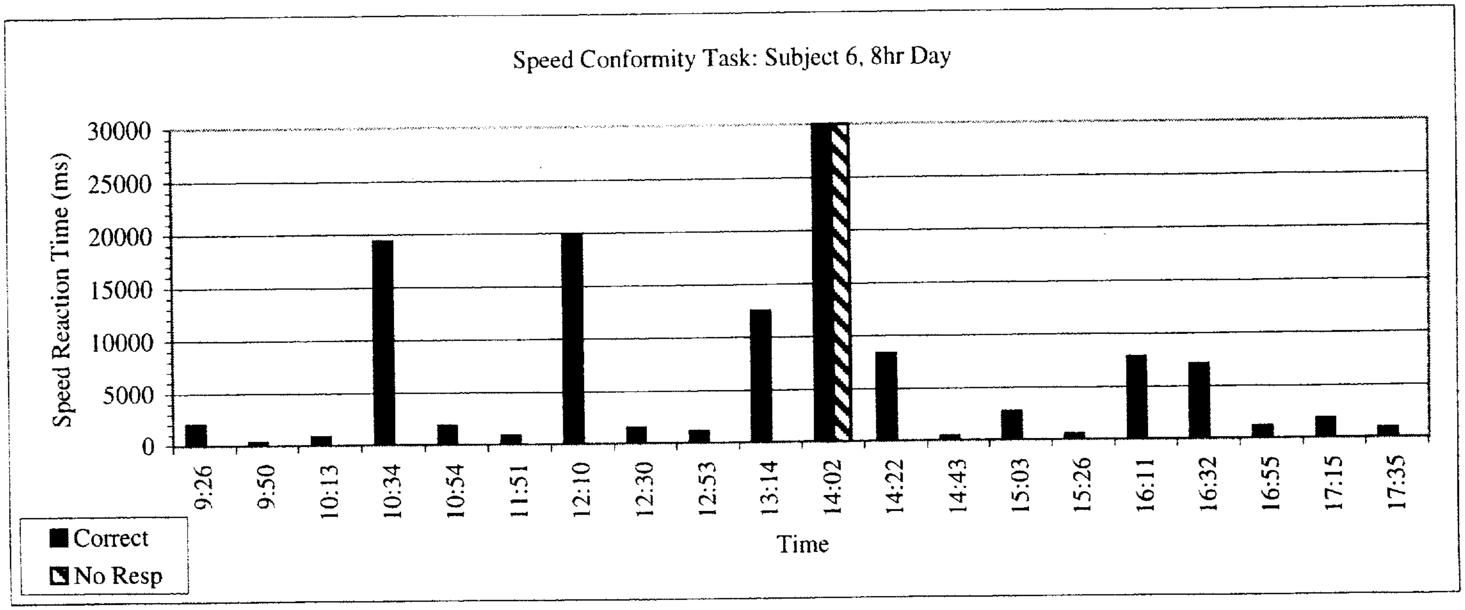

LED Task: Subject 5, 8hr Night
LED Reaction Time (ms)
30000
25000
20000
15000
10000
5000
0
22:25
22:46
23:09
23:29
23:51
0:36
0:58
1:19
1:41
2:03
2:47
3:11
3:31
3:54
4:14
4:53
5:13
5:33
5:53
6:17
Time
Correct
No Resp

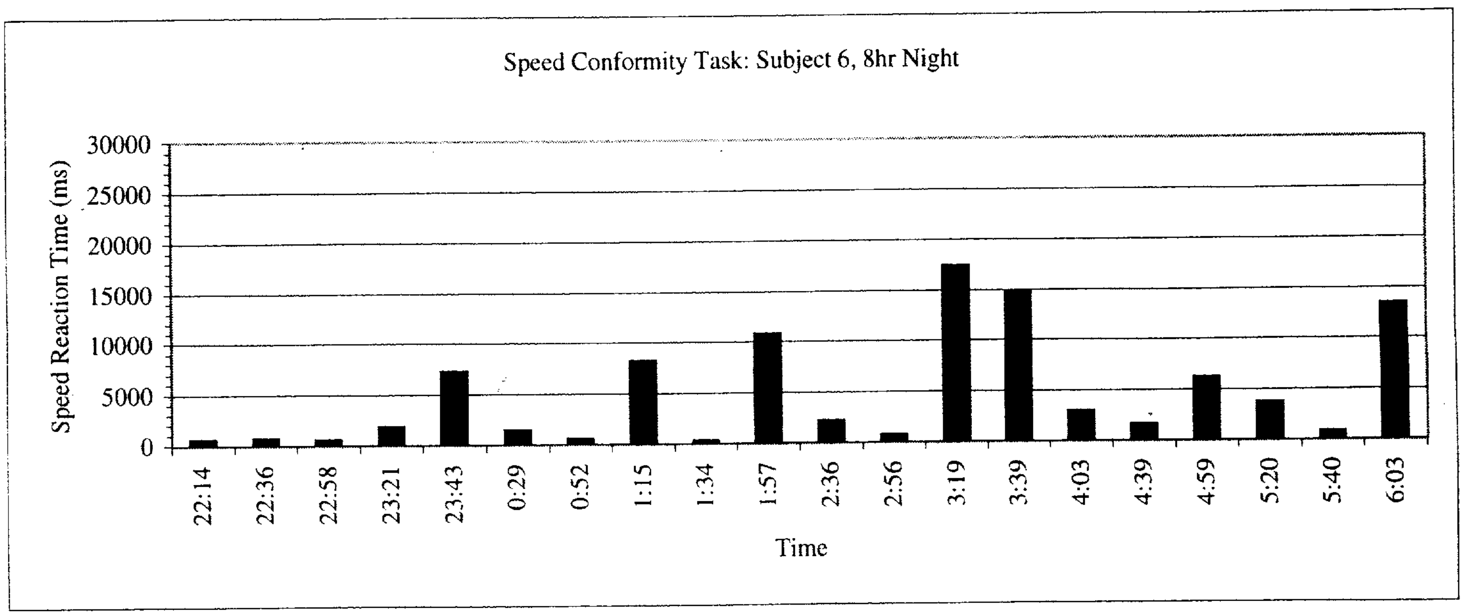

TrainSentry Alerter Task: Subject 6, 8hr Day
TrainSentry Reaction Time (ms)
30000
25000
20000
15000
10000
5000
0
8:36
11:08
15:43
13:53
17:54
9:22
9:46
10:07
10:28
10:50
11:35
12:01
12:23
12:45
13:10
13:58
14:16
14:34
14:57
15:18
Time


Arithmetic Task: Subject 6, 8hr Night
Arithmetic Reaction Time (ms)
30000
25000
20000
15000
10000
5000
0
22:10
22:32
22:51
23:15
23:34
0:24
0:48
1:09
1:30
1:50
2:30
2:51
3:15
3:35
3:57
4:35
4:53
5:11
5:34
5:55
Time
Correct
Wrong

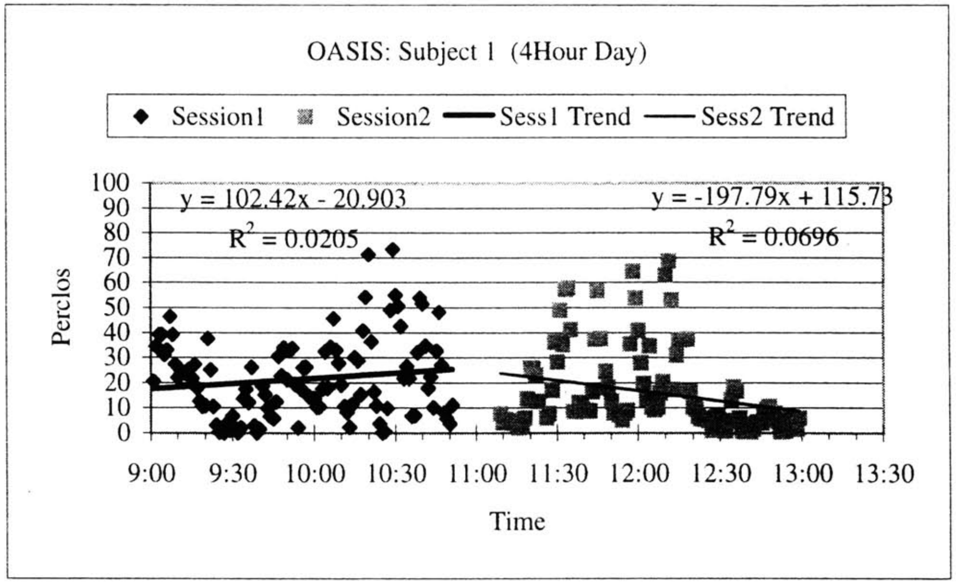

LED Task: Subject 6, 8hr Day
LED Reaction Time (ms)
30000
25000
20000
15000
10000
5000
0
9:42
10:04
10:24
10:44
11:04
11:41
12:05
12:27
12:48
13:07
14:11
14:31
14:52
15:12
15:36
16:19
16:44
17:03
17:26
17:46
Time
Correct
Wrong
No Resp

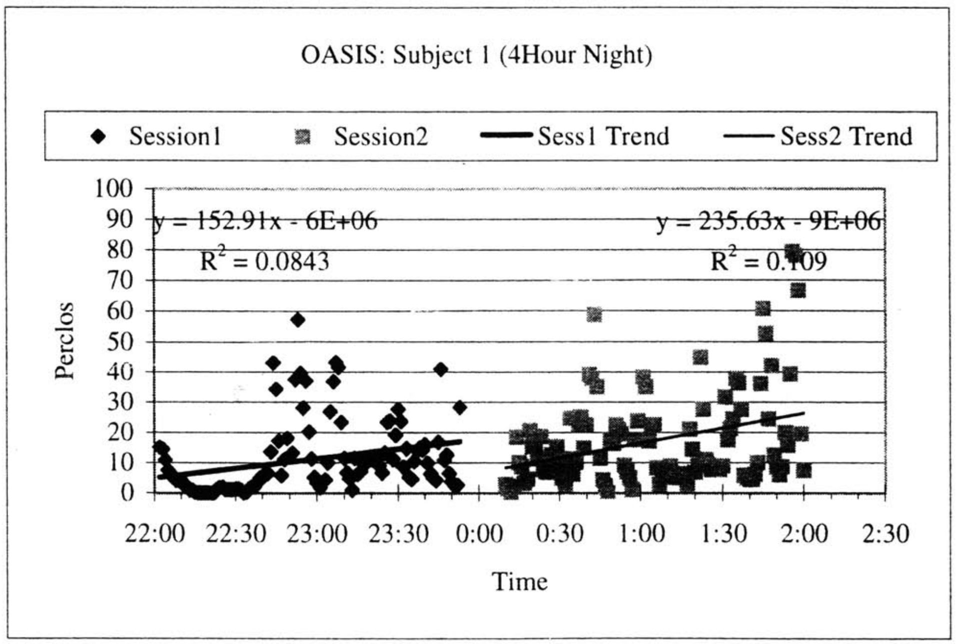

LED Task: Subject 6, 8hr Night
LED Reaction Time (ms)
30000
25000
20000
15000
10000
5000
0
22:05
22:29
22:55
23:18
23:39
0:20
0:41
1:04
1:24
1:46
2:24
2:45
3:08
3:31
3:54
4:48
5:08
5:29
5:49
6:13
Time

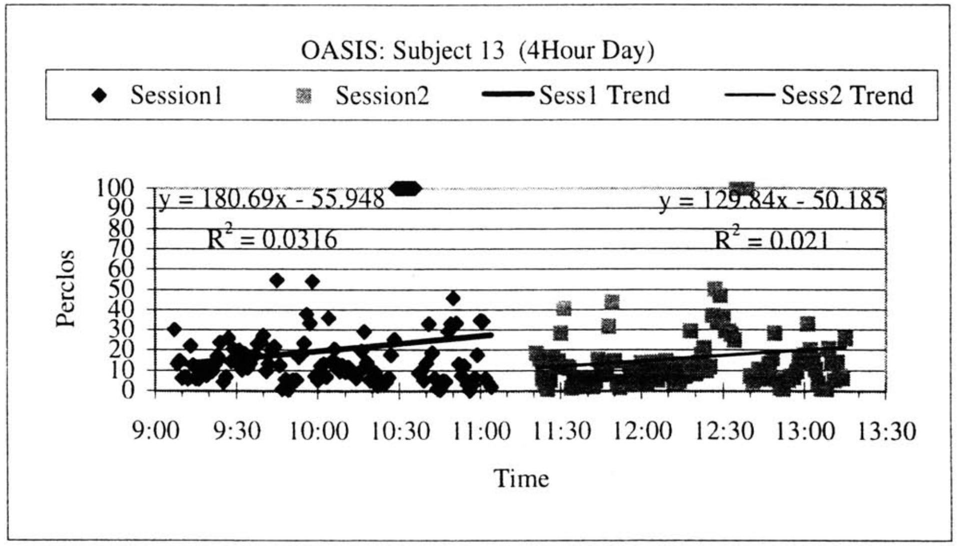

Speed Conformity Task: Subject 6, 8hr Day
Speed Reaction Time (ms)
30000
25000
20000
15000
10000
5000
0
9:26
9:50
10:13
10:34
10:54
11:51
12:10
12:30
12:53
13:14
14:02
14:22
14:43
15:03
15:26
16:11
16:32
16:55
17:15
17:35
Time
Correct
No Resp

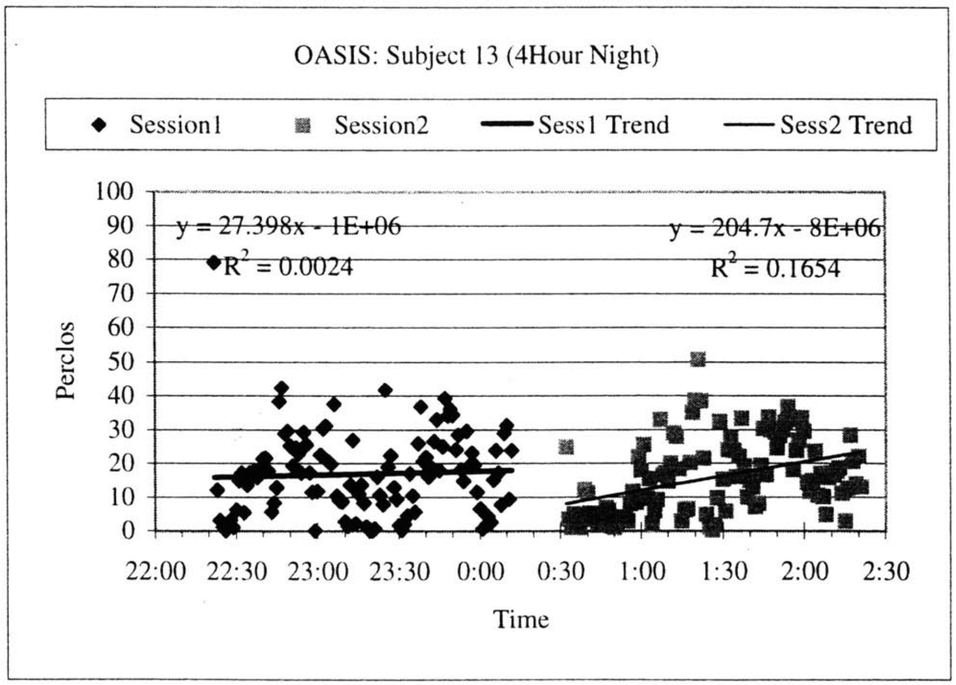

Speed Conformity Task: Subject 6, 8hr Night
Speed Reaction Time (ms)
30000
25000
20000
15000
10000
5000
0
22:14
22:36
22:58
23:21
23:43
0:29
0:52
1:15
1:34
1:57
2:36
2:56
3:19
3:39
4:03
4:39
4:59
5:20
5:40
6:03
Time

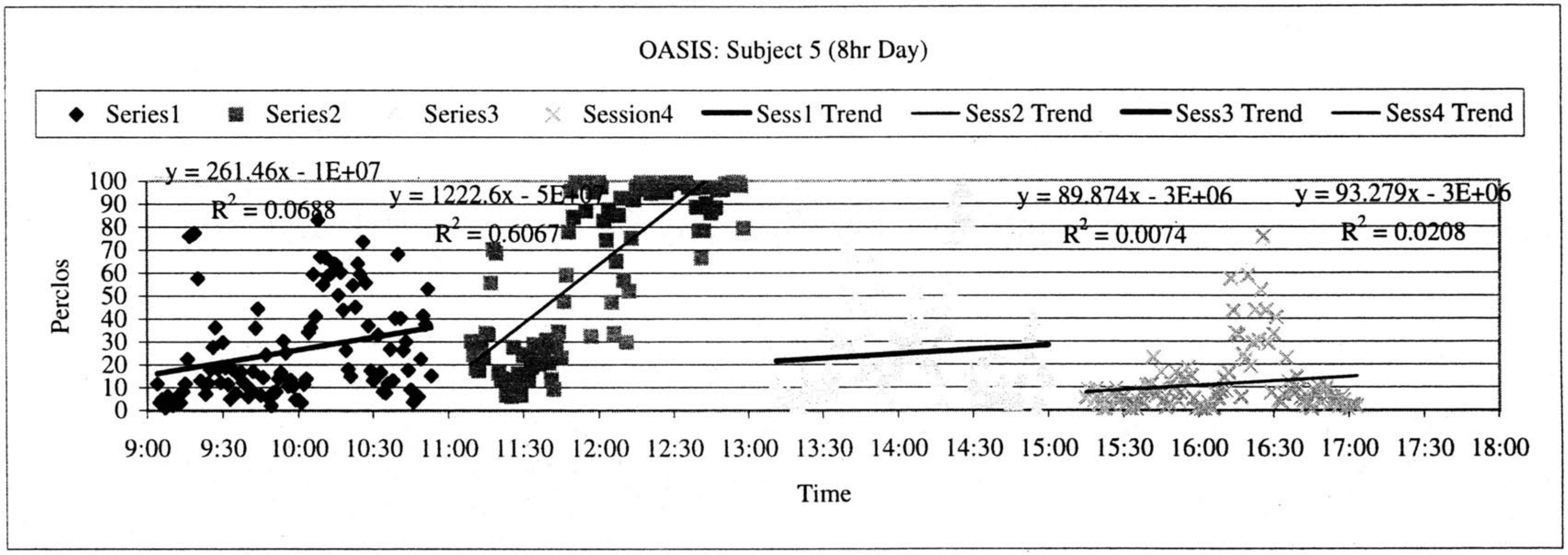
A3. Graphs of Perclos Values over Simulator Run Time for Each Subject

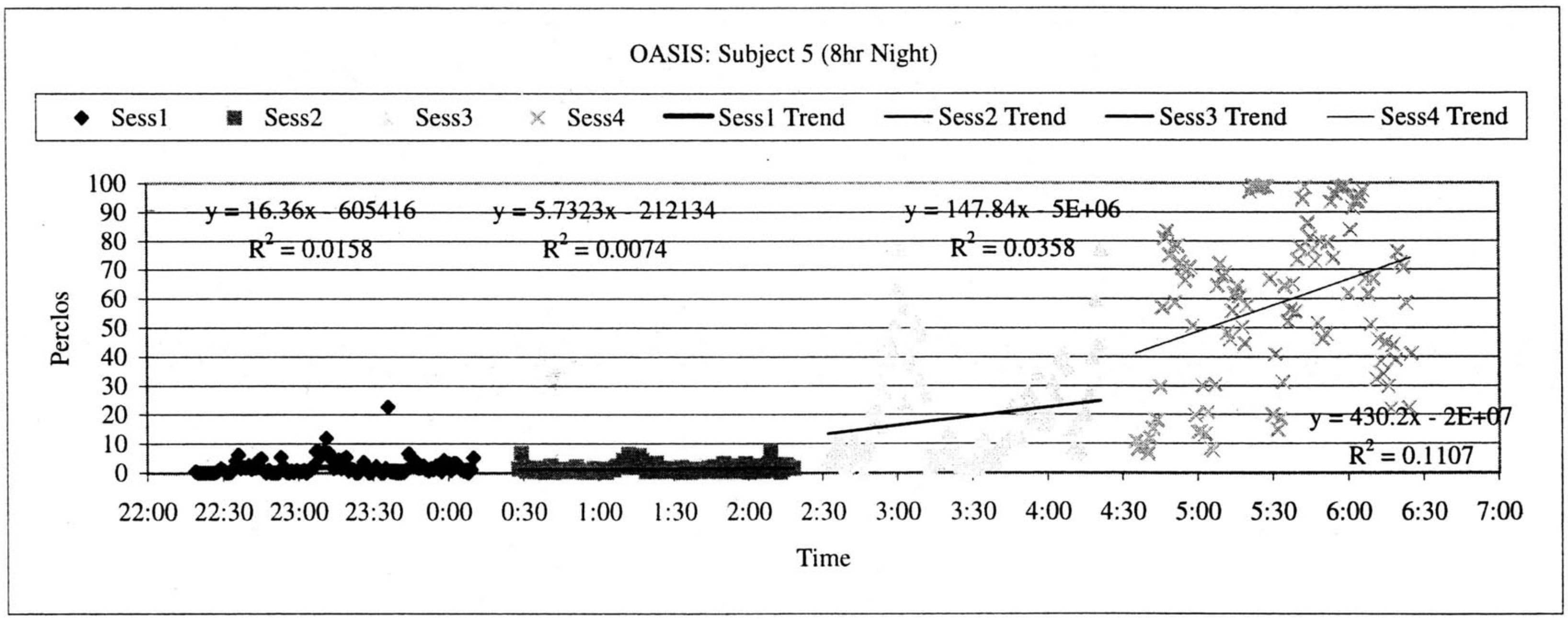


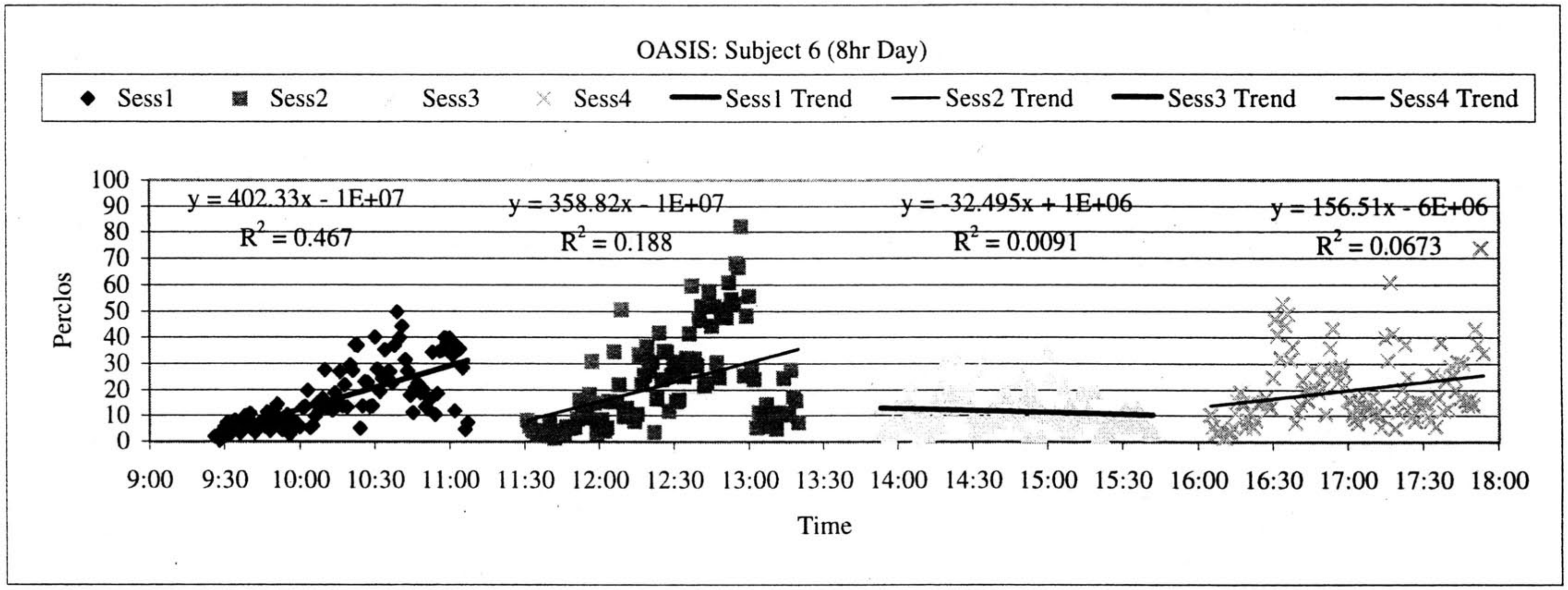


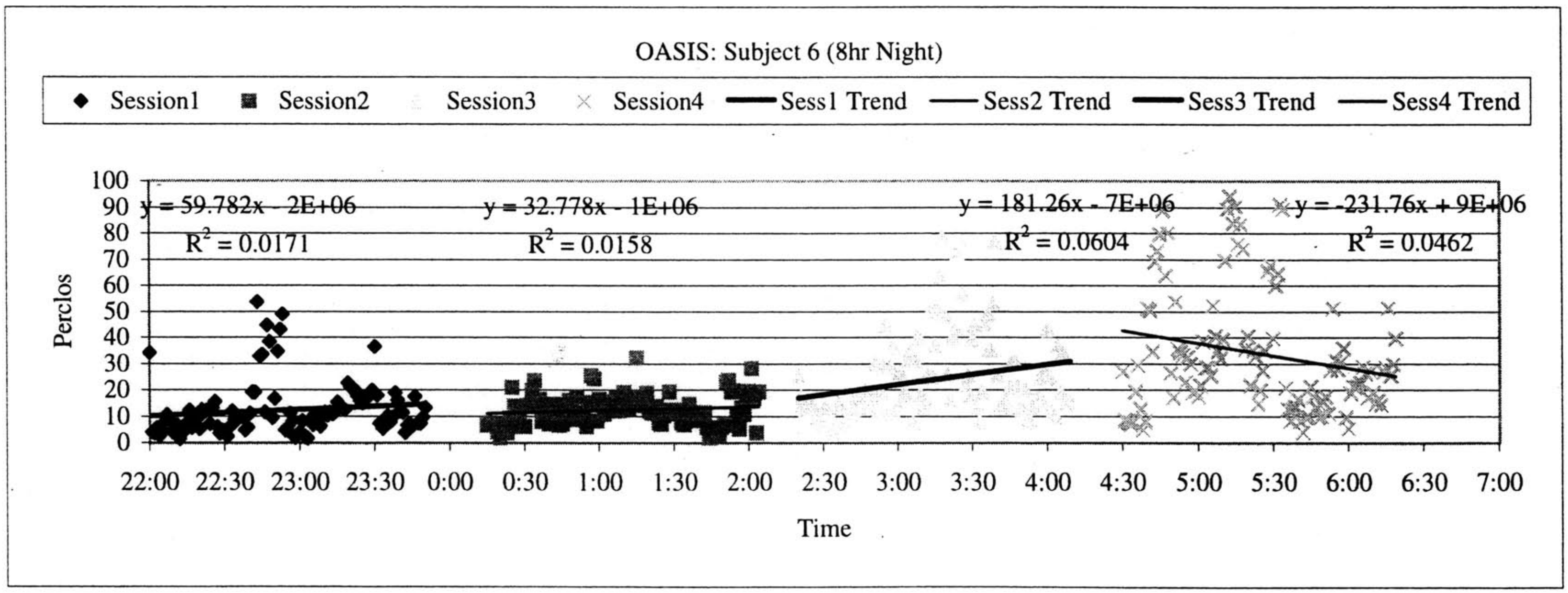

OASIS: Subject 13 (4Hour Day)
Session1
Session2
Sess1 Trend
Sess2 Trend
y = 180.69x - 55.948
R² = 0.0316
y = 129.84x - 50.185
R² = 0.021
Perclos
100
90
80
70
60
50
40
30
20
10
0
9:00
9:30
10:00
10:30
11:00
11:30
12:00
12:30
13:00
13:30
Time


OASIS: Subject 13 (4Hour Night)
Session1
Session2
Sess1 Trend
Sess2 Trend
y = 27.398x - 1E+06
R² = 0.0024
y = 204.7x - 8E+06
R² = 0.1654
Perclos
100
90
80
70
60
50
40
30
20
10
0
22:00
22:30
23:00
23:30
0:00
0:30
1:00
1:30
2:00
2:30
Time


OASIS: Subject 5 (8hr Day)
Series1
Series2
Series3
Session4
Sess1 Trend
Sess2 Trend
Sess3 Trend
Sess4 Trend
y = 261.46x - 1E+07
R^2 = 0.0688
y = 1222.6x - 5E+07
R^2 = 0.6067
y = 89.874x - 3E+06
R^2 = 0.0074
y = 93.279x - 3E+06
R^2 = 0.0208
Perclos
0
10
20
30
40
50
60
70
80
90
100
9:00
9:30
10:00
10:30
11:00
11:30
12:00
12:30
13:00
13:30
14:00
14:30
15:00
15:30
16:00
16:30
17:00
17:30
18:00
Time


OASIS: Subject 5 (8hr Night)
Sess1
Sess2
Sess3
Sess4
Sess1 Trend
Sess2 Trend
Sess3 Trend
Sess4 Trend
y = 16.36x - 605416
R^2 = 0.0158
y = 5.7323x - 212134
R^2 = 0.0074
y = 147.84x - 5E+06
R^2 = 0.0358
y = 430.2x - 2E+07
R^2 = 0.1107
Perclos
0
10
20
30
40
50
60
70
80
90
100
22:00
22:30
23:00
23:30
0:00
0:30
1:00
1:30
2:00
2:30
3:00
3:30
4:00
4:30
5:00
5:30
6:00
6:30
7:00
Time


OASIS: Subject 6 (8hr Day)
Sess1
Sess2
Sess3
Sess4
Sess1 Trend
Sess2 Trend
Sess3 Trend
Sess4 Trend
y = 402.33x - 1E+07
R^2 = 0.467
y = 358.82x - 1E+07
R^2 = 0.188
y = -32.495x + 1E+06
R^2 = 0.0091
y = 156.51x - 6E+06
R^2 = 0.0673
Perclos
0 10 20 30 40 50 60 70 80 90 100
9:00 9:30 10:00 10:30 11:00 11:30 12:00 12:30 13:00 13:30 14:00 14:30 15:00 15:30 16:00 16:30 17:00 17:30 18:00
Time


OASIS: Subject 6 (8hr Night)
Session1
Session2
Session3
Session4
Sess1 Trend
Sess2 Trend
Sess3 Trend
Sess4 Trend
y = 59.782x - 2E+06
R^2 = 0.0171
y = 32.778x - 1E+06
R^2 = 0.0158
y = 181.26x - 7E+06
R^2 = 0.0604
y = -231.76x + 9E+06
R^2 = 0.0462
Perclos
0 10 20 30 40 50 60 70 80 90 100
22:00 22:30 23:00 23:30 0:00 0:30 1:00 1:30 2:00 2:30 3:00 3:30 4:00 4:30 5:00 5:30 6:00 6:30 7:00
Time

A4. Regression Graphs for Each Subject

a. Regression Between Train Task Reaction Time and Average Perclos 2Minutes Before Train Task

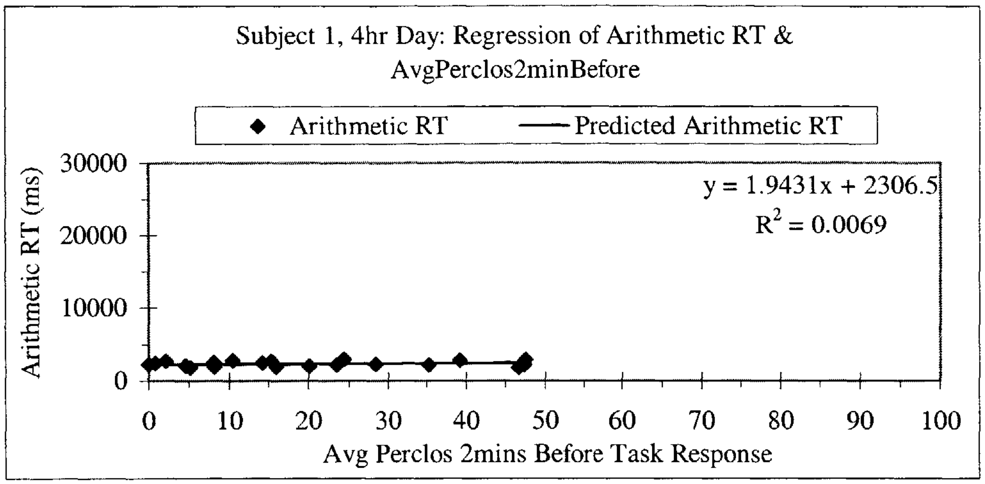
b. Regression Between Train Task Reaction Time and Average Perclos 2Minutes After Train Task

Subject 1: Correlation of Perclos Before each task & Task RT and Correlation of Perclos After each task & Task RT

	Arith Day	TrainSen Night	LED Day	LED Night	Speed Day	Speed Night
AvgPerclos2minsBefore	0.083	0.020	0.308	0.438	0.077	0.047
AvgPerclos2minsAfter	0.022	0.202	0.149	0.404	0.400	0.188

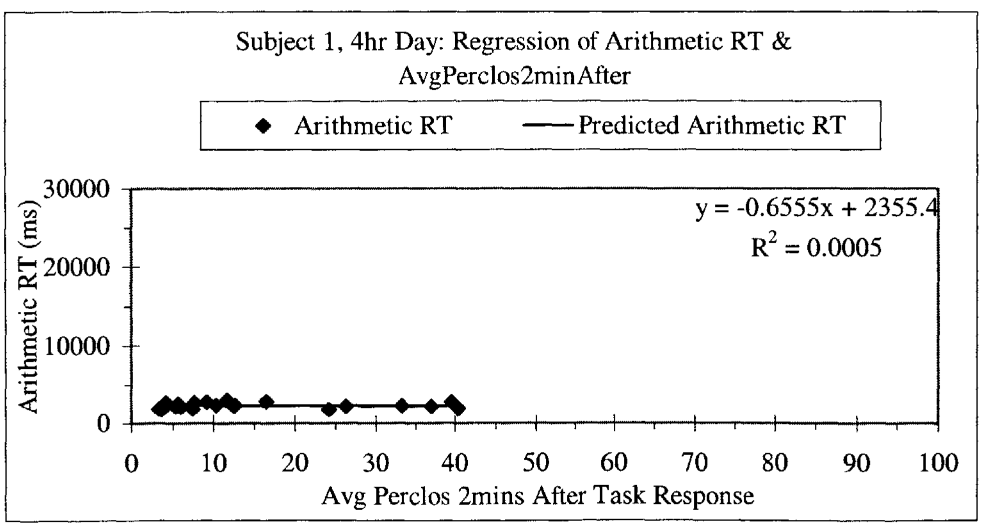
SUMMARY OUTPUT: Subject 1, Regression (ArithRT & PerclosBefore- 4hr Day)

Regression Statistics	
Multiple R	0.083
R Square	0.007
Adjusted R Square	-0.048
Standard Error	383.766
Observations	20.000



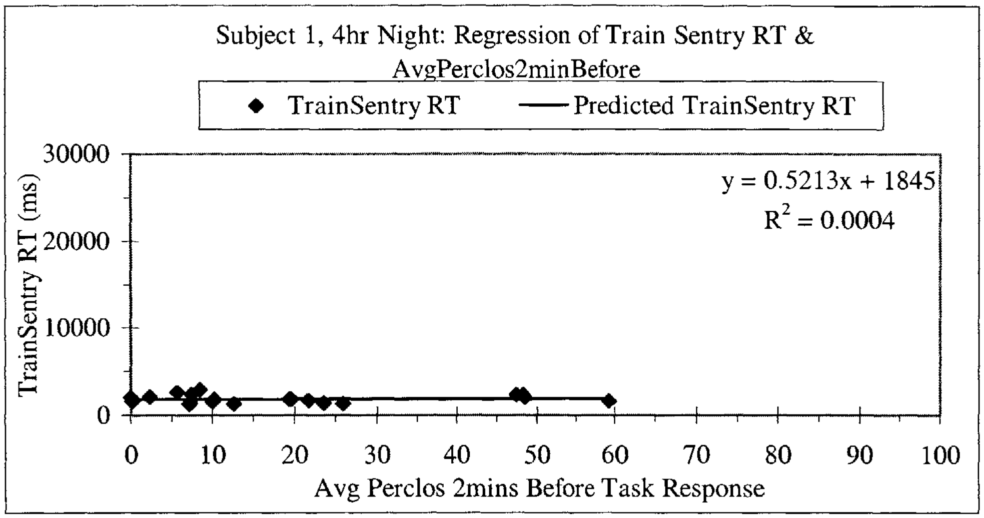
SUMMARY OUTPUT: Subject 1, Regression (ArithRT & PerclosAfter- 4hr Day)

Regression Statistics	
Multiple R	0.022
R Square	0.000
Adjusted R Square	-0.055
Standard Error	385.008
Observations	20.000



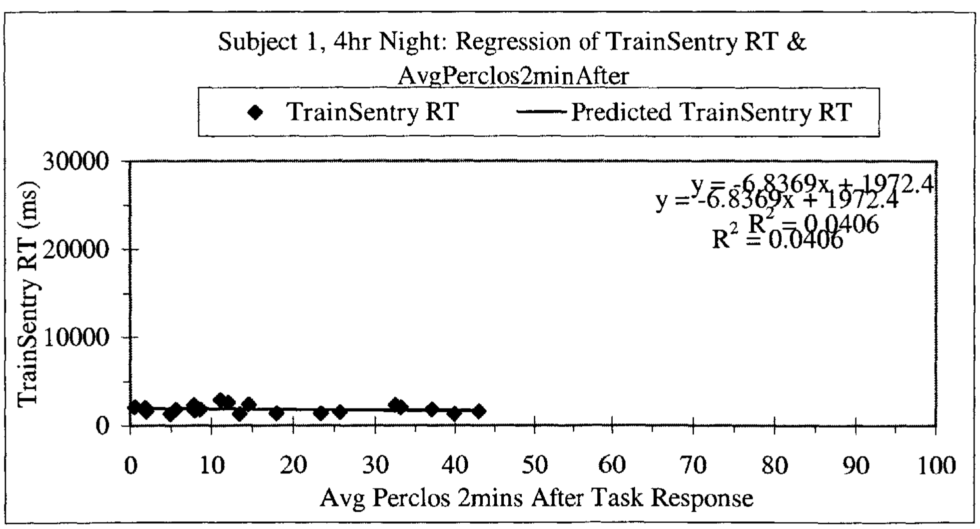
SUMMARY OUTPUT: Subject 1, Regression (TrainSentry & PerclosBefore- 4hr Night)

Regression Statistics	
Multiple R	0.020
R Square	0.000
Adjusted R Square	-0.055
Standard Error	475.385
Observations	20.000



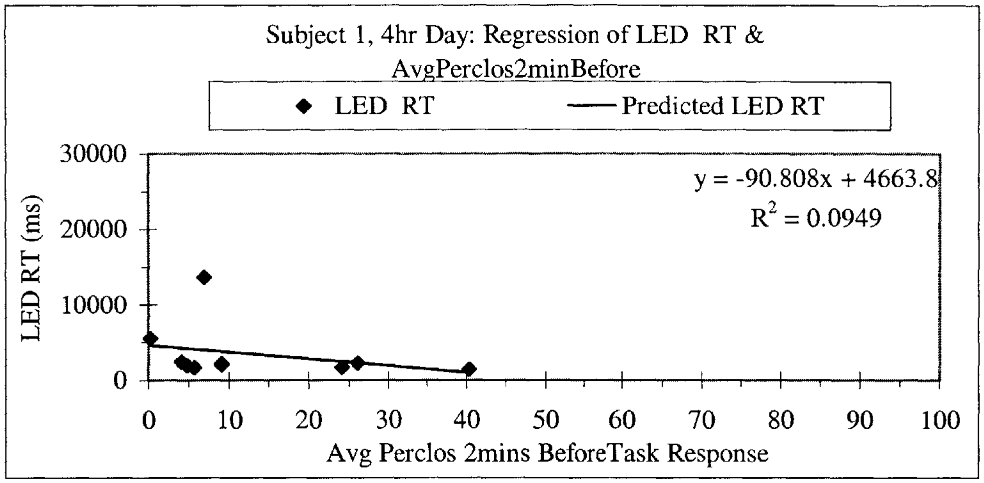
SUMMARY OUTPUT: Subject 1, Regression (TrainSentry & PerclosAfter- 4hr Night)

Regression Statistics	
Multiple R	0.202
R Square	0.041
Adjusted R Square	-0.013
Standard Error	465.721
Observations	20.000



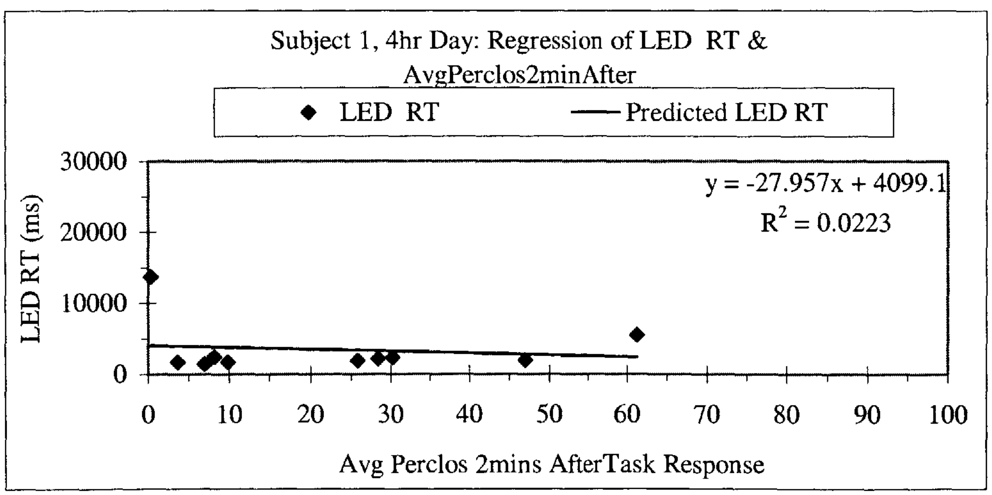
SUMMARY OUTPUT: Subject 1, Regression (LED & PerclosBefore- 4hr Day)

Regression Statistics	
Multiple R	0.308
R Square	0.095
Adjusted R Square	-0.018
Standard Error	3806.563
Observations	10.000



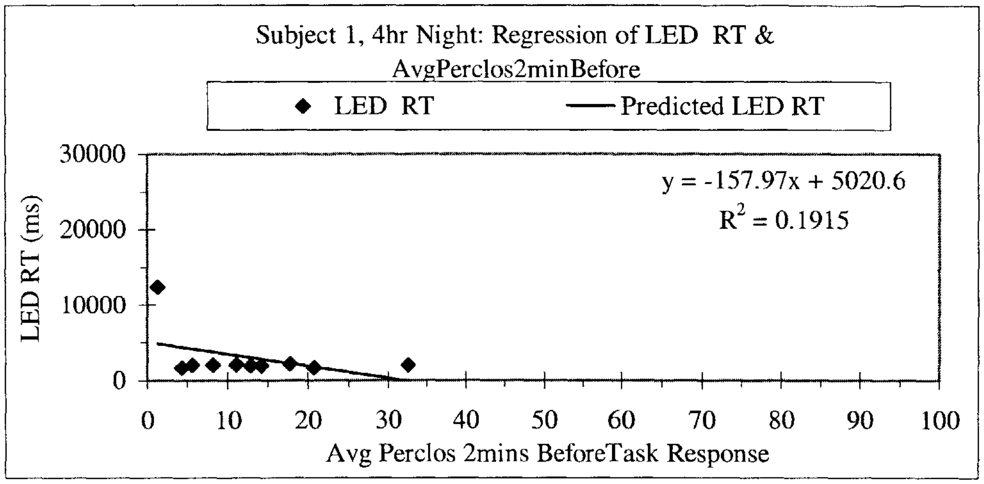
SUMMARY OUTPUT: Subject 1, Regression (LED & PerclosAfter- 4hr Day)

Regression Statistics	
Multiple R	0.149
R Square	0.022
Adjusted R Square	-0.100
Standard Error	3956.290
Observations	10.000



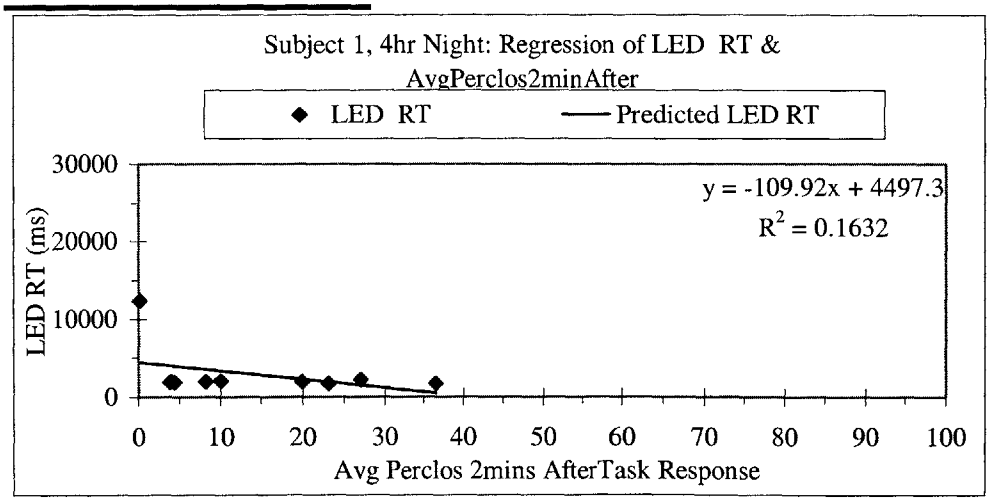
SUMMARY OUTPUT: Subject 1, Regression (LED & PerclosBefore- 4hr Night)

Regression Statistics	
Multiple R	0.438
R Square	0.192
Adjusted R Square	0.090
Standard Error	3156.780
Observations	10.000



SUMMARY OUTPUT: Subject 1, Regression (LED & PerclosAfter- 4hr Night)

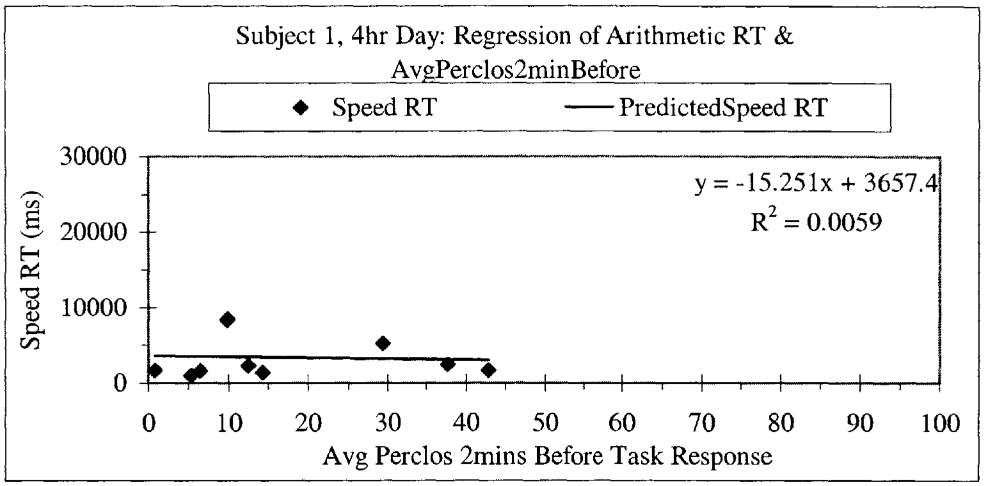
Regression Statistics	
Multiple R	0.404
R Square	0.163
Adjusted R Square	0.059
Standard Error	3211.551
Observations	10.000



[redacted]

SUMMARY OUTPUT: Subject 1, Regression (Speed & PerclosBefore- 4hr Day)

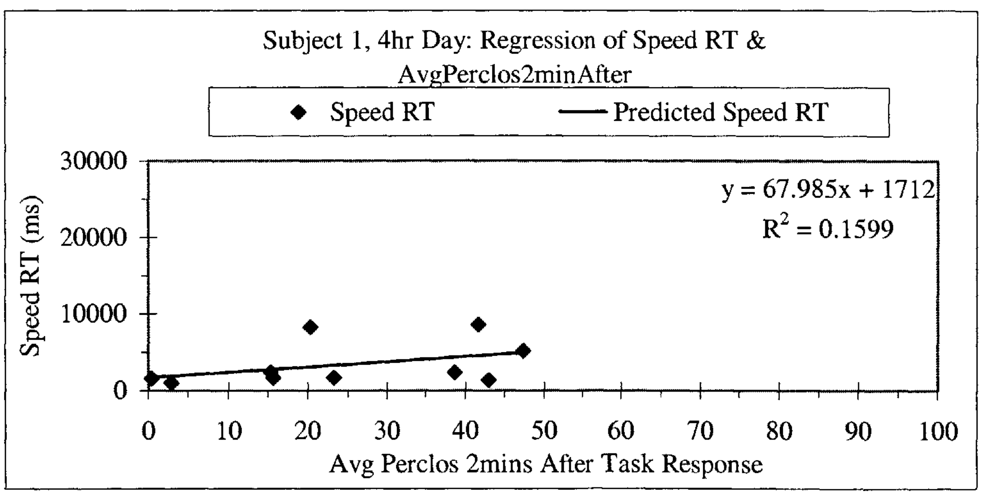
Regression Statistics	
Multiple R	0.077
R Square	0.006
Adjusted R Square	-0.118
Standard Error	3045.924
Observations	10.000



[redacted]

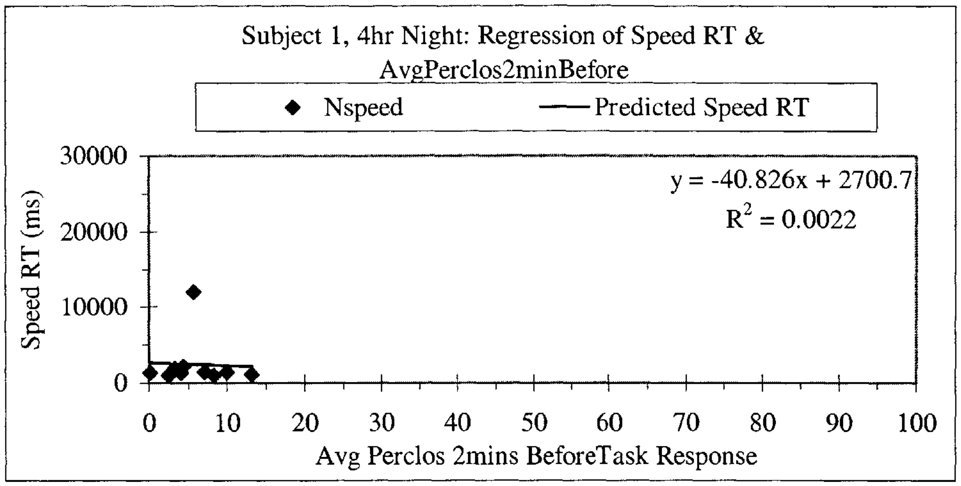
SUMMARY OUTPUT: Subject 1, Regression (Speed & PerclosAfter- 4hr Day)

Regression Statistics	
Multiple R	0.400
R Square	0.160
Adjusted R Square	0.055
Standard Error	2800.056
Observations	10.000



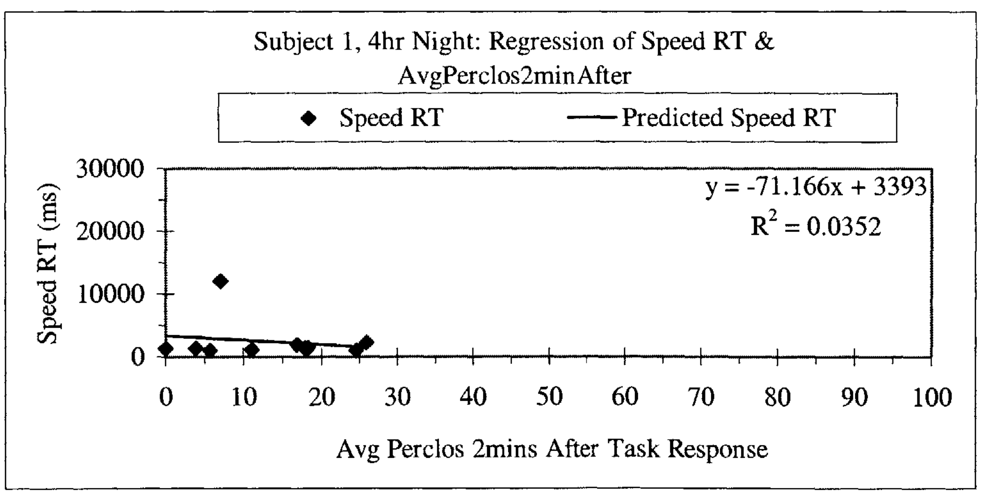
SUMMARY OUTPUT: Subject 1, Regression (Speed & PerclosBefore- 4hr Night)

Regression Statistics	
Multiple R	0.047
R Square	0.002
Adjusted R Square	-0.123
Standard Error	3574.562
Observations	10.000



SUMMARY OUTPUT: Subject 1, Regression (Speed & PerclosAfter- 4hr Night)

Regression Statistics	
Multiple R	0.188
R Square	0.035
Adjusted R Square	-0.085
Standard Error	3514.922
Observations	10.000

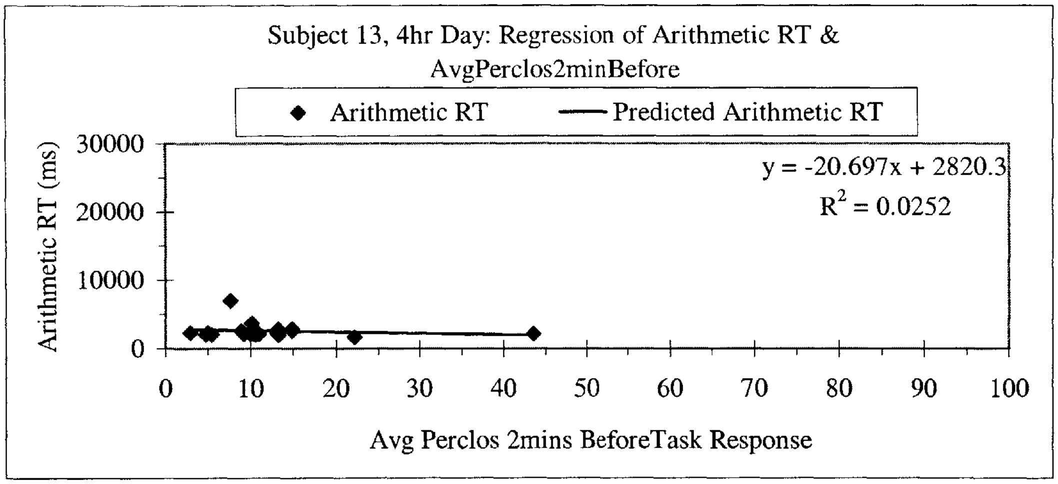


Subject 13: Correlation of Perclos Bef/After for each task

	Arithmetic Day	TrainSentry Night	LED Day	LED Night	Speed Day	Speed Night
AvgPerclos2minsBefore	0.159	0.440	0.231	0.578	0.826	0.220
AvgPerclos2minsAfter	0.077	0.206	0.282	0.367	0.109	0.200

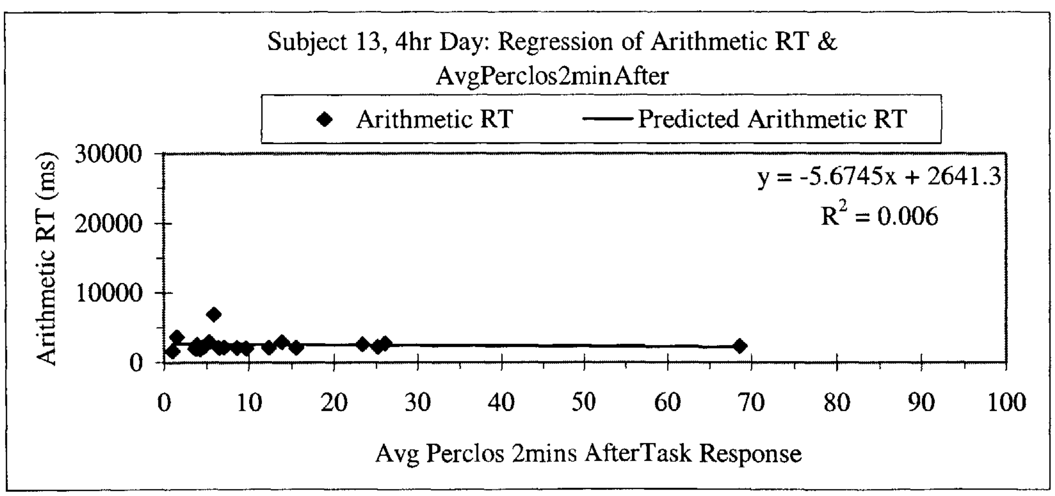
SUMMARY OUTPUT: Subject 13, Regression (Arithmetic & PerclosBefore- 4hr Day)

Regression Statistics	
Multiple R	0.159
R Square	0.025
Adjusted R Square	-0.029
Standard Error	1134.813
Observations	20.000



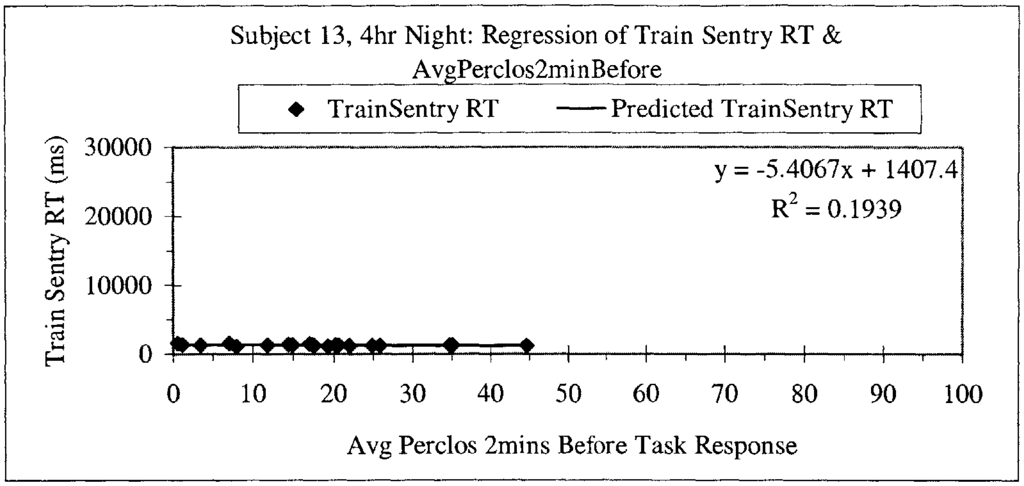
SUMMARY OUTPUT: Subject 13, Regression (Arithmetic & PerclosAfter- 4hr Day)

Regression Statistics	
Multiple R	0.077
R Square	0.006
Adjusted R Square	-0.049
Standard Error	1145.958
Observations	20.000



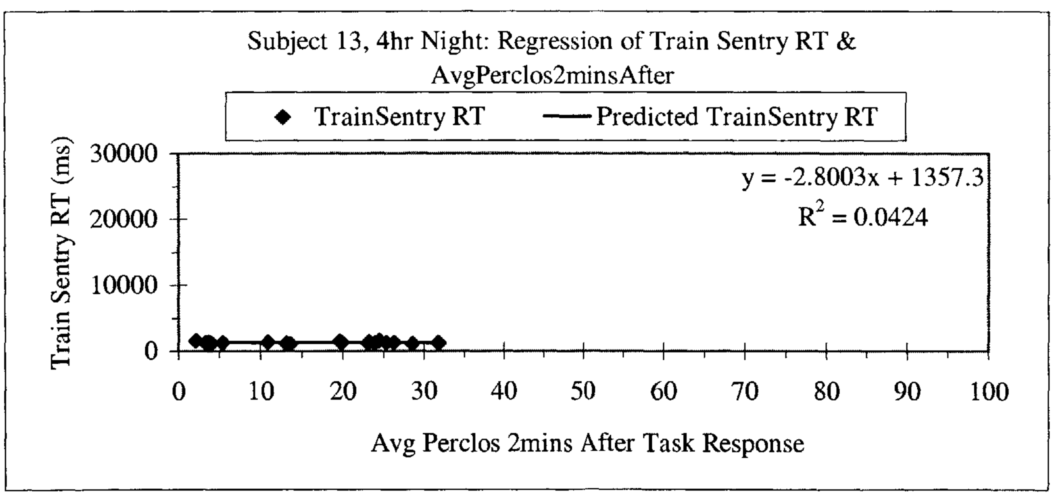
SUMMARY OUTPUT: Subject 13, Regression (TrainSentry & PerclosBefore- 4hr Night)

Regression Statistics	
Multiple R	0.440
R Square	0.194
Adjusted R Square	0.149
Standard Error	130.111
Observations	20.000



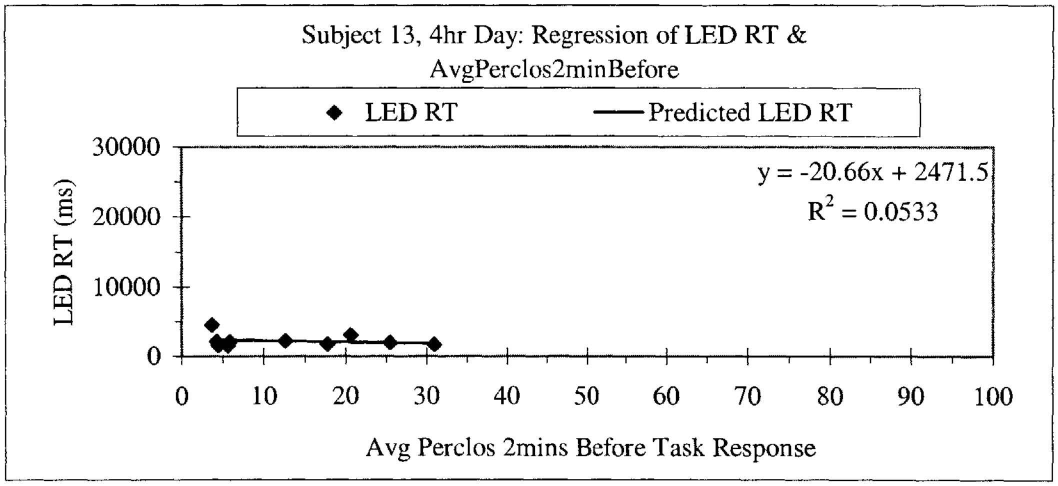
SUMMARY OUTPUT: Subject 13, Regression (TrainSentry & PerclosAfter- 4hr Night)

Regression Statistics	
Multiple R	0.206
R Square	0.042
Adjusted R Square	-0.011
Standard Error	141.811
Observations	20.000



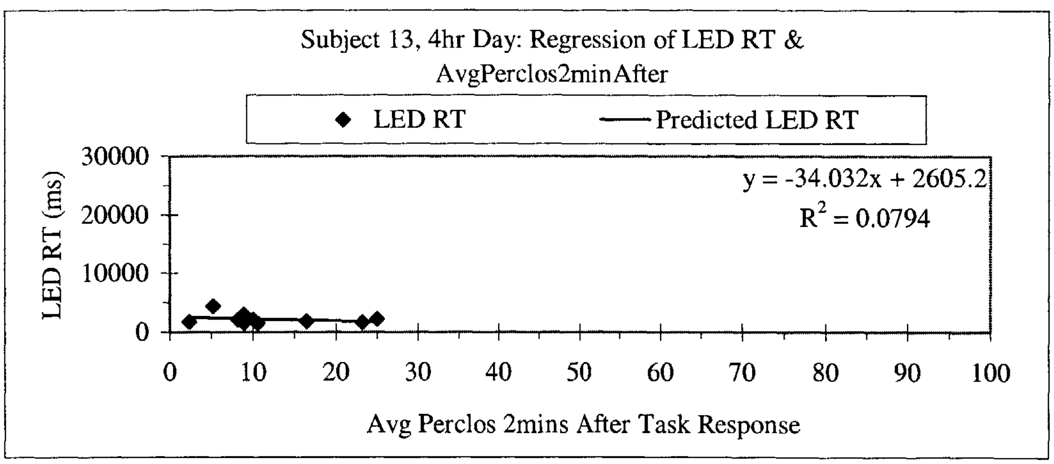
SUMMARY OUTPUT: Subject 13, Regression (LED & PerclosBefore- 4hr Day)

Regression Statistics	
Multiple R	0.231
R Square	0.053
Adjusted R Square	-0.065
Standard Error	921.755
Observations	10.000



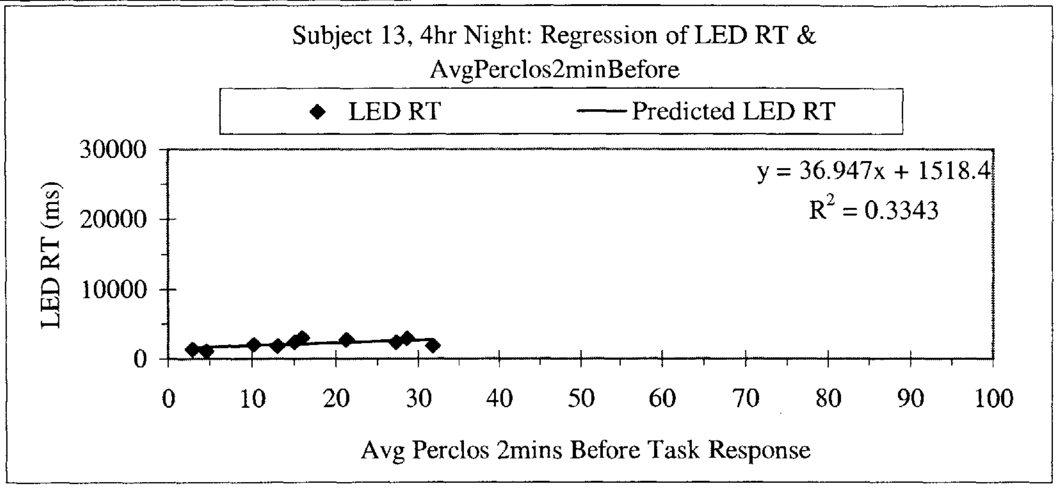
SUMMARY OUTPUT: Subject 13, Regression (LED & PerclosAfter- 4hr Day)

Regression Statistics	
Multiple R	0.282
R Square	0.079
Adjusted R Square	-0.036
Standard Error	908.981
Observations	10.000



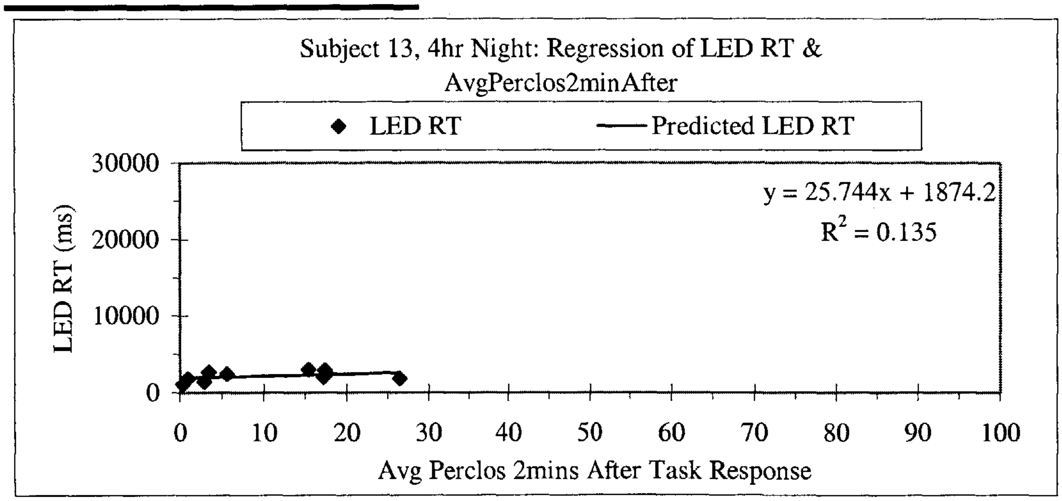
SUMMARY OUTPUT: Subject 13, Regression (LED & PerclosBefore- 4hr Night)

Regression Statistics	
Multiple R	0.578
R Square	0.334
Adjusted R Square	0.251
Standard Error	550.754
Observations	10.000



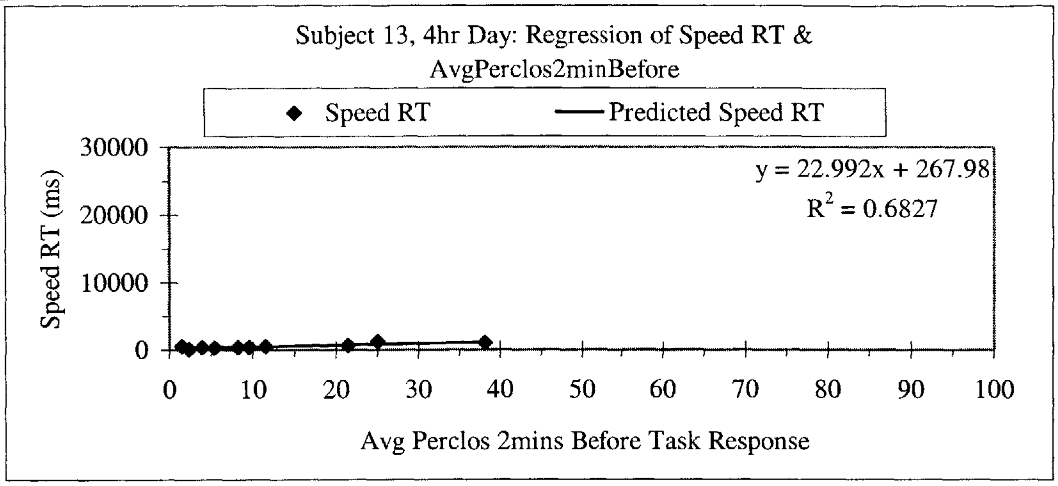
SUMMARY OUTPUT: Subject 13, Regression (LED & PerclosAfter- 4hr Night)

Regression Statistics	
Multiple R	0.367
R Square	0.135
Adjusted R Square	0.027
Standard Error	627.790
Observations	10.000



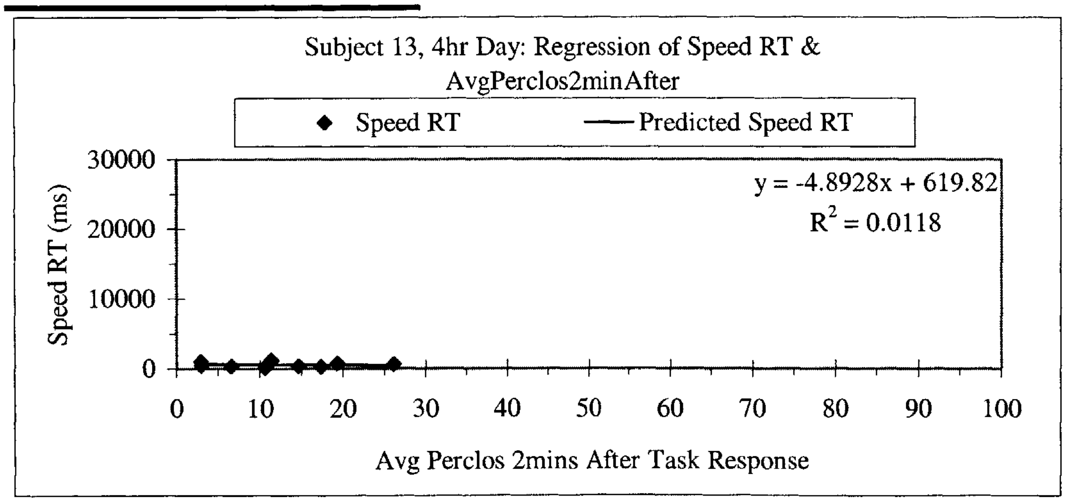
SUMMARY OUTPUT: Subject 13, Regression (Speed & PerclosBefore- 4hr Day)

Regression Statistics	
Multiple R	0.826
R Square	0.683
Adjusted R Square	0.643
Standard Error	197.553
Observations	10.000



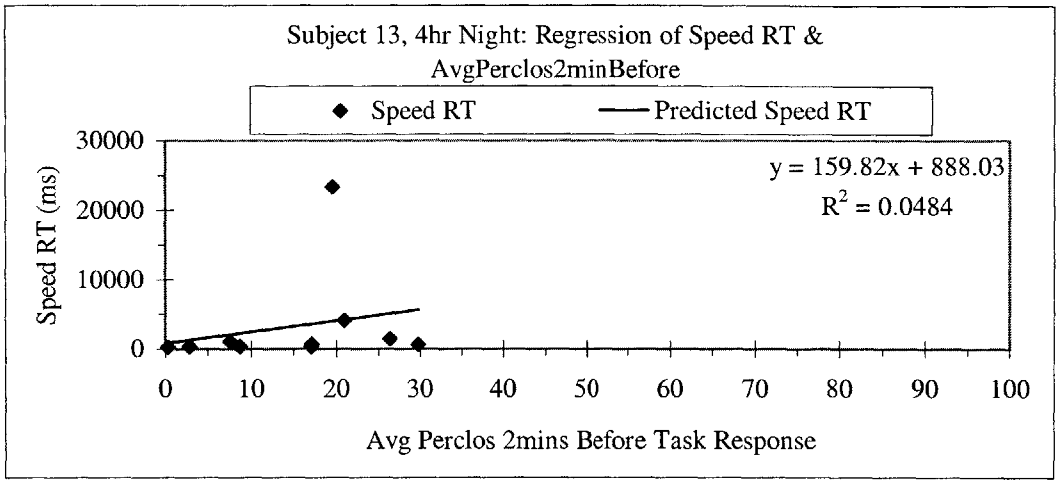
SUMMARY OUTPUT: Subject 13, Regression (Speed & PerclosAfter- 4hr Day)

Regression Statistics	
Multiple R	0.109
R Square	0.012
Adjusted R Square	-0.112
Standard Error	348.638
Observations	10.000



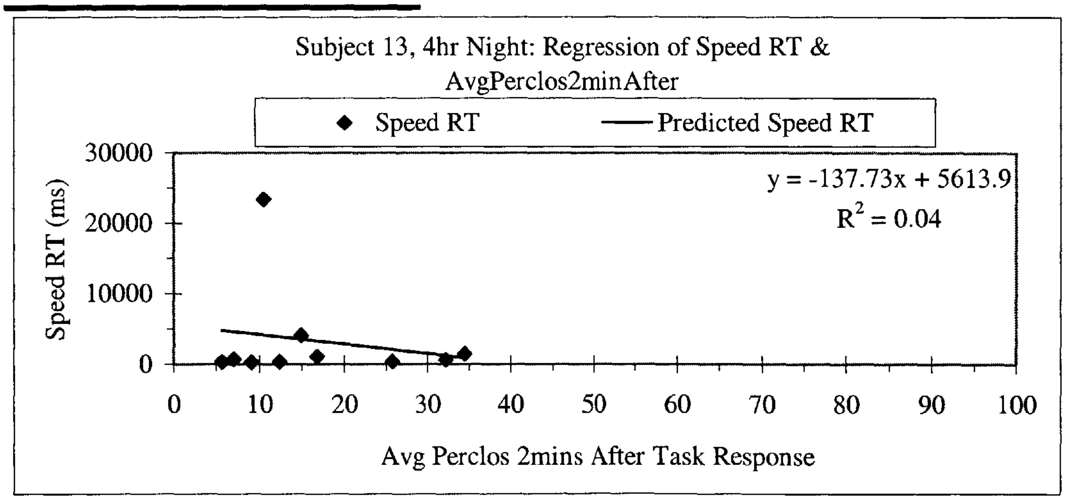
SUMMARY OUTPUT: Subject 13, Regression (Speed & PerclosBefore- 4hr Night)

Regression Statistics	
Multiple R	0.220
R Square	0.048
Adjusted R Square	-0.071
Standard Error	7405.318
Observations	10.000



SUMMARY OUTPUT: Subject 13, Regression (Speed & PerclosAfter- 4hr Night)

Regression Statistics	
Multiple R	0.200
R Square	0.040
Adjusted R Square	-0.080
Standard Error	7437.844
Observations	10.000

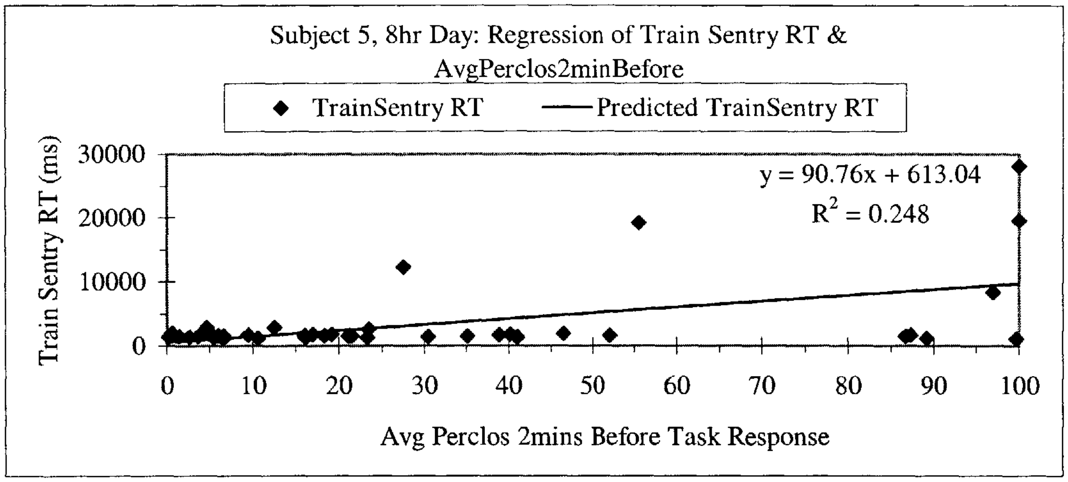


Subject 5: Correlation of Perclos Bef/After for each task

	Arithmetic Night	TrainSentry Day	LED Day	LED Night	Speed Day	Speed Night
AvgPerclos2minBefore	0.291	0.498	0.262	0.175	0.121	0.134
AvgPerclos2minAfter	0.499	0.280	0.020	0.060	0.000	0.197

SUMMARY OUTPUT: Subject 5, Regression (TrainSentry & PerclosBefore- 8hr Day)

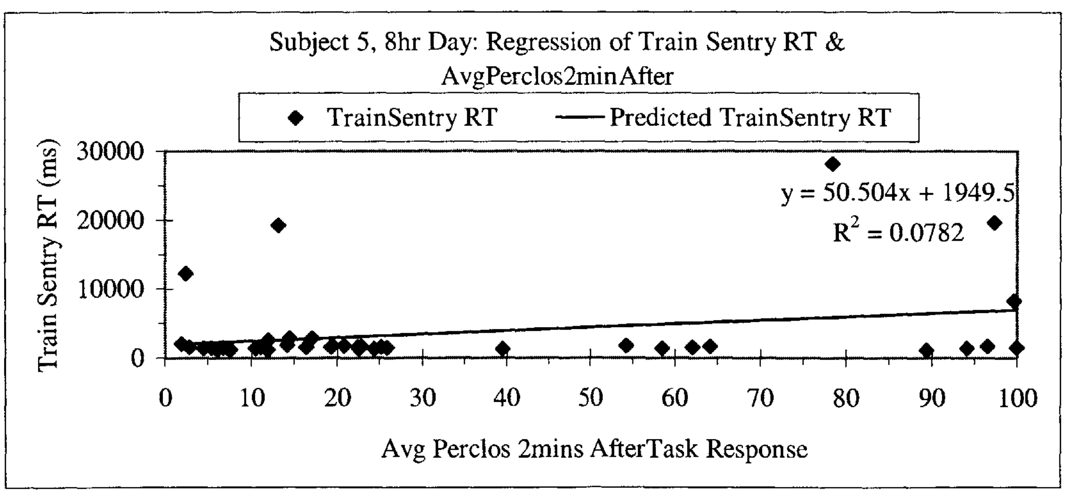
Regression Statistics	
Multiple R	0.498
R Square	0.248
Adjusted R Square	0.228
Standard Error	5150.276
Observations	40.000



[redacted]

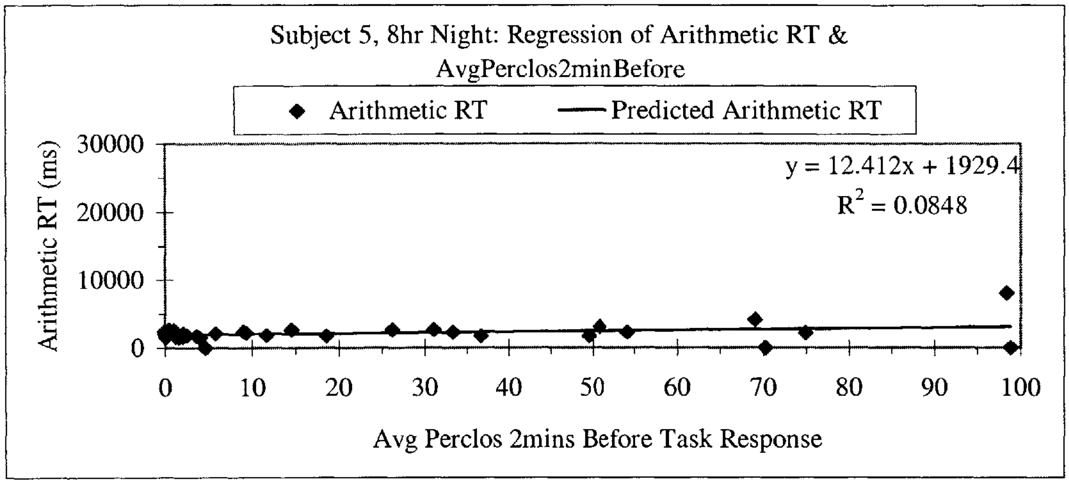
SUMMARY OUTPUT: Subject 5, Regression (TrainSentry & PerclosAfter- 8hr Day)

Regression Statistics	
Multiple R	0.280
R Square	0.078
Adjusted R Square	0.054
Standard Error	5701.931
Observations	40.000



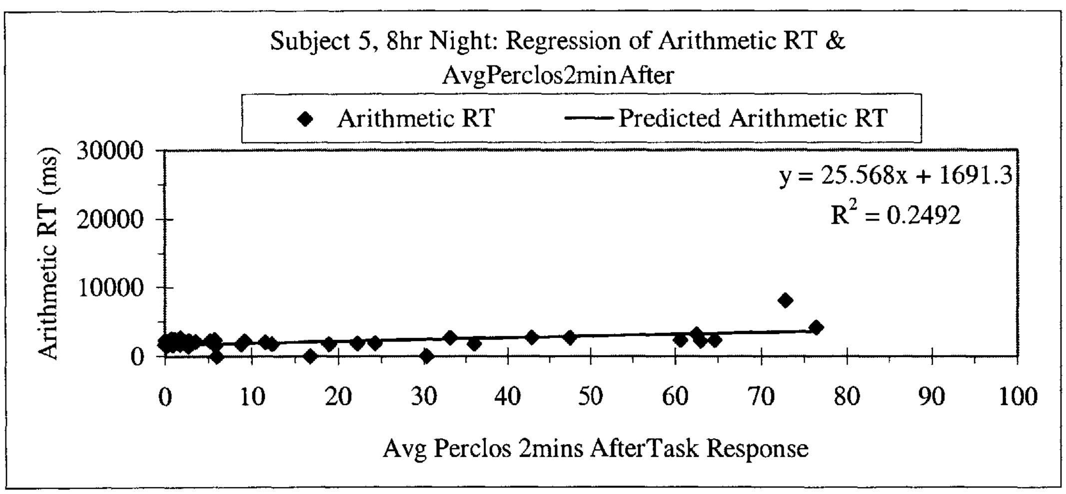
SUMMARY OUTPUT: Subject 5, Regression (Arithmetic & PerclosBefore- 8hr Night)

Regression Statistics	
Multiple R	0.291
R Square	0.085
Adjusted R Square	0.061
Standard Error	1186.940
Observations	40.000



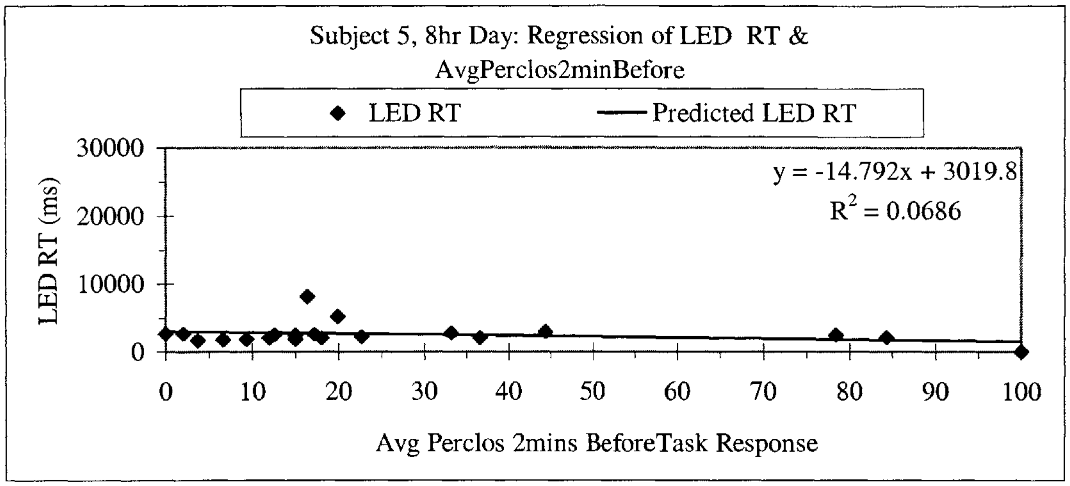
SUMMARY OUTPUT: Subject 5, Regression (Arithmetic & PerclosAfter- 8hr Night)

Regression Statistics	
Multiple R	0.499
R Square	0.249
Adjusted R Square	0.229
Standard Error	1075.066
Observations	40.000



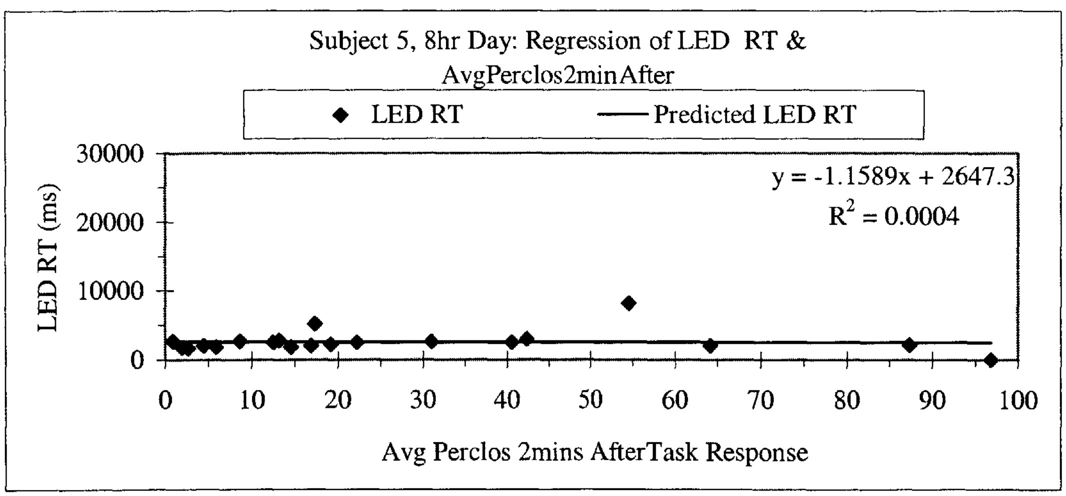
SUMMARY OUTPUT: Subject 5, Regression (LED & PerclosBefore- 8hr Day)

Regression Statistics	
Multiple R	0.262
R Square	0.069
Adjusted R Square	0.017
Standard Error	1593.023
Observations	20.000



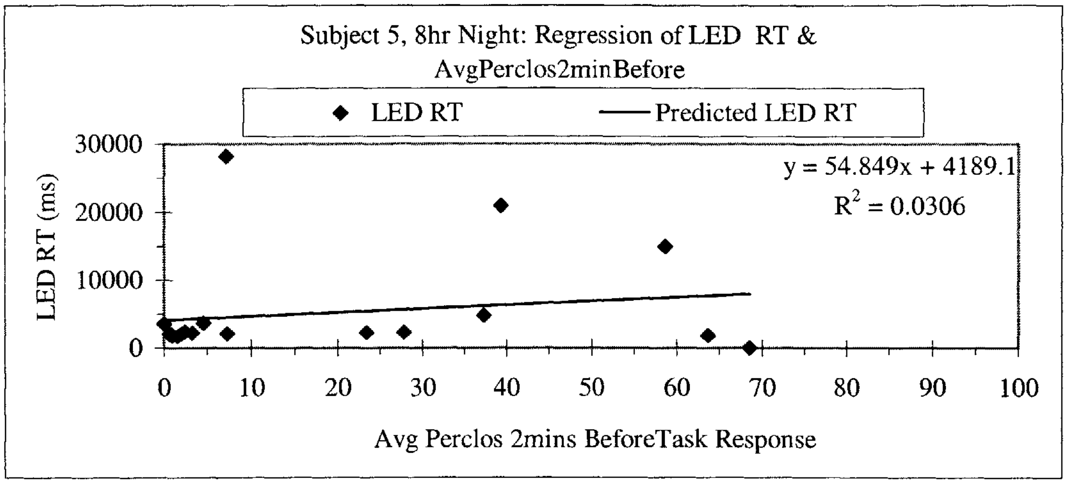
SUMMARY OUTPUT: Subject 5, Regression (LED & PerclosAfter- 8hr Day)

Regression Statistics	
Multiple R	0.020
R Square	0.000
Adjusted R Square	-0.055
Standard Error	1650.340
Observations	20.000



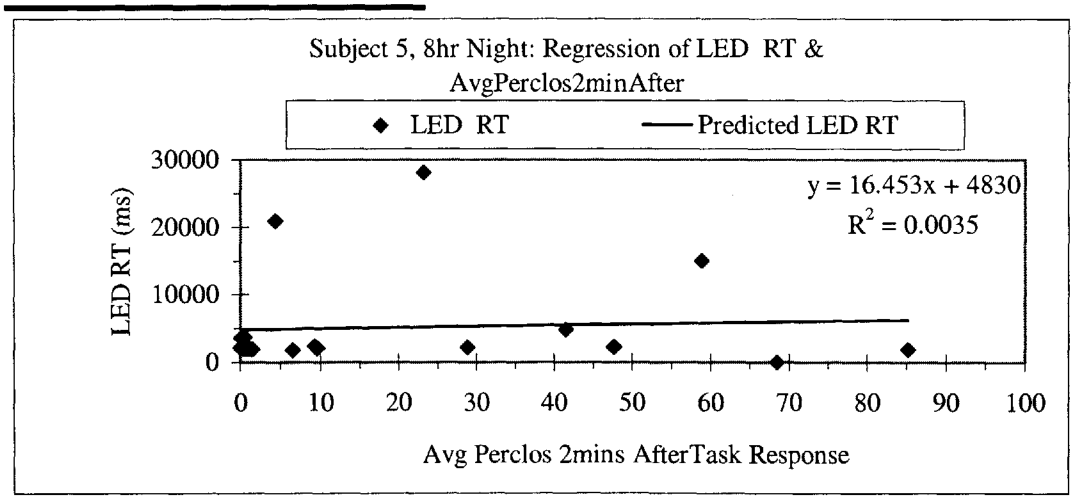
SUMMARY OUTPUT: Subject 5, Regression (LED & PerclosBefore- 8hr Night)

Regression Statistics	
Multiple R	0.175
R Square	0.031
Adjusted R Square	-0.023
Standard Error	7435.903
Observations	20.000



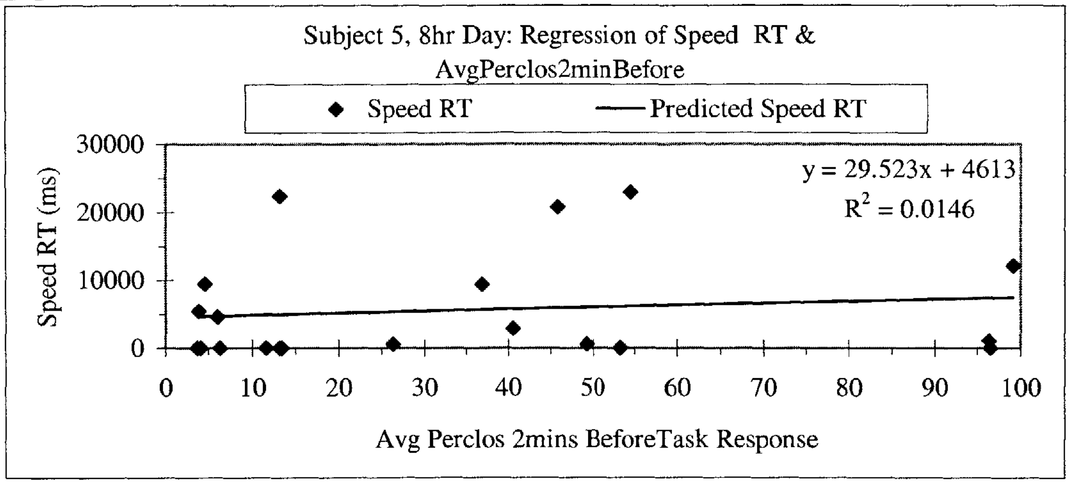
SUMMARY OUTPUT: Subject 5, Regression (LED & PerclosAfter- 8hr Night)

Regression Statistics	
Multiple R	0.060
R Square	0.004
Adjusted R Square	-0.052
Standard Error	7538.895
Observations	20.000



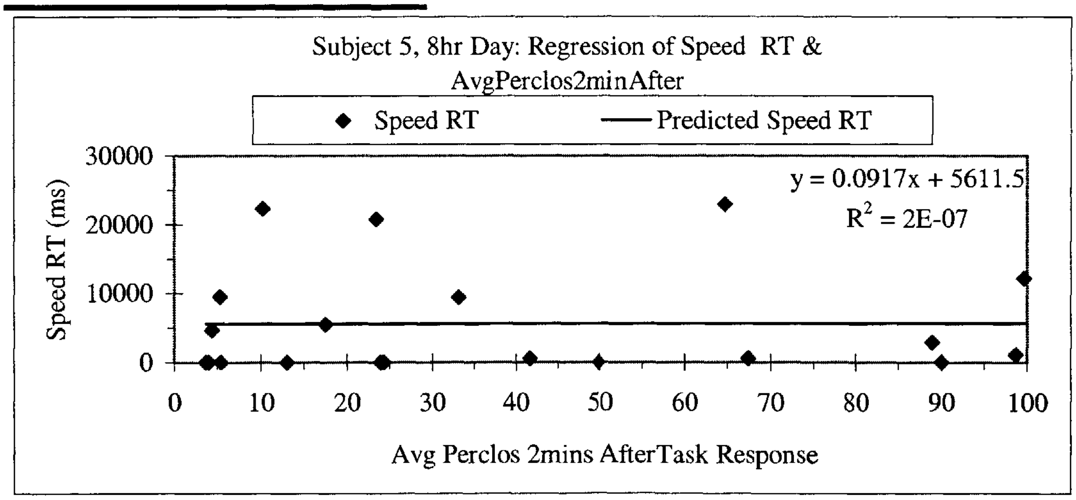
SUMMARY OUTPUT: Subject 5, Regression (Speed & PerclosBefore- 8hr Day)

Regression Statistics	
Multiple R	0.121
R Square	0.015
Adjusted R Square	-0.040
Standard Error	8134.877
Observations	20.000



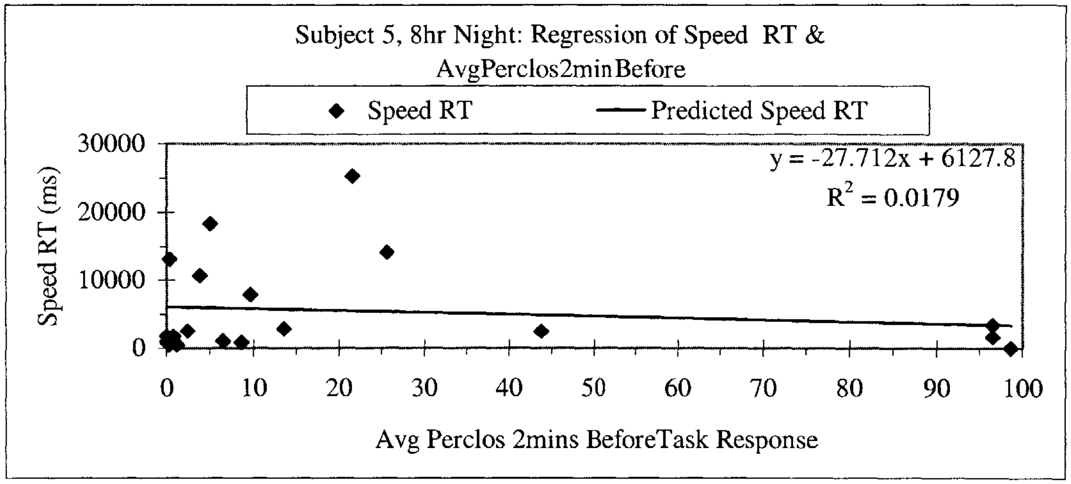
SUMMARY OUTPUT: Subject 5, Regression (Speed & PerclosAfter- 8hr Day)

Regression Statistics	
Multiple R	0.000
R Square	0.000
Adjusted R Square	-0.056
Standard Error	8194.935
Observations	20.000



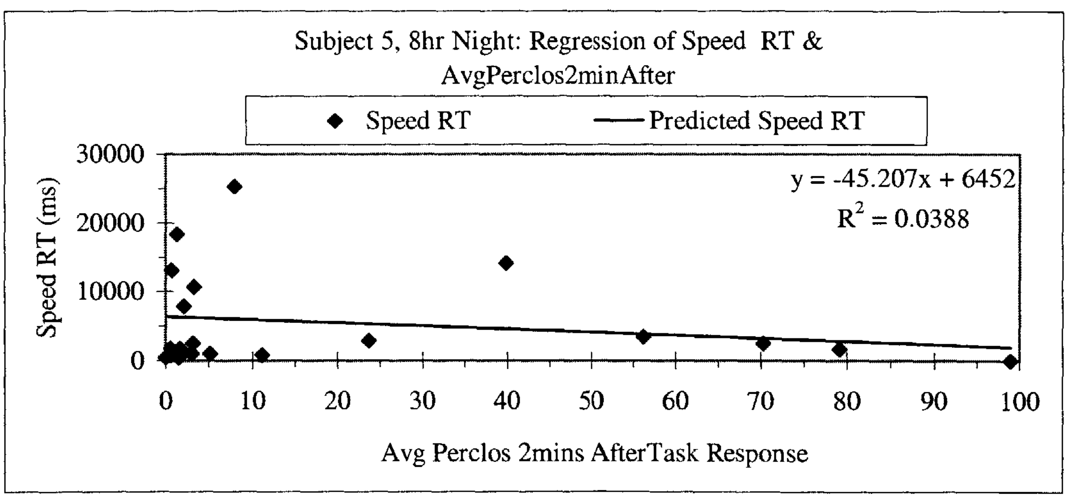
SUMMARY OUTPUT: Subject 5, Regression (Speed & PerclosBefore- 8hr Night)

Regression Statistics	
Multiple R	0.134
R Square	0.018
Adjusted R Square	-0.037
Standard Error	7226.796
Observations	20.000



SUMMARY OUTPUT: Subject 5, Regression (Speed & PerclosAfter- 8hr Night)

Regression Statistics	
Multiple R	0.197
R Square	0.039
Adjusted R Square	-0.015
Standard Error	7149.835
Observations	20.000

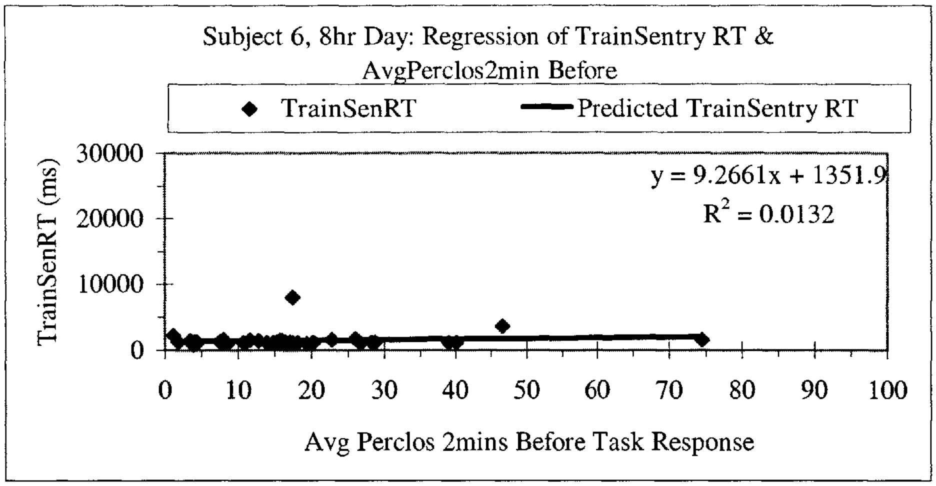


Subject 6: Correlation of Perclos Before each task & Task RT and Correlation of Perclos After each task & Task RT

Subject 6	Arith Night	TrainSen Day	LED Day	LED Night	Speed Day	Speed Night
AvgPerclos2minBefore	0.581	0.115	0.297	0.658	0.228	0.561
AvgPerclos2minAfter	0.188	0.109	0.082	0.111	0.047	0.114

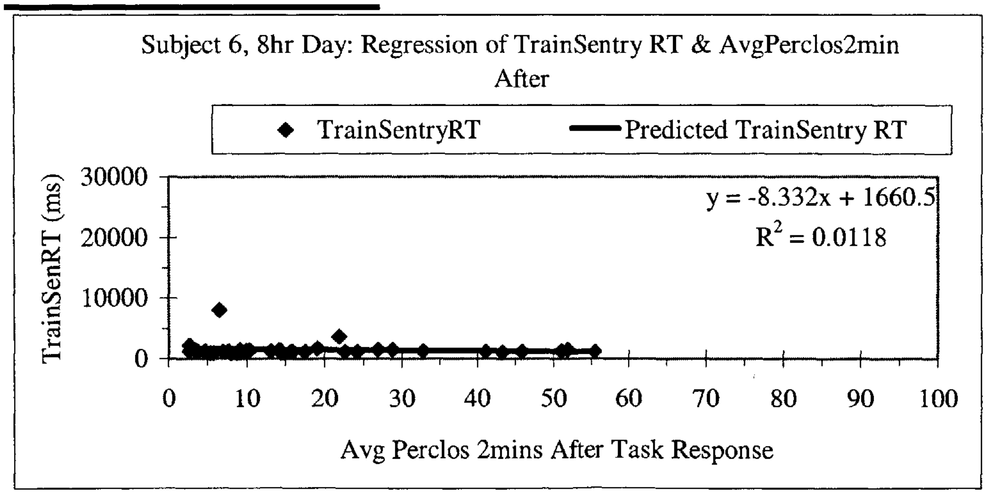
SUMMARY OUTPUT: Subject 6, Regression (TrainSentry & PerclosBefore- 8hr Day)

Regression Statistics	
Multiple R	0.115
R Square	0.013
Adjusted R Square	-0.013
Standard Error	1142.598
Observations	40.000



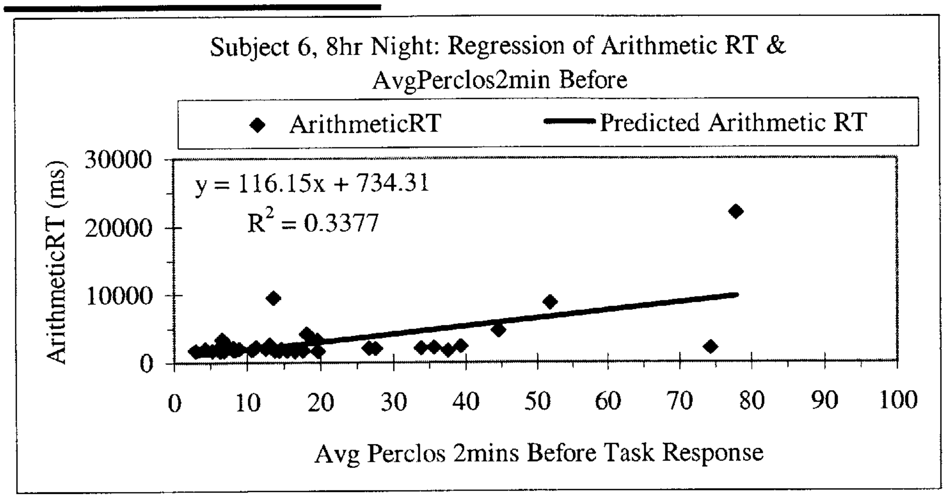
SUMMARY OUTPUT: Subject 6, Regression (TrainSentry & PerclosAfter- 8hr Day)

Regression Statistics	
Multiple R	0.108
R Square	0.012
Adjusted R Square	-0.014
Standard Error	1143.451
Observations	40.000



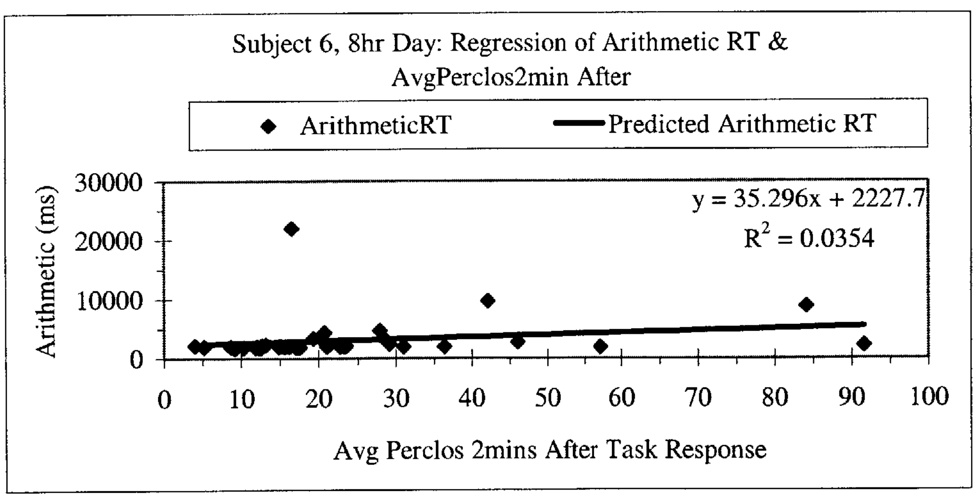
SUMMARY OUTPUT: Subject 6, Regression (Arithmetic & PerclosBefore- 8hr Night)

Regression Statistics	
Multiple R	0.581
R Square	0.338
Adjusted R Square	0.320
Standard Error	2887.839
Observations	40.000



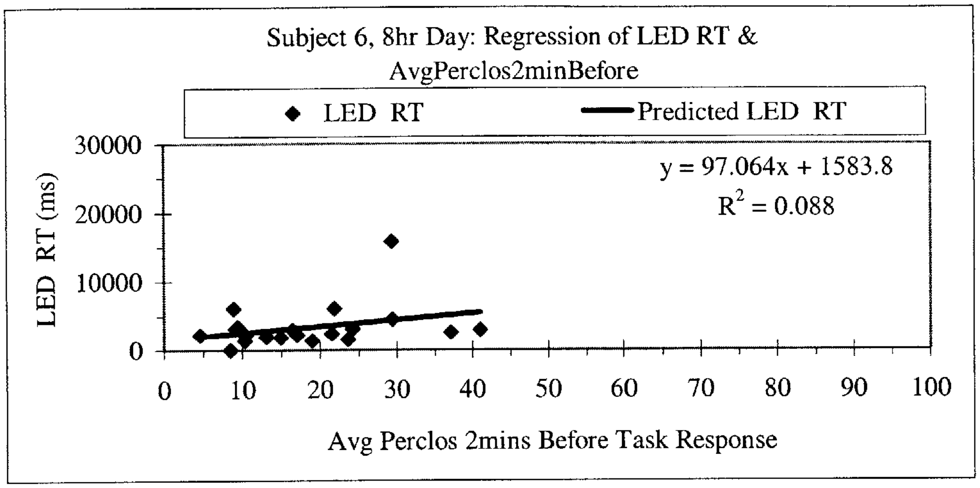
SUMMARY OUTPUT: Subject 6, Regression (Arithmetic & PerclosAfter- 8hr Night)

Regression Statistics	
Multiple R	0.188
R Square	0.035
Adjusted R Square	0.010
Standard Error	3485.009
Observations	40.000



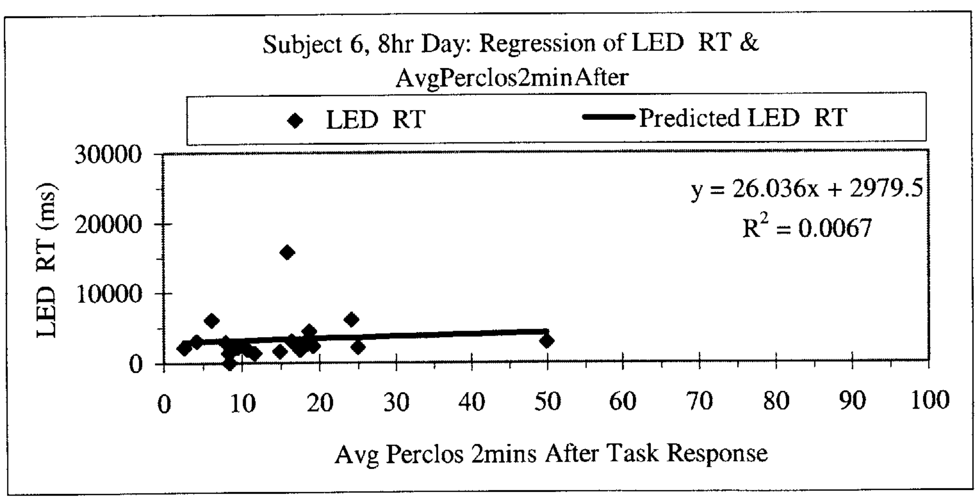
SUMMARY OUTPUT: Subject 6, Regression (LED & PerclosBefore- 8hr Day)

Regression Statistics	
Multiple R	0.297
R Square	0.088
Adjusted R Square	0.037
Standard Error	3213.337
Observations	20.000



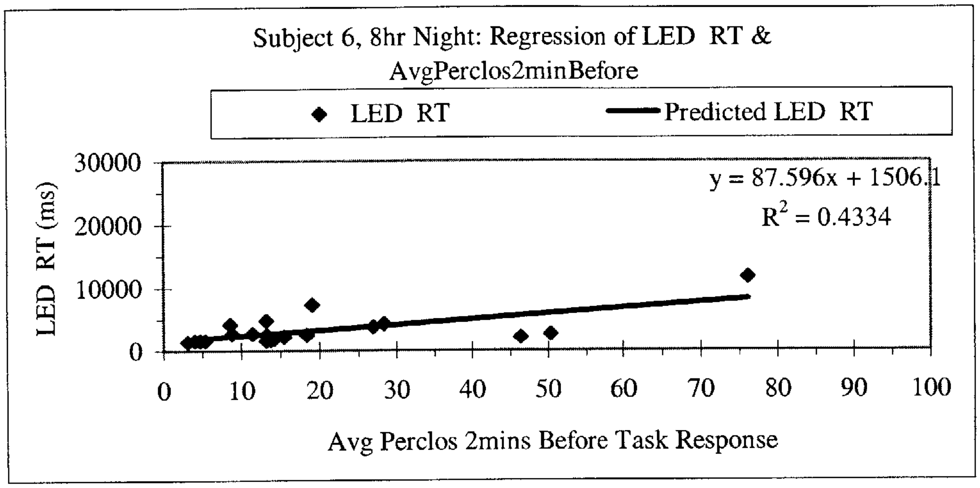
SUMMARY OUTPUT: Subject 6, Regression (LED & PerclosAfter- 8hr Day)

Regression Statistics	
Multiple R	0.082
R Square	0.007
Adjusted R Square	-0.048
Standard Error	3353.519
Observations	20.000



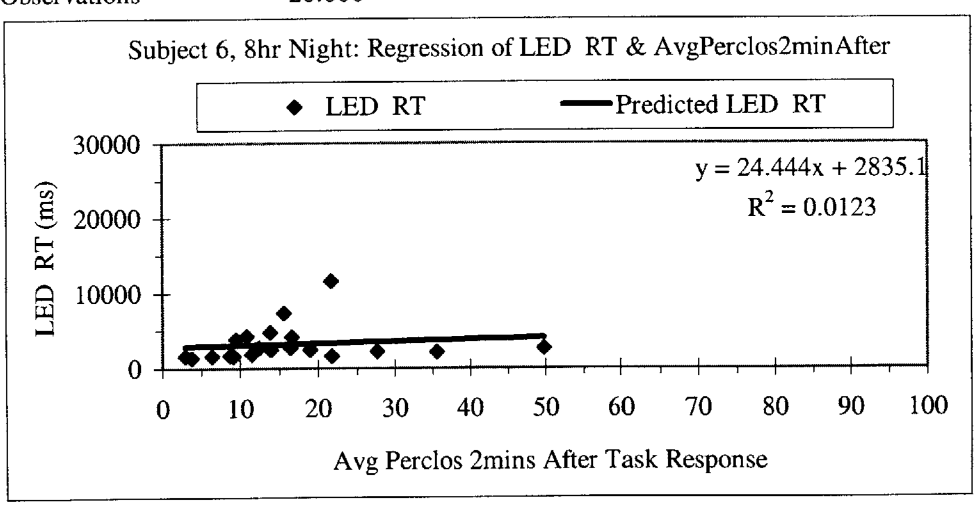
SUMMARY OUTPUT: Subject 6, Regression (LED & PerclosBefore- 8hr Night)

Regression Statistics	
Multiple R	0.658
R Square	0.433
Adjusted R Square	0.402
Standard Error	1893.903
Observations	20.000



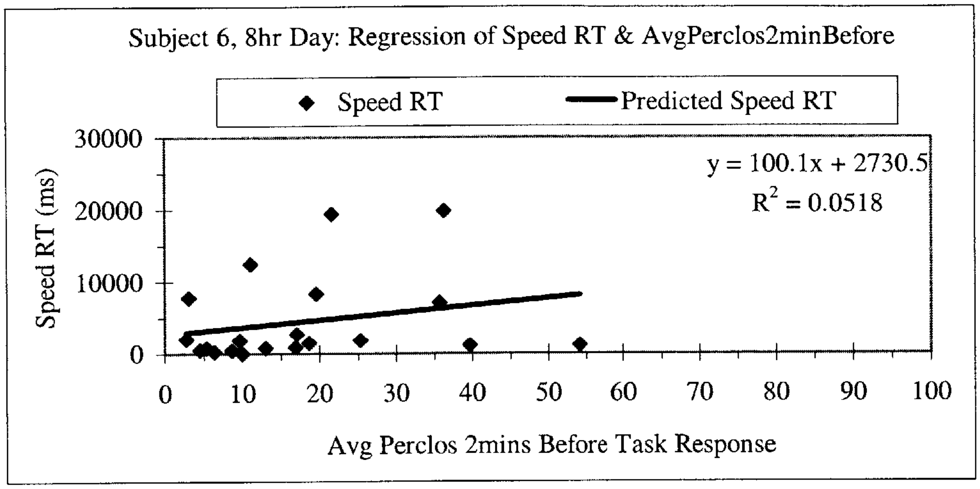
SUMMARY OUTPUT: Subject 6, Regression (LED & PerclosAfter- 8hr Night)

Regression Statistics	
Multiple R	0.111
R Square	0.012
Adjusted R Square	-0.043
Standard Error	2500.441
Observations	20.000



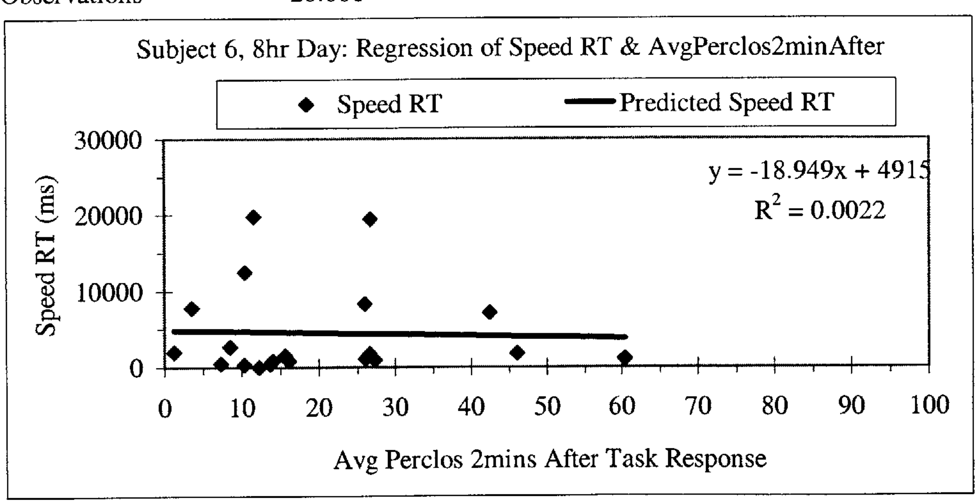
SUMMARY OUTPUT: Subject 6, Regression (Speed & PerclosBefore- 8hr Day)

Regression Statistics	
Multiple R	0.228
R Square	0.052
Adjusted R Square	-0.001
Standard Error	6155.939
Observations	20.000



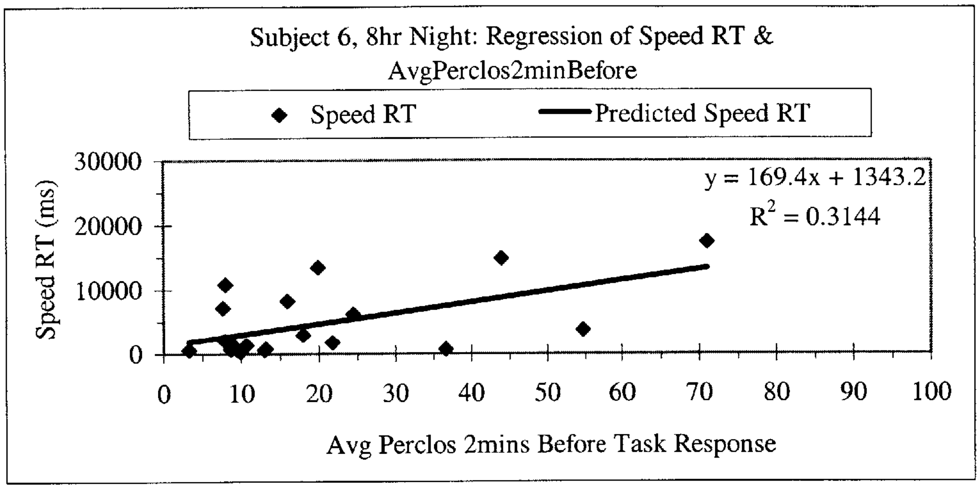
SUMMARY OUTPUT: Subject 6, Regression (Speed & PerclosAfter- 8hr Day)

Regression Statistics	
Multiple R	0.047
R Square	0.002
Adjusted R Square	-0.053
Standard Error	6315.028
Observations	20.000



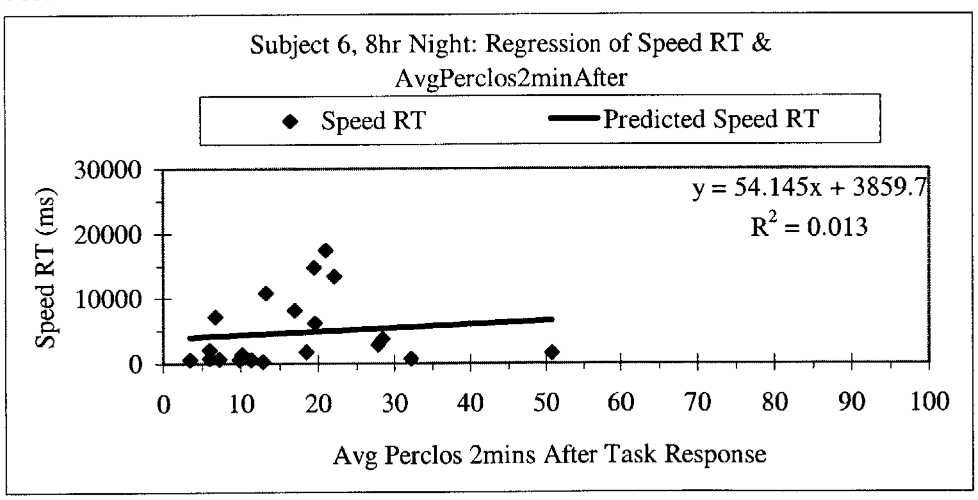
SUMMARY OUTPUT: Subject 6, Regression (Speed & PerclosBefore- 8hr Night)

Regression Statistics	
Multiple R	0.561
R Square	0.314
Adjusted R Square	0.276
Standard Error	4592.473
Observations	20.000



SUMMARY OUTPUT: Subject 6, Regression (Speed & PerclosAfter- 8hr Night)

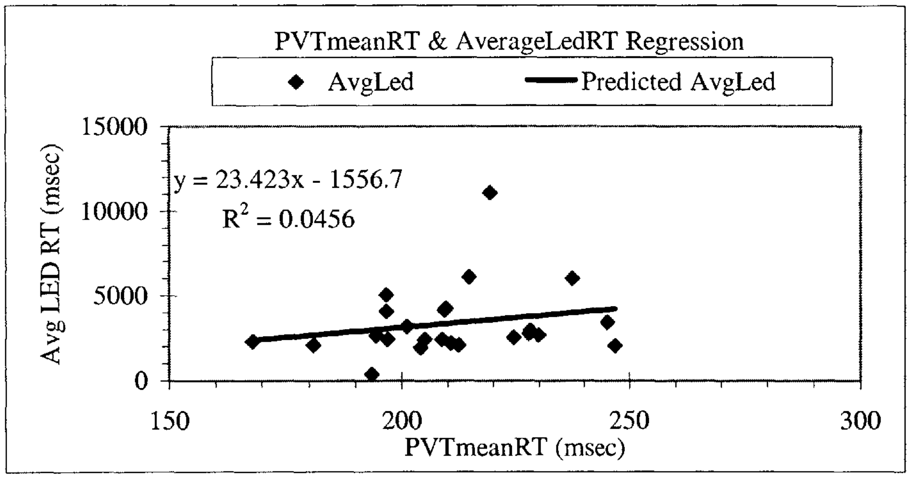
Regression Statistics	
Multiple R	0.114
R Square	0.013
Adjusted R Square	-0.042
Standard Error	5509.982
Observations	20.000



A5. Graphs of Regression Between Average Train Task Reaction Time (all Subject Data Combined) and PVT Average Reaction Time

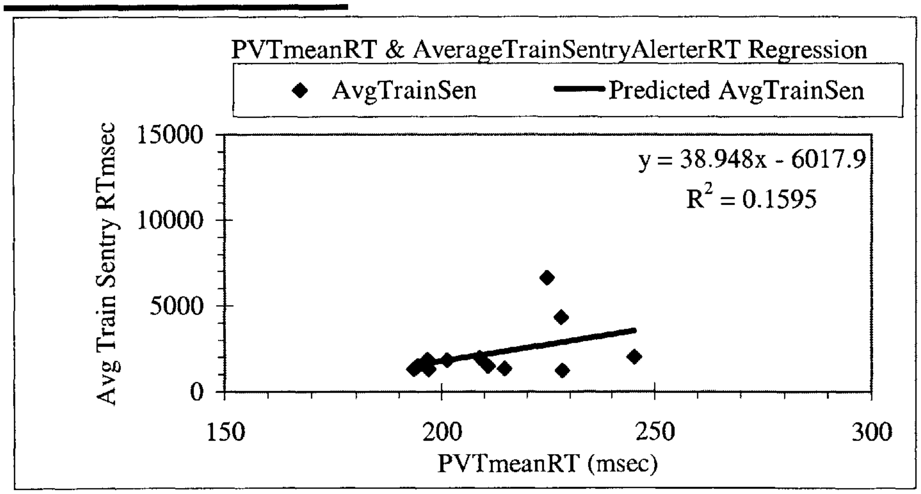
SUMMARY OUTPUT: PVT Mean RT & Avg LED RT

Regression Statistics	
Multiple R	0.213603
R Square	0.045626
Adjusted R Square	0.002245
Standard Error	2102.928
Observations	24



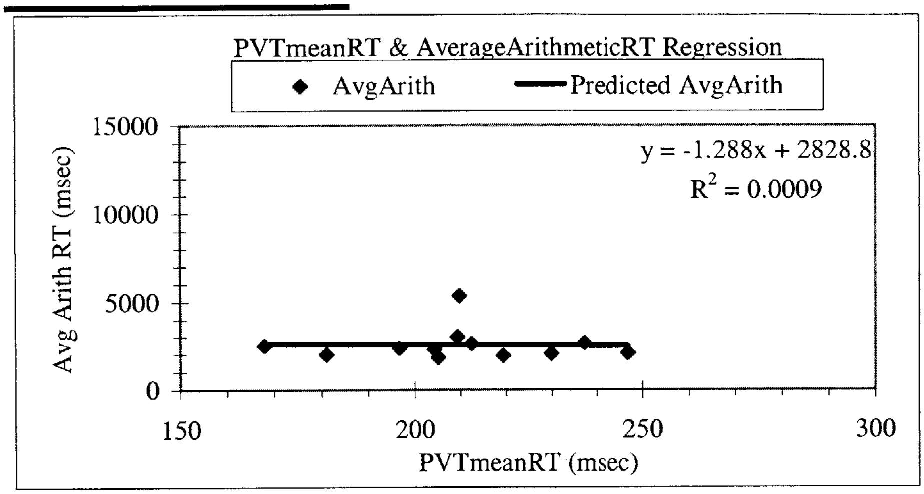
SUMMARY OUTPUT: PVT Mean RT & Avg TrainSentry RT

Regression Statistics	
Multiple R	0.399346
R Square	0.159477
Adjusted R Square	0.075425
Standard Error	1554.28
Observations	12



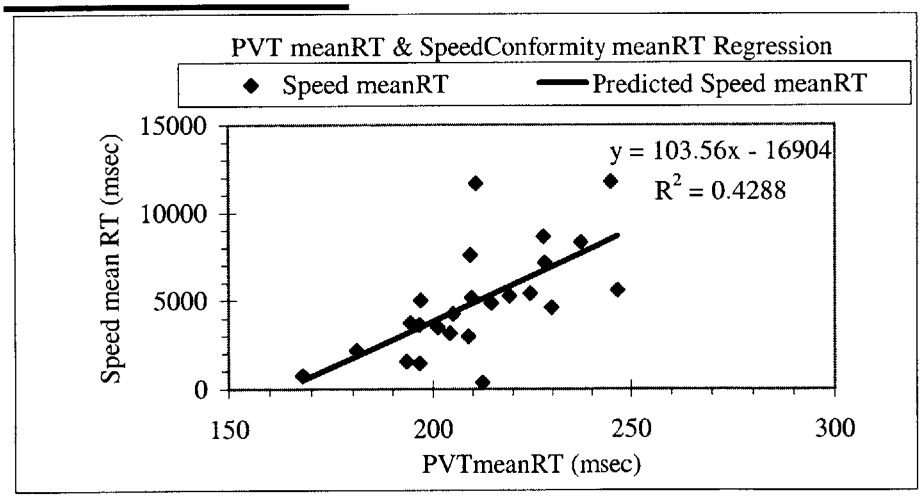
SUMMARY OUTPUT: PVT Mean RT & Avg Arithmetic RT

Regression Statistics	
Multiple R	0.030431
R Square	0.000926
Adjusted R Square	-0.09898
Standard Error	986.2711
Observations	12



SUMMARY OUTPUT: PVT Mean RT & Avg Speed RT

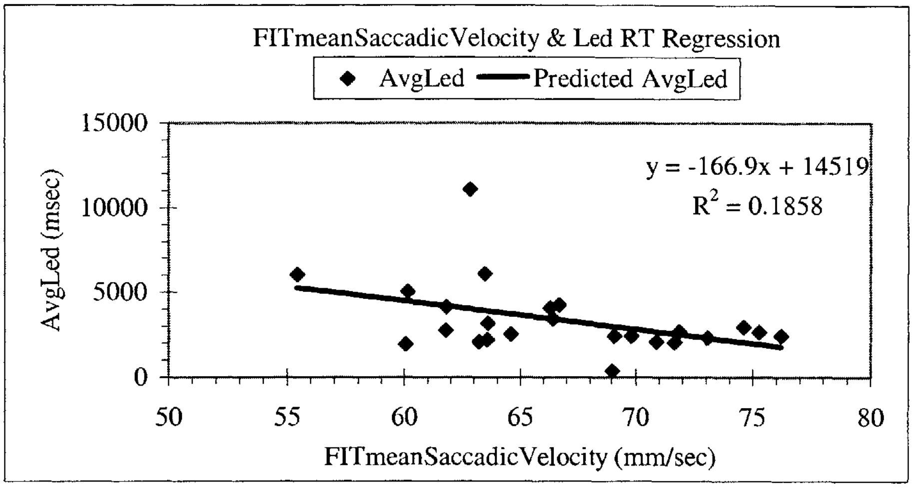
Regression Statistics	
Multiple R	0.654865
R Square	0.428849
Adjusted R Square	0.402887
Standard Error	2346.195
Observations	24



A6. Graphs of Regression Between Average Train Task Reaction Time (all Subject Data Combined) & FIT2000 Average Saccadic Velocity

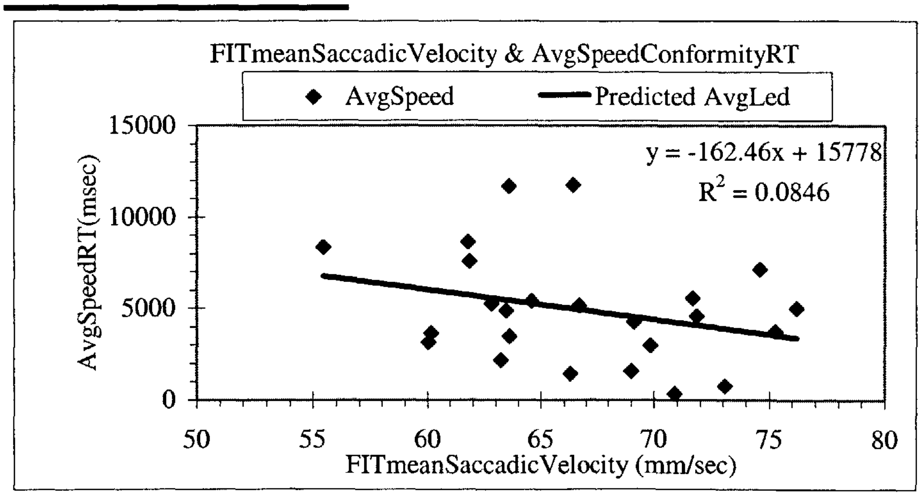
SUMMARY OUTPUT: FIT2000 MeanSaccadicVelocity & AvgLED RT

Regression Statistics	
Multiple R	0.431064
R Square	0.185816
Adjusted R Square	0.148808
Standard Error	1942.345
Observations	24



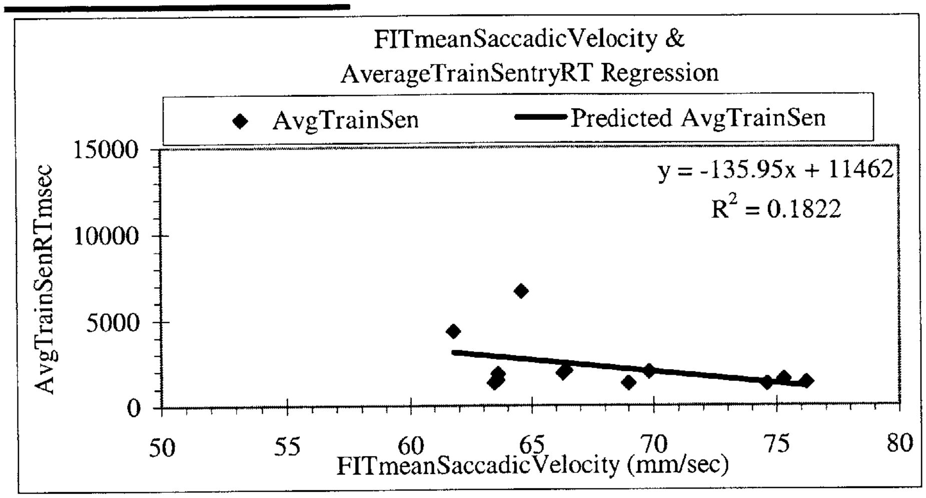
SUMMARY OUTPUT: FIT2000 MeanSaccadicVelocity & AvgSpeed RT

Regression Statistics	
Multiple R	0.29094
R Square	0.084646
Adjusted R Square	0.043039
Standard Error	2970.183
Observations	24



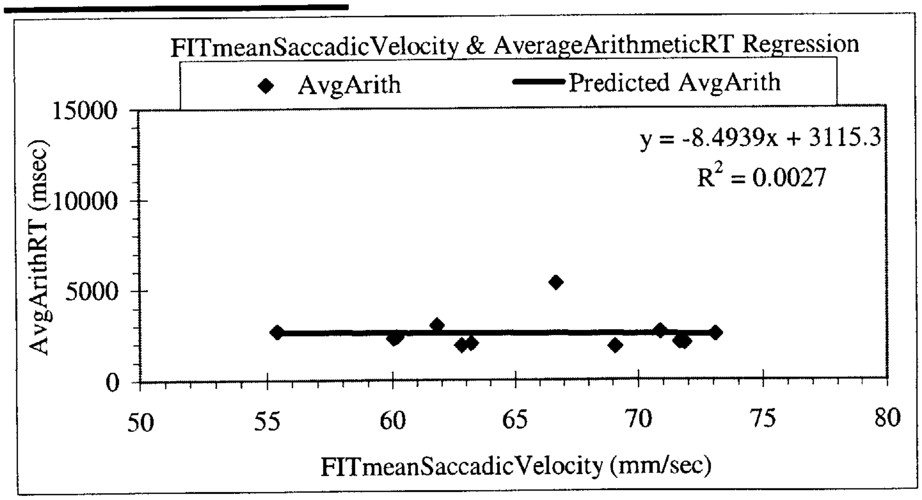
SUMMARY OUTPUT: FIT2000 MeanSaccadicVelocity & Avg TrainSentry RT

Regression Statistics	
Multiple R	0.426818
R Square	0.182174
Adjusted R Square	0.100391
Standard Error	1533.151
Observations	12



SUMMARY OUTPUT: FIT2000 MeanSaccadicVelocity & Avg Arithmetic RT

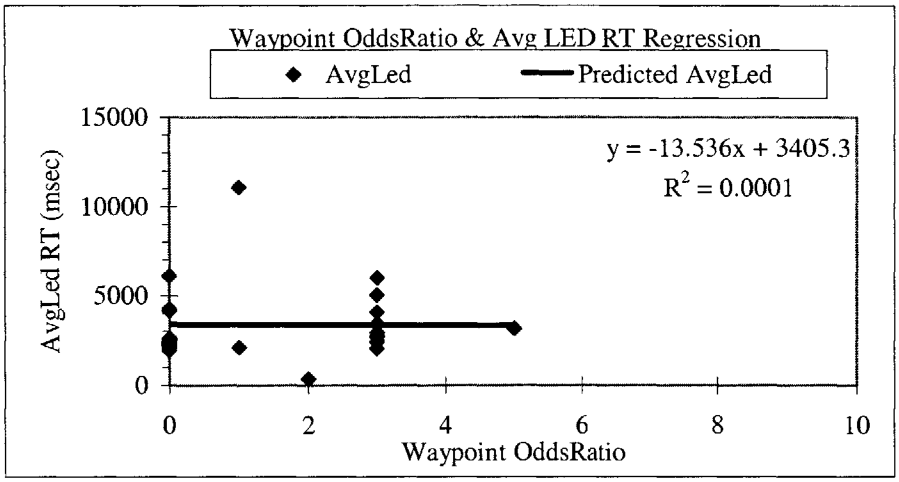
Regression Statistics	
Multiple R	0.051973
R Square	0.002701
Adjusted R Square	-0.09703
Standard Error	985.3945
Observations	12



A7. Graphs of Regression Between Average Train Task Reaction Time (all Subject Data Combined) and Waypoint Odds Ratio

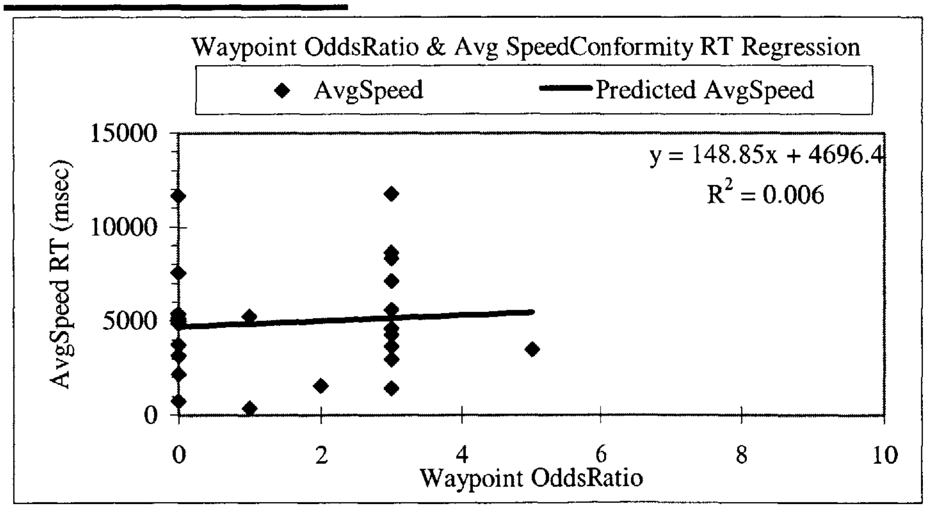
SUMMARY OUTPUT: WaypointOddsRation & AvgLED RT

Regression Statistics	
Multiple R	0.010177
R Square	0.000104
Adjusted R Square	-0.04535
Standard Error	2152.497
Observations	24



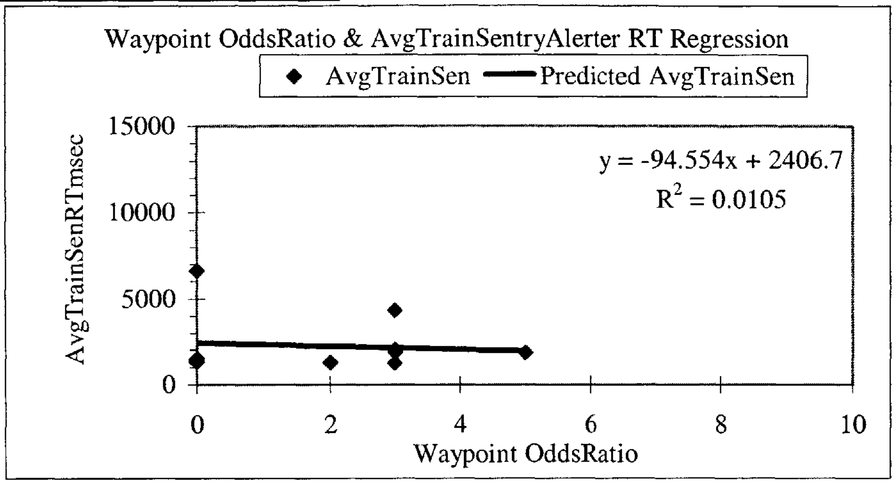
SUMMARY OUTPUT: WaypointOddsRation & Avg Speed Conformity RT

Regression Statistics	
Multiple R	0.077601
R Square	0.006022
Adjusted R Square	-0.03916
Standard Error	3095.116
Observations	24



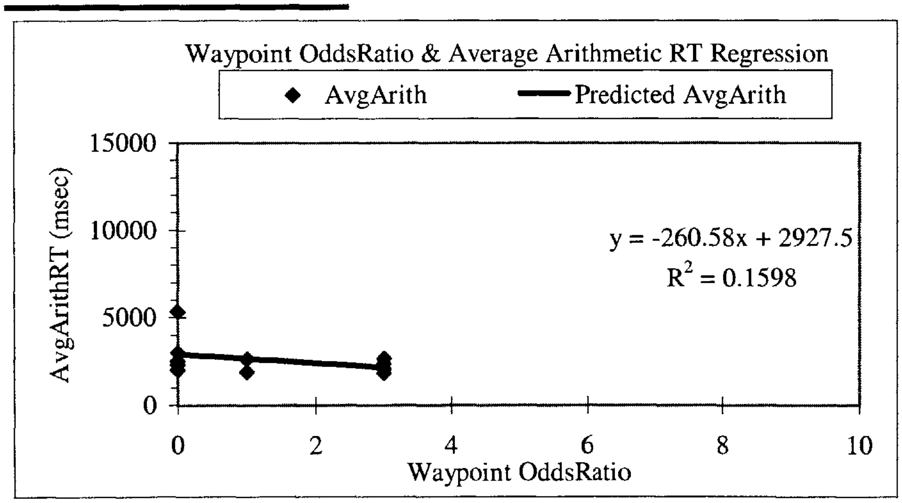
SUMMARY OUTPUT: WaypointOddsRation & Avg TrainSentry RT

Regression Statistics	
Multiple R	0.102336
R Square	0.010473
Adjusted R Square	-0.08848
Standard Error	1686.43
Observations	12



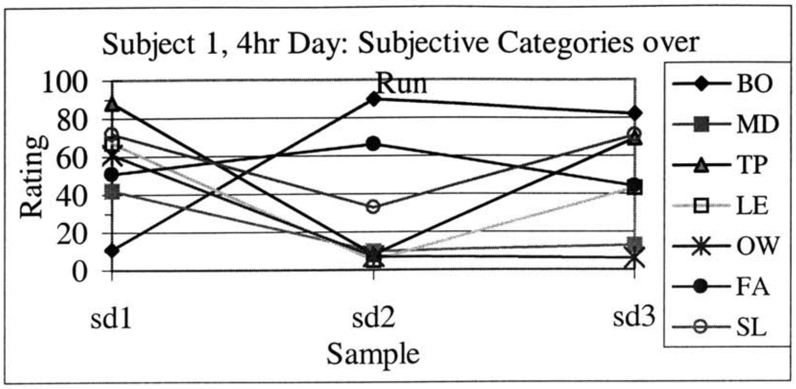
SUMMARY OUTPUT: WaypointOddsRatio & Avg Arithmetic RT

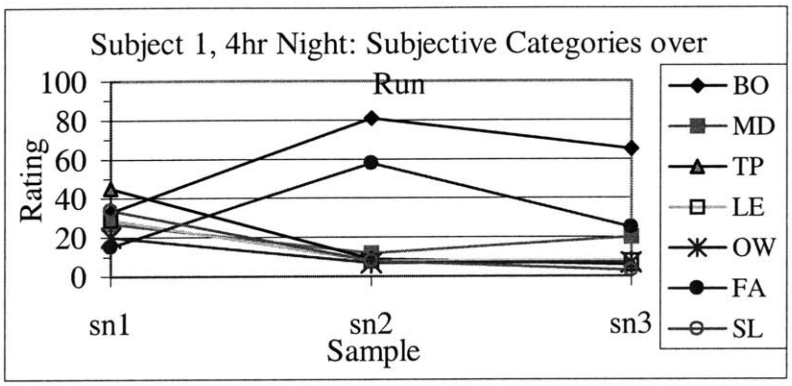
Regression Statistics	
Multiple R	0.399783
R Square	0.159826
Adjusted R Square	0.075809
Standard Error	904.4447
Observations	12

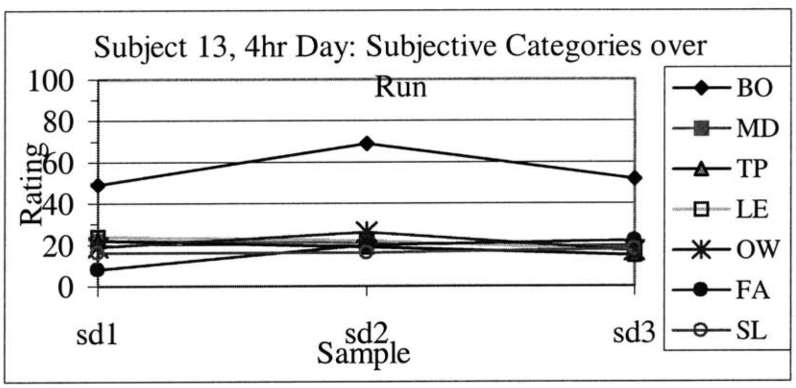


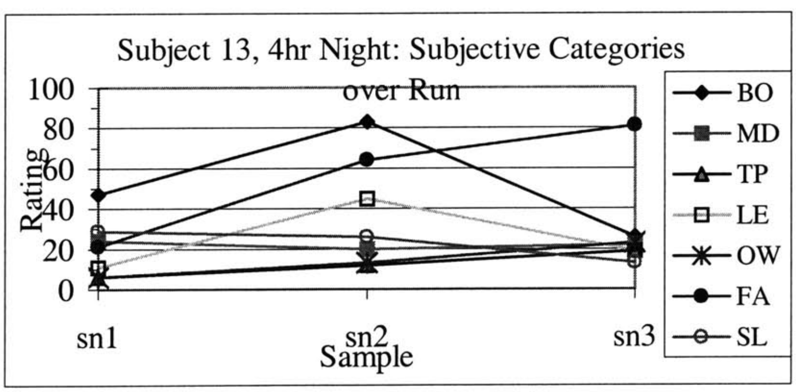
A8. Graphs of Subjective Ratings Over Simulation Run Time

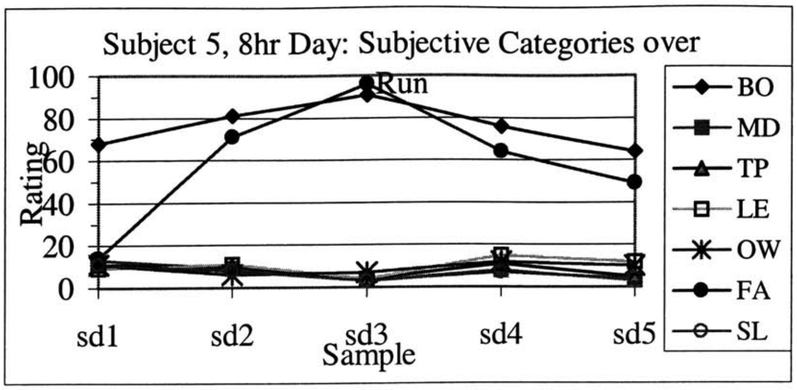
Legend Key: BO = Boredom, MD = Mental Demand, TP = Time Pressure, LE = Leve OW = Overall Workload, FA = Fatigue, SL = Stress Level

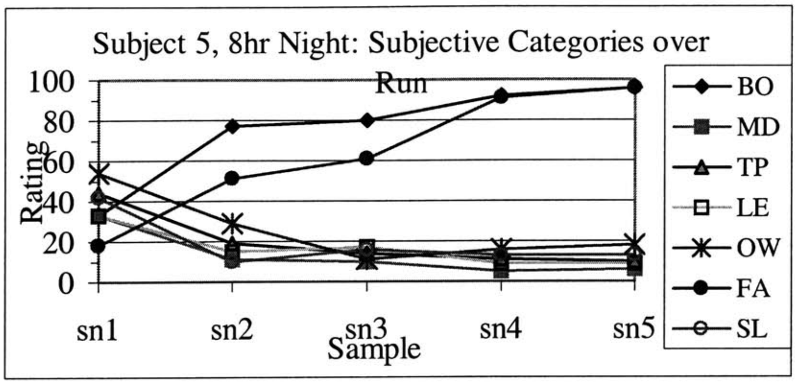


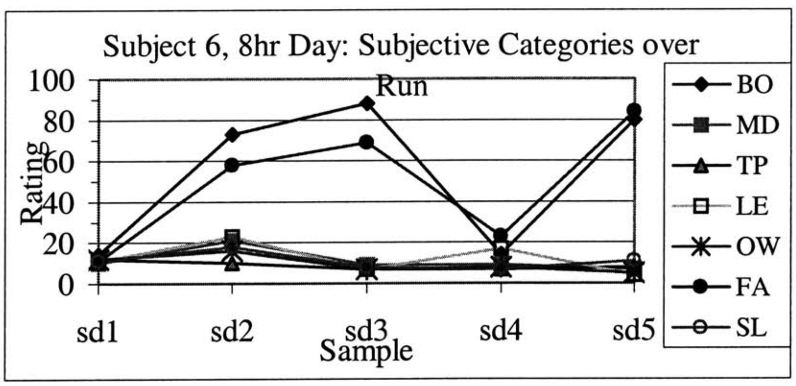







Subject 5, 8hr Day: Subjective Categories over Run
100
80
60
40
20
0
Rating
sd1
sd2
sd3
sd4
sd5
Sample
BO
MD
TP
LE
OW
FA
SL


Subject 5, 8hr Night: Subjective Categories over Run
100
80
60
40
20
0
Rating
sn1
sn2
sn3
sn4
sn5
Sample
BO
MD
TP
LE
OW
FA
SL


Subject 6, 8hr Day: Subjective Categories over Run
100
80
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40
20
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Rating
sd1
sd2
sd3
sd4
sd5
Sample
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MD
TP
LE
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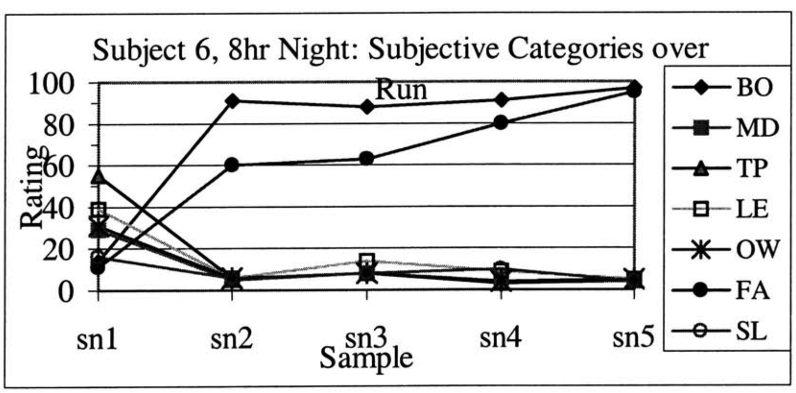
FA
SL


Subject 6, 8hr Night: Subjective Categories over Run
100
80
60
40
20
0
Rating
sn1
sn2
sn3
sn4
sn5
Sample
BO
MD
TP
LE
OW
FA
SL

Appendix B: Subject Selection Survey

Participant Background Survey

ID Number ____________ **Date** ______________

Instructions

This survey is anonymous. Please do not put your name anywhere on the survey.

Thank you for your participation in this research study. This survey has been developed to validate various fatigue monitoring and alerter technologies currently available to the US railroad industry. The demographic information you will be providing on this survey will help us in our evaluation of your simulator performance. This survey is divided into 6 different sections, and should take you about 15 minutes to complete. Please fill in the blanks; circle; or place check marks, as appropriate. There are no right or wrong answers. This is not a test. Your honest answers to the questions are necessary for the results to be useful. Please leave blank any questions you find objectionable or uncomfortable. Also, due to the confidential nature of this information, we kindly ask that you do not share or discuss your answers with anyone else until after all data collection has been concluded. All information you provide will be safeguarded and never linked with your name or other identifying information.

I f you have any questions about the survey, please call:

Viengvilay Oudonesom (617) 494-3101
Stephen Popkin, Ph.D. (617) 494-3532

Turn the page to begin....

SECTION 1 - ABOUT YOURSELF

1. Your age: ______ years

2. Sex: ___ Female ___ Male

3. Height: ____ Feet ____ Inches Weight: ______ Pounds

4. How long have you been at MIT?
_____ years and _____ months

5. What is your date of birth (MM/DD/YYYY)? _________

6. If previously employed before entering MIT, what was your position?_____________

7. (a) Are you currently holding a job? ____ Yes ____ No (If No, go to #8)
 (b) What is your job? _____________________________________
 (c) How many hours per week do you work your job? ________hours
 (d) What shift/hours do you work? _______________________

8. What is your marital status?

____ Single ____ Divorced _____ Other
____ Married ____ Widowed

9. a) How many children or other dependents do you have (not including spouse)? ____
 b) How many dependents due you have under the age of 2 years? ____

10. What is your education level? Check the highest level that applies.

____ No High School

____ Some High School (___ years)

____ GED

____ High School Diploma

____ Some College (___ years)

____ Associates Degree (2-year program)

____ Bachelors Degree (4-year program)

____ Graduate Degree

11. (a) Do you drink caffeinated beverages? Check one. ____ Yes ____ No

    (b) About how many cups and cans of these beverages do you drink per day?

    _______ cups and cans/day

12. (a) Do you smoke cigarettes? Check one. ____ Yes ____ No

    (b) About how much do you smoke *per day*? Circle one.

    less than 1/2 pack   about 1 pack   more than 1 pack   more than 2 packs

13. How many alcoholic beverages (including beer) do you drink in an average week?

    A)_____ drinks/week   B) Weekday average_____   C) Weekend Average_____

SECTION 2 - YOUR HEALTH

1. Please indicate with a ✓whether you have experienced any of the following conditions or symptoms. Include approximate dates where possible, whether you saw a doctor (Yes or No), the treatment prescribed for the condition (e.g., surgery, medication, counseling, relaxation therapy, exercise, etc.) and if the condition is under control.

	Dates	Doctor	Treatment	Controlled?
❑ **Hypertension/ High blood pressure**		Y / N		Y / N

	Dates	Doctor	Treatment	Controlled?
❑ **Nervousness or anxiety**		Y / N		Y / N
❑ **Heart disease**		Y / N		Y / N
❑ **Eczema, hives, or other skin disorders**		Y / N		Y / N
❑ **Ulcers or other gastrointestinal problems**		Y / N		Y / N
❑ **Depression or other disturbances of mood**		Y / N		Y / N
❑ **Asthma**		Y / N		Y / N
❑ **Persistent back/neck/ shoulder pain**		Y / N		Y / N
❑ **Migraine or tension headaches**		Y / N		Y / N
❑ **Insomnia or other sleep disturbances**		Y / N		Y / N

2. How many days have you been ill in the last 6 months? _______ days

3. On average, how often do you exercise or play a sport? Circle one.

   Never 1 Day/Week 2-3 Days/Week 4-5 Days/Week 6-7 Days/Week

4. In general, how would you rate your health? Circle one.

   Excellent Good Fair Poor

5. Some people feel younger or older than their biological age. How old do you feel?
   ________ years old

SECTION 3 – YOUR LIFE SCHEDULE

1. What is your current sleep/wake schedule?

	Sun	Mon	Tues	Wed	Thurs	Fri	Sat
Primary Sleep Start							
Primary Sleep End							
Extra Sleep Start							
Extra Sleep End							

2. If you hold an outside job, on average, how many consecutive days do you work per week, before having a day off? ______ days

3. If you hold an outside job, how many hours are you SCHEDULED to work in an average week? _____ hours

4. What is the total (round trip) time you spend on your daily commute?

   _______ hours _______ minutes

5. How often do you feel well-rested and alert over the course of your day? Circle one.

   Never Occasionally Frequently Always

6. How often do you feel physically drained at the end of your day? Circle one.

   Never Occasionally Frequently Always

7. How often do you feel mentally drained at the end of your day? Circle one.

   Never Occasionally Frequently Always

SECTION 4 – YOUR SLEEP HABITS

1. How many hours of sleep do you get per day (including naps)?

   (a) during workweek _____ hours/day (b) during days off _____ hours/day

2. (a) How often do you wake up feeling tired or exhausted during the school week?

   Never Occasionally Frequently Always

   (b) How often do you wake up feeling tired or exhausted during your weekends?

   Never Occasionally Frequently Always

3. How often do you use prescription or over-the-counter sleep aids? Circle one.

   Never Occasionally Frequently Always

4. (a) Do you ever take naps of one hour or less during the school week?
   ____ Yes ____ No (If No, go to # 7)

   (b) Do you ever take naps of one hour or less during your weekends?
   ____ Yes ____ No

5. (a) On average, how many naps do you take per day during the school week?

   _____ naps/day

   (b) On average, how many naps do you take per day during your weekends?

   _____ naps/day

6. (a) On average, how many days per week do you take at least one nap?

   _____ days/week

   (b) At what time of day and for how long do you usually take your naps?

   I usually start my nap at ____:____ and it lasts, on average, for _______ minutes.

7. Some people employ a "split sleep" strategy, where total sleep time is divided into two or more blocks over a 24-hour period. For example, someone might sleep for four hours after work, get up to spend time with family, and then go back to sleep for a few more hours.

   (a) Do you ever use a split sleep strategy? ___ Yes ___ No (If No, go to # 8)

   (b) On average, how many days per week do you split your sleep?

   _____ days/week

   (c) How many blocks do you typically divide your sleep time into, and about how long is each block? Check the number of blocks and fill in the appropriate amount of time.

   ___ 2 Blocks: Block 1 ____hrs. Block 2 ___ hrs.

   ___ 3 Blocks: Block 1 ____hrs. Block 2 ___ hrs. Block 3___ hrs.

   ___ Other (please describe):

8. The term "insomnia" refers to problems in getting to sleep or staying asleep. There are three varieties: (a) difficulty in falling asleep initially; (b) frequent awakenings (difficulty in staying asleep); and (c) early awakenings where you wake up too early and cannot get back to sleep. Please indicate with a ✔ if you have any of these forms of insomnia and if so, how often you experience the symptoms. It is possible to have more than one form of insomnia.

   (a) ______ Difficulty falling asleep ______ nights/week

   (b) ______ Frequent awakenings ______ nights/week

   (c) ______ Early awakenings ______ nights/week

SECTION 5 – QUALITY OF LIFE

This section contains questions about how you have been feeling lately. There are no right or wrong answers. Please read each question carefully and decide how often you have had these feelings during the past month, whether at work or at home.

Never	*Almost Never*	*Sometimes*	*Fairly Often*	*Very Often*
1	*2*	*3*	*4*	*5*

In the **last month**, how often have you:

1. been upset because of something that happened unexpectedly?	1	2	3	4	5
2. felt that you were unable to control important things in your life?	1	2	3	4	5
3. felt nervous and stressed?	1	2	3	4	5
4. dealt successfully with irritating life hassles?	1	2	3	4	5
5. felt that you were effectively coping with important changes occurring in your life?	1	2	3	4	5
6. felt confident in your ability to handle your personal problems?	1	2	3	4	5
7. felt that things were going your way?	1	2	3	4	5
8. found that you could not cope with all the things you had to do?	1	2	3	4	5
9. been able to control the irritations in your life?	1	2	3	4	5
10. felt that you were on top of things?	1	2	3	4	5
11. been angered by things happening that were outside of your control?	1	2	3	4	5
12. found yourself preoccupied with the things you need to accomplish?	1	2	3	4	5
13. been able to control the way you spend your time?	1	2	3	4	5
14. felt difficulties were piling up so high that you could not overcome them?	1	2	3	4	5

SECTION 6 – ADDITIONAL SLEEP QUESTIONS

1. How many hours sleep do you feel you usually need per day, irrespective of your school and work schedule?

 __________hours ____________mins

2. How do you feel about the sleep you normally get?

	No where near enough	Could do with a lot more	Could do with a bit more	Get the right amount	Get Plenty
During School Week					
During Weekend					
Overall					

3. How well do you normally sleep?

	Extremely Badly	Quite Badly	Moderatel y Well	Quite Well	Extremely Well
During School Week					
During Weekend					
Overall					

4. How rested do you normally feel after sleep?

	Definitely Not Rested	Not Very Rested	Moderatel y Rested	Quite Rested	Extremely Rested
During School Week					
During Weekend					
Overall					

5. Do you ever wake up earlier than you intended?

	Almost Never	Rarely	Sometime s	Frequentl y	Almost Always
During School Week					
During Weekend					
Overall					

6. Do you have difficulty in falling asleep?

	Almost Never	Rarely	Sometimes	Frequently	Almost Always
During School Week					
During Weekend					
Overall					

7. Do you take sleeping pills?

	Almost Never	Rarely	Sometimes	Frequently	Almost Always
During School Week					
During Weekend					
Overall					

8. Do you use alcohol to help you to sleep?

	Almost Never	Rarely	Sometimes	Frequently	Almost Always
During School Week					
During Weekend					
Overall					

9. Do you ever feel tired on

	Almost Never	Rarely	Sometimes	Frequently	Almost Always
The School Week					
The Weekend					
Overall					

10. The following items relate to how tired or energetic you generally feel, irrespective of whether you have had enough sleep or have been working very hard. Some people appear to "suffer" from permanent tiredness, even on rest days and holidays, while others seem to have limitless energy. Please indicate the degree to which the following statements apply to your own normal feelings.

	Not At All		Somewhat		Very Much So
I generally feel I have plenty of energy					
I usually feel drained					
I generally feel quite active					
I feel tired most of the time					
I generally feel full of vigor					
I usually feel rather lethargic					
I generally feel alert					
I often feel exhausted					
I usually feel lively					
I feel weary much of the time					

11. Please check the response for each item that best describes you.
    (a) Considering only your own "feeling best" rhythm, at what time would you get up if you were entirely free to plan your day?
    05:00 – 06:30 a.m. _____
    06:30 – 07:45 a.m. _____
    07:45 – 09:45 a.m. _____
    09:45 – 11:00 a.m. _____
    11:00a.m. – 12:00 (noon) _____

    (b) Considering only you own "feeling best" rhythm, at what time would you go to bed if you were entirely free to plan you evening?
    08:00 – 09:00 p.m. _____
    09:00 – 10:15 p.m. _____
    10:15 p.m. – 12:30 a.m. _____
    12:30 – 01:45 a.m. _____
    01:45 – 03:00 a.m. _____

(c) Assuming normal circumstance, how easy do you find getting up in the morning?
Not at all easy ______
Slightly easy ______
Fairly easy ______
Very easy ______

(d) How alert do you feel during the first half hour after having awakened in the morning?
Not at all alert ______
Slightly alert ______
Fairly alert ______
Very alert ______

(e) During the first half hour after having awakened in the morning, how tired do you feel?
Very tired ______
Fairly tired ______
Fairly refreshed ______
Very refreshed ______

(f) You have decided to engage in some physical exercise. A friend suggests that you do this one hour twice a week and the best time for him is 7:00 – 8:00 a.m. Bearing in mind nothing else but your own "feeling best" rhythm, how do you think you would perform?
Would be in good form ______
Would be in reasonable form ______
Would find it difficult ______
Would find it very difficult ______

(g) At what time in the evening do you feel tired and, as a result, in need of sleep?
08:00 – 09:30 p.m. ______
09:00 – 10:15 p.m. ______
10:15 p.m. – 12:03 a.m. ______
12:30 – 01:45 a.m. ______
01:45 – 03:00 a.m. ______

(h) You wish to be at your peak performance for a test which you know is going to be mentally exhausting and lasting for two hours. You are entirely free to plan your day, and considering only your own "feeling best" rhythm, which ONE of the four testing times would you choose?
08:00 – 10:00 a.m. ______
11:00 a.m. – 01:00 p.m. ______
03:00 – 05:00 p.m. ______
07:00 – 09:00 p.m. ______

(i) One hears about "morning" and "evening" types of people. Which ONE of these types do you consider yourself to be?

Definitely a morning type	_____
More a morning than an evening type	_____
More an evening than a morning type	_____
Definitely an evening type	_____

(j) When would you prefer to rise (provided you have a full day's work – 8 hours) if you were totally free to arrange your time?

Before 06:30 a.m.	_____
06:30 a.m. – 07:30 a.m.	_____
07:30 a.m. – 08:30 a.m.	_____
08:30 a.m. or later	_____

(k) If you always had to rise at 06:00 a.m., what do you think it would be like?

Very difficult and unpleasant	_____
Rather difficult and unpleasant	_____
A little unpleasant but no great problem	_____
Easy and not unpleasant	_____

(l) How long a time does it usually take before you "recover your senses" in the morning after rising from a night's sleep?

0-10 minutes	_____
11-20 minutes	_____
21-40 minutes	_____
More than 40 minutes	_____

(m) Please indicate to what extent you are a morning or evening *active* individual?

Pronounced morning active (morning alert and evening tired)	_____
To some extent, morning active	_____
To some extent, evening active	_____
Pronounced evening active (morning tired and evening alert)	_____

11. How likely are you to doze off or fall asleep in the following situations, in contrast to feeling just tired? This refers to your usual way of life in recent times. Even if you have not done some of these things recently try to work out how they would have affected you. Use the following scale to choose the most appropriate number for each situation.

0 = no chance of dozing
1 = slight chance of dozing
2 = moderate chance of dozing
3 = high chance of dozing

SITUATION	CHANCE OF DOZING
Sitting and Reading	
Watching TV	
Sitting inactive in a public place (e.g. a theatre or a meeting)	
As a passenger in a car for an hour without a break	
Lying down to rest in the afternoon when circumstances permit	
Sitting and talking to someone	
Sitting quietly after a lunch without alcohol	
In a car, while stopped for a few minutes in traffic	

☺ ***THANK YOU FOR YOUR PARTICIPATION!*** ☺

Appendix C: Subjective Rating Scales

Subjective Rating Scales

Draw a hash mark over the line position that best reflects your current state for each item.

ID Number ____________________ **Date** ____________________ **EXP Day:**_____

The time is now _______:_______ **AM or PM (circle one)**

Boredom

0 Very Low — 100 Very High

Mental Demand

0 Very Low — 100 Very High

Time Pressure

0 Very Low — 100 Very High

Your Level of Effort

0 Very Low — 100 Very High

Overall Workload

0 Very Low — 100 Very High

Fatigue

0 Not Fatigued — 100 Very Fatigued

Stress Level

0 Low Stress — 100 High Stress

Appendix D: Sleep Log

Sleep Log

Please fill out this sleep log every day at home, before you go to work. Make sure you are wearing your Actiwatch!

ID Number ____________________ **Date** ____________________

The time is now __________ **AM or PM (circle one)**

What time did you go to bed? ________ AM or PM

About how long did it take you to fall asleep? ________ hours _______ minutes

What time did you wake up? ________ AM or PM

What time did you get out of bed? ________ AM or PM

How many hours do you feel you slept? ________ hours

Number of awakenings: ________

How many times did you get out of bed? ________

If you take any **sleep aids**, please provide details on type, quantity, and frequency. Include prescription and over-the-counter medication, alcohol, melatonin, herbal remedies, & others:____________________________________

____

If you removed your Actiwatch for any reason, including to shower/bathe, please write down the beginning and ending times that the Actiwatch was NOT being worn:____________________________________

____

If you took any **naps** in the last 24 hours, please provide the beginning and end times for each:______________

____

Rate Your Sleep

Ease of falling asleep:

Very Easy Fairly Easy Fairly Difficult Very Difficult

Ease of getting up:

Very Easy Fairly Easy Fairly Difficult Very Difficult

Length of sleep:

More than Sufficient Sufficient Insufficient Wholly Insufficient

Quality of sleep:

Very Good Good Fair Poor Very Poor

How do you feel at this moment? (*circle the appropriate number*)

1	2	3	4	5	6	7	8	9
Very Alert		Alert		Neither Alert nor Sleepy		Sleepy but no effort required to stay awake		Very sleepy, fighting sleep, effort to keep

Mood Scale

For EACH item, choose ONE of the four answers that best describes how you feel now by placing a ✓ in the appropriate block.

Items	Not at All	A Little	Quite A Bit	Extremely
Active				
Alert				
Annoyed				
Carefree				
Cheerful				
Able to Concentrate				
Considerate				
Defiant				
Dependable				
Drowsy				
Dull				
Efficient				
Friendly				
Full of Pep				
Good-natured				
Grouchy				
Happy				
Jittery				
Kind				
Lively				
Pleasant				
Relaxed				
Satisfied				
Sleepy				
Sluggish				
Tense				
Able to Think Clearly				
Tired				
Able to Work Hard				

Appendix E: Debriefing Form

Debriefing Form A

Evaluation of Alertness Monitoring Devices, Pilot

ID Number ____________ **Date** ______________

The Entire lab staff would like to thank you for your participation in this experiment. We realize that this was not an easy protocol to follow, and therefore thank you for your fortitude and diligence in completing all the tasks. As this was a pilot test of the experiment, we would like you to answer the following questions so that we may enhance and refine the final version of the protocol.

1. What part(s) of the experiment/protocol did you find objectionable or a hardship?

2. What did you enjoy about the study?

3. Was the reward money an incentive to perform your best? If not, what might have worked better? -Please be specific.

4. Do you feel a reward incentive would have changed the way you performed the non-simulation tasks (e.g., digit cancellation, PVT, Waypoint)? If so, how?

5. Was there enough refreshments and rest time to your liking? If not please explain.

6. What defects did you notice in the simulation portion of the protocol (i.e., clicking sounds, aberrant images/lights, non-simulator-related sounds, voices, etc.).

7. How aware were you of time during the simulation run? Were you able to guess well when the experimental block was nearing its end? How might these be eliminated?

8. Did you notice any patterns in the presentation of simulation-based performance tasks? If so, what were they?

9. How did you occupy yourself mentally during the simulation runs?

10. Overall, how did you feel we handled you during the experiment? How might your experience have been improved?

11. Overall, what was your impression of the entire experimental procedure you have just undergone? How might it have been improved?

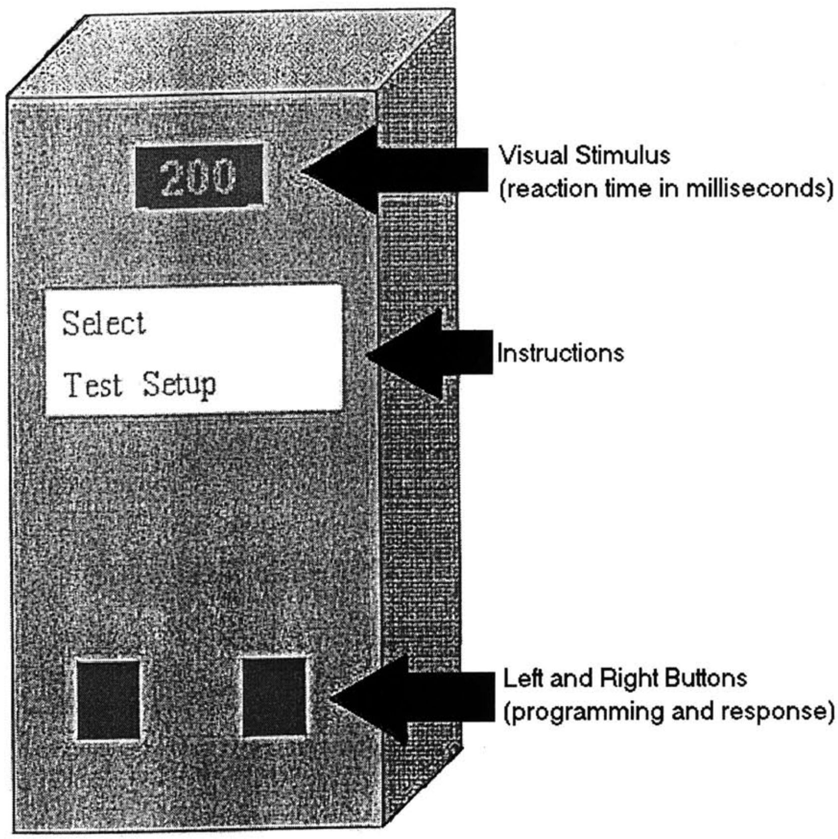
12. General comments and observations.

Appendix F: Equipment Instructions for Subject

Tests Prior to the Simulation run

• PVT-192

The PVT-192 is a computerized test-presentation and data capture system to measure your reaction time to stimuli. Human reaction time (RT) is used as an index of motor performance. The figure below is a picture of a PVT-192 unit. The unit has two push buttons, one on the Right and one on the Left, and two displays. The smaller display is a 4-digit LED numeric display. A series of numbers used to test your reaction time and your performance feedback will show in this display. The larger display is a 16character LCD alphanumeric display. The larger display will show instruction prompts.



The following is a description of what you will do when working on the PVT-192.
First indicate how you feel right now (when the Mood Word is displayed on the larger display) by using the LEFT button to move the cursor closer to NO or YES. Press the RIGHT button to register your choice. The button you will press for the rest of the test will depend on which hand is your dominant hand. If your dominant hand is RIGHT, then you will press the RIGHT button. If your dominant hand is LEFT, you will press the LEFT button. During the test, as soon as you

see the red numbers in the top window, press and release the button using your dominant hand. You may use your thumb or finger, but use the SAME FINGER for all the tests once you have decided. The numbers in the smaller display show how fast you responded each time- the smaller the number, the better you did. Try to do your best and get the lowest number you possibly can. If you press too early (before the numbers appear) you will see an error message "FS". If you press the other button (the one that does not correspond to your dominant hand), you will see an error message –"ERR". If you forget to release the button, after a short time the test screen will remind you. When the test is completed, the mood word will be presented again. When done, DO NOT turn the PVT-192 off, the test administrator will do this.

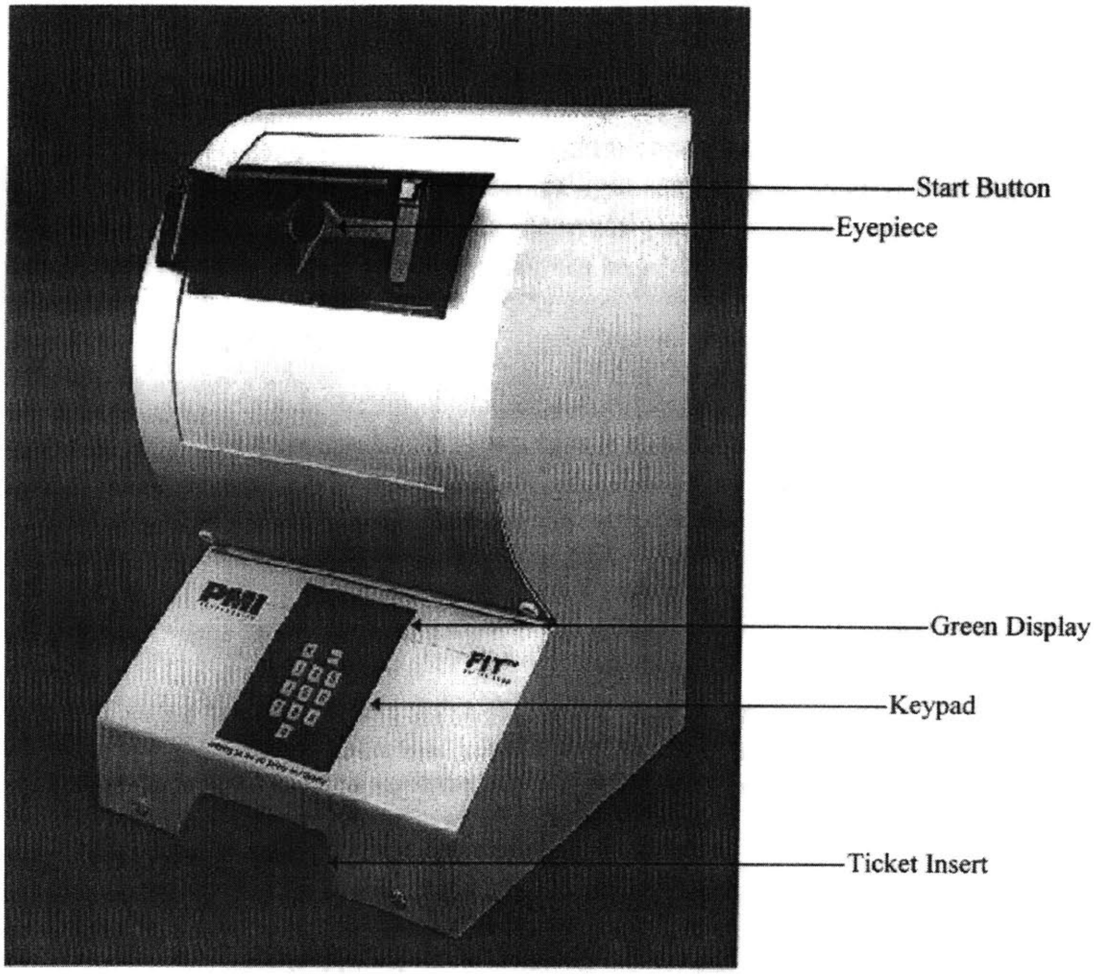
• **WAYPOINT**

Waypoint is a computerized test presentation and data collection system that tests your awareness of important events, such as events you see while driving. The goal of Waypoint is to predict how safe a driver you are by computing a high-risk odds ratio for your performance on the test. Simple instructions on the computer screen will guide you through the test.

The following description will give you an idea of what to expect during the test.
The test uses a touch screen monitor, so you will be inputting your responses by touching the correct button on the screen.
First, press the green <CONTINUE> bar on the screen to begin the test introduction. The next screen will explain the task to you. The task is to touch letters and numbers in order, a number first followed by a letter. The number and letter buttons will be scrambled on the screen and you are to touch them according to the following sequence: 1 – A – 2 – B – 3 – C – 4 – D – 5 – E, etc. You should do this as quickly as possible without making a mistake. If you make a mistake, find and touch the correct button and then go on with the sequence. You will be given two practice trials, and then you'll be asked to start the real test by pressing the <1> button on the screen. Once the test is completed, a message will appear that tells you what your high-risk odds ratio is. The lower your high risks odds ratio, the safer a driver you are predicted to be.

• FIT2000

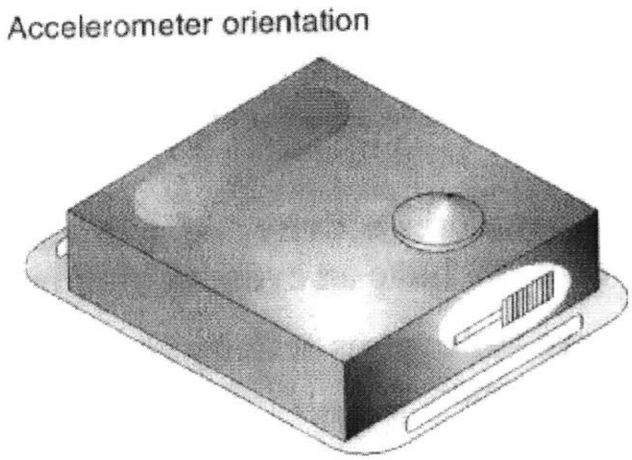
The FIT 2000 is a test that claims to reduce the risk of human error and accidents in the workplace by screening for the current effects of factors which may cause a person to be at "high risk". FIT2000 defines "High risk" as the active presence of a factor(s) that will cause a person's motor skills, decision-making ability or alertness to decrease. The main testing unit of FIT2000 is the Screener. (See figure below.) The screener looks like an eye-examining machine often used in the optometrist's office.



The following is what to expect when you are using the FIT2000.
First, you will rest your forehead on the Forehead Rest. The height of the Forehead Rest can be adjusted to accommodate your height. Position ONE eye in front of the eyepiece. Make sure you can see the green light in the center of the sighting tube as you look through the eyepiece. You must ALWAYS USE THE SAME EYE for all subsequent tests on this machine. Try to hold steady during the test. To start the test, you will press and release either of the green buttons on each side of the forehead rest, and the screener will beep. The center green light will start moving side to side. Follow the green light with your eye without moving your head. The green light will move side to side 3-6 times and then return to the center. The light will pause at the center for 5-6seconds, during which you can blink your eyes. After the pause, four green lights will begin to flash 4-7times. Look straight at the center light and try not to blink. If the test is complete, a beep will indicate that the test is over. Otherwise, a buzz will indicate that the test will run again, and you will push one of the green buttons beside the forehead rest to start the process again.

• **Actiwatch –AW64**

The Actiwatch is an activity monitor designed for long term monitoring of gross motor activity in human subjects. It contains an accelerometer that is capable of sensing any motion with a minimal resultant force of 0.01g. The Mini Mitter Company, which developed the Actiwatch, has created an algorithm to analyze sleep/wake cycles according to data stored in the watch. The watch can store several days of data. (See figure below.)

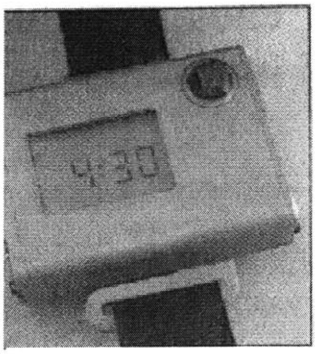


When you come to the introductory meeting, you will be given the Actiwatch. Put it around the wrist of your dominant hand. Please keep the watch on until you return to the lab to take the second set of baseline tests. When you return to take the second set of baseline tests, we will ask you to remove the Actiwatch so that we can download its data. Then we'll ask you to put the Actiwatch back on. When you come for the first 4hr or 8hr simulator run, you will be asked to return the Actiwatch permanently.

Please note that you should only take off the Actiwatch when you are taking a shower, swimming, or when the Actiwatch will be in contact with a substantial amount of water. Otherwise, keep the watch on, even when you are sleeping. Before you sleep, please press the button on the face of the Actiwatch to mark the time you went to bed, and right after you wake up, press the button again to mark the time you woke up. Also, be careful not to bang or drop the Actiwatch because it has sensitive parts that may break or malfunction upon impact and thus improperly record data. If you should accidentally drop or bang the Actiwatch, please email or call us as soon as possible so that we may check the watch. Also please be careful not to loose the watch because it is a $1000 unit.

• **Motionlogger Actigraph Sleepwatch-S Model**

The Sleepwatch is also an activity monitor designed for long term monitoring of gross motor activity in human subjects. The Sleepwatch utilizes a precision piezoelectric bimorph-ceramic cantilevered bean, which generates a voltage each time the actigraph is moved. The voltage is passed to the analog circuitry where the original signal is amplified and filtered. The Sleepwatch scores sleep using the validated Cole-Kripke algorithm. It also keeps track of the amount and duration of light the watch is exposed to. The Sleepwatch also has a time display on its face of the local time.



When you come to the introductory meeting, you will be given the Sleepwatch. Put it around the wrist of your dominant hand. Please keep the watch on until you return to the lab to take the second set of baseline tests. When you return to take the second set of baseline tests, we will ask you to remove the Sleepwatch so that we can download its data. Then we'll ask you to put the Sleepwatch back on. When you come for the first 4hr or 8hr simulator run, you will be asked to return the Sleepwatch permanently.

Please note that you should only take off the Sleepwatch when you are taking a shower, swimming, or when the Sleepwatch will be in contact with a substantial amount of water. Otherwise, keep the watch on, even when you are sleeping. Also, be careful not to bang or drop the Sleepwatch because it has sensitive parts that may break or malfunction upon impact and thus improperly record data. If you should accidentally drop or bang the Sleepwatch, please email or call us as soon as possible so that we may check the watch. Also please be careful not to loose the watch because it is a $2000 unit.

<u>Tests During the Simulation Run</u>

• **Train Simulator**
You will be testing technologies in current use or under development for the locomotive industry. The instrument panel has been simplified and instruments that are not necessary for the goals of this study have been removed. This has been done to eliminate the problems associated with teaching non-locomotive engineers how to operate a train correctly as well as to eliminate the specific problem of the learning curve. This study is a test bed study to get preliminary data on vigilance/alerter technologies, and we'll be using non-locomotive engineer subjects. In later studies, we will use real locomotive engineers and reinstate the whole instrument panel and train functions. The following will be included in the train simulator for the current study:

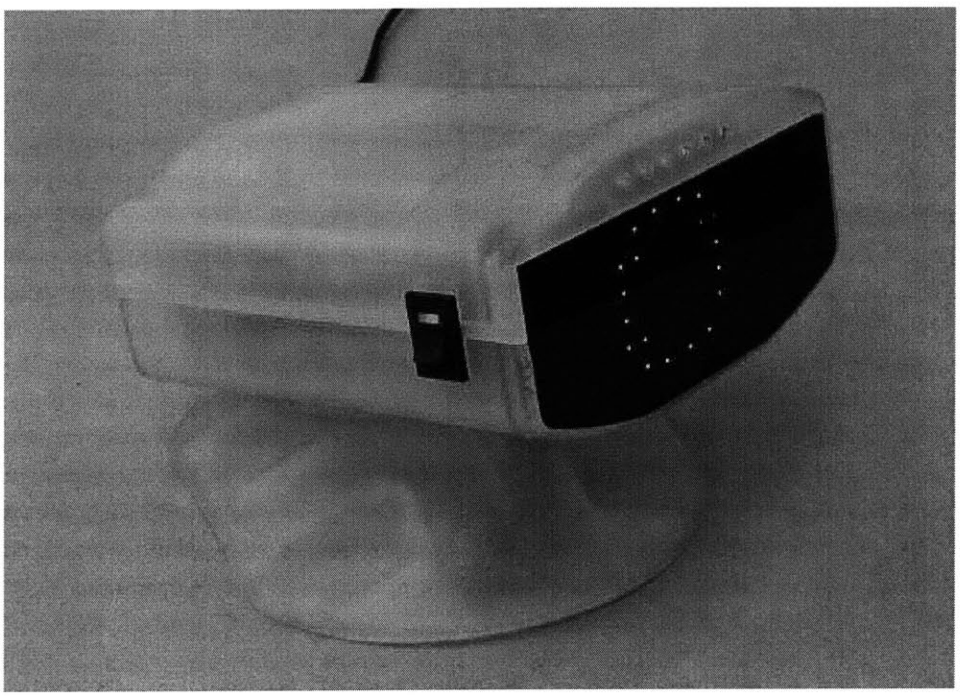
• **Train Sentry Alerter**
The Train Sentry III is an electronic device designed to monitor the alertness of the locomotive engineer. It belongs to a class of standard alerter devices used in North American trains. After a predetermined period of time, the system requests acknowledgement by the means of visual and auditory alarms. First, the light on the alerter response button will illuminate. If you do not respond to this light, the auditory alarm will start and another set of lights in the front corner of the train cabin will flash red. To respond to the alarms, press the response button. Once you respond, the alarms will stop and reset themselves. In a real locomotive, failure to respond to the alarms results in the system de-energizing a magnet valve in the locomotive brake system. This results in a power-down sequence, which will bring the locomotive to a safe and complete stop. If you don't respond to the alarms during the simulation, the simulation will go into an emergency pause state. Please avoid going into the emergency state by responding to the alarms as quickly as possible.

• **Arithmetic Alerter**
The Arithmetic Alerter is currently being developed and works in conjunction with the Train Sentry Alerter. The arithmetic alerter imposes a cognitive task, a simple addition or subtraction problem, in addition to the sequence of alarm events imposed by the Train Sentry Alerter. When the alerter first starts, an addition or subtraction problem will appear on the instrument panel. You will enter the correct answer to the problem on a numeric keypad. Just press the number once. If your answer is correct, the problem will disappear and the alarms will turn off and reset. If the answer you entered was incorrect, the problem will remain on the instrument panel until you enter the correct answer. If you do not enter the correct answer in a predetermined time, the auditory alarm will start and the lights in the upper corner of the cab will start flashing red. Again, if you do not respond to these alarms during the simulation, the simulation will go into an emergency pause state. Please avoid going into the emergency state by responding to the arithmetic problem correctly and as quickly as you can.

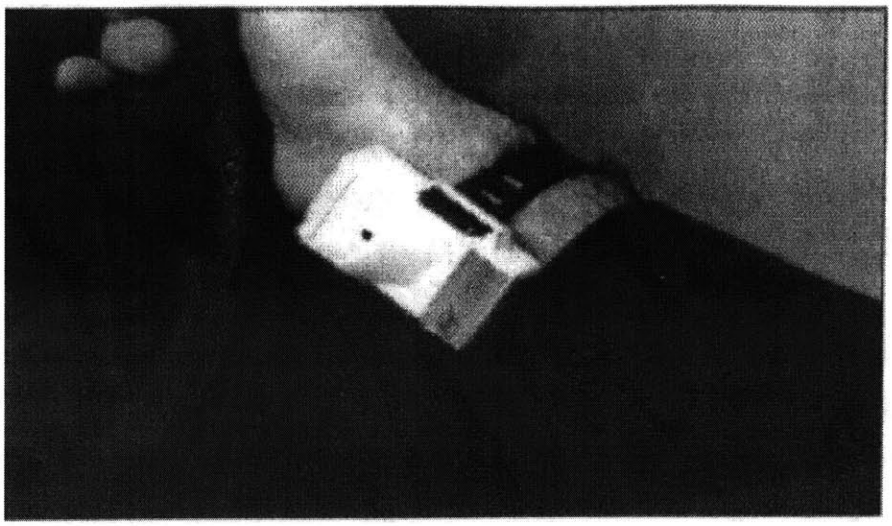
• **Cruise Control**
A company has developed a cruise control for the locomotive. This is a new technology for this industry, but one that still remains under development. Volpe is trying to expedite the development in addition to testing the aforementioned alerter technologies. During the simulation, you will be asked to monitor locomotive speed and to make corrections if it falls outside the acceptable range. If the speed too high, you will pull the speed control joystick towards your body to decrease the speed. If the speed is too low, you will push the joystick forward, away from your body to increase the speed. You will also be asked from time to time to make corrective movements based on LED output. Red and green LEDs are provided alongside the out-the-window view of the simulator. When the speed control algorithm detects a fault between internal speed values and speed values displayed on the speedometer, it will light up a red LED for you to slow the train down, or a green LED for you to increase speed. Again to decrease speed, you will pull the speed joystick towards your body, and to increase speed, you will push the speed joystick away from your body.

• **Oasis/Copilot**
The Copilot is a device, which claims to automatically track and detects fatigue from eye position and eyelid closure (PERCLOS). PERCLOS is the percentage of eyelid closure over the pupil over time. In other words, it is the measure of the portion of time the subject's eyes were closed at least some percentage (e.g. 80% eyelid closure) over a one-minute period. The measurements involve slow eyelid closures and droops, rather than blinks. The monitor takes two simultaneous images of the driver at two wavelengths of light. The monitor then measures the reflection of light from the eyes to determine eye position and eyelid closure.

You do not have to prepare for the Copilot test. The Copilot camera will be positioned in the cab and will collect data while you are operating the train. (See the figure below.)

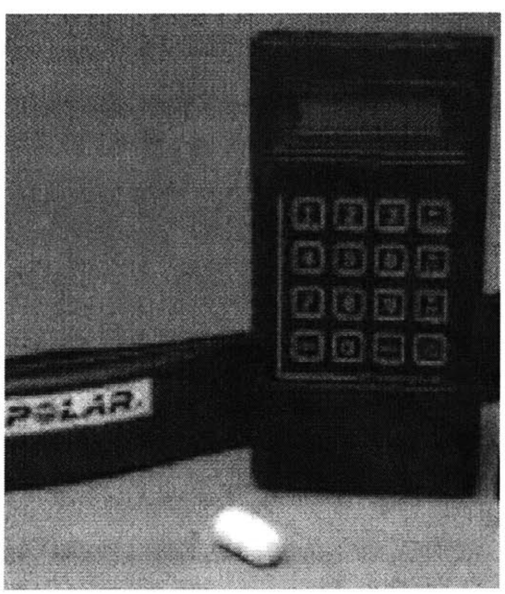


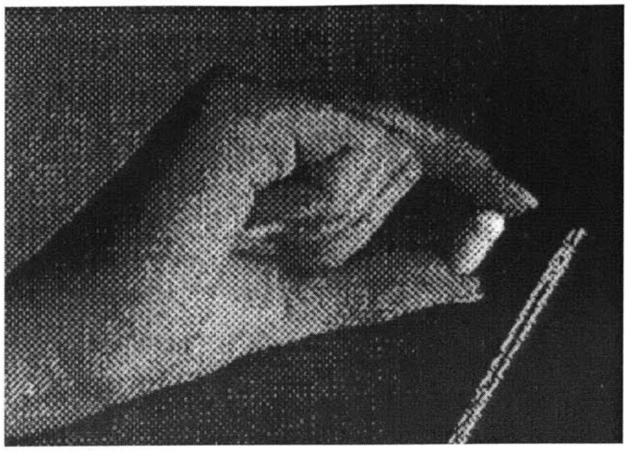
• **NOVAlert SAM-10**
NOVAlert is a wrist-worn sensor/monitor/transmitter for broad monitoring and alerting tasks. Atlas Interactive Technologies, the company which developed NOVAlert claims that the device identifies signs of performance decrement, memory impairment, distorted perception, inattention, drowsiness and increasing propensity of impending sleep by recording and analyzing micro muscle activity.

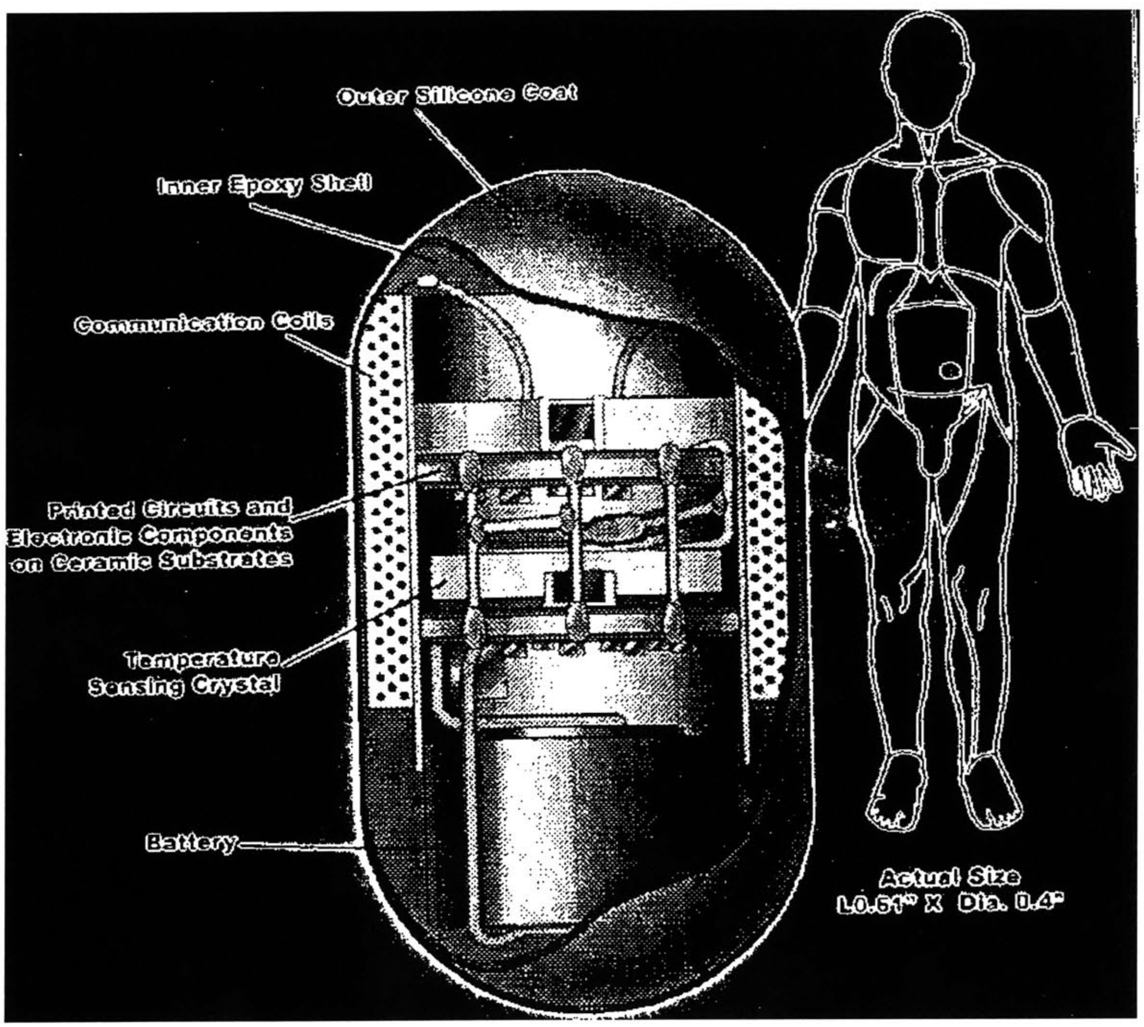


You will be asked to wear the NOVAlert wrist unit on your dominant wrist and index finger while you are operating the train simulator. The wrist unit is attached to the NOVAlert-O-Meter, a small receiving and decoding unit that should be placed in a waist pouch that you will be asked to wear during the simulation run. You do not need to do anything else. The NOVAlert will record data while you operate the train simulator.

•CorTemp
CorTemp is a wireless core body temperature monitoring system. It provides a complete clinical electronic thermometer system that records accurate temperature measurements of your internal body. The CorTemp consists of the CorTemp Temperature Sensor pill and the CorTemp2000 (CT2000) Ambulatory Receiver. The CorTemp Temperature Sensor pill takes your internal body temperature reading at specified intervals and transmits those readings to the CT2000 Ambulatory Receiver. (See figure below)






Outer Silicone Coat
Inner Epoxy Shell
Communication Coils
Printed Circuits and
Electronic Components
on Ceramic Substrates
Temperature
Sensing Crystal
Battery
Actual Size
L0.61" X Dia. 0.4"

The CorTemp Sensor pill is powered by a non-rechargeable Silver-Oxide battery and is encapsulated in epoxy resin, which is then coated with silicone rubber. The Sensor utilizes a temperature sensitive crystal, which vibrates in direct proportion of the temperature of the substance surrounding it. This vibration creates an electromagnetic flux, which transmits harmlessly through the surrounding substance. The CT2000 Receiver receives this signal and translates it to digital temperature information, which is displayed on the unit and stored to memory.

If you volunteer to use CorTemp, before each run on the 4hr or 8hr train simulation, you will be given the CorTemp Sensor pill to swallow. You will also be given a waist pouch or belt to carry the CT2000 Receiver unit. You do not need to do anything else. CorTemp will record your temperature data while you operate the train simulator. The CorTemp Sensor pill is disposable and will pass through your system according to your metabolism. The CorTemp Sensor pill has been proven to be safe and has been approved by the FDA.

Appendix G: Detailed Procedures for Experiment

VOLPE VIGILANCE STUDY
OVERVIEW OF PROCEDURES FOR 5+ DAYS OF THE EXPERIMENT FOR EACH SUBJECT

Day 0:
Prior to the participant coming in for Day 1 Baseline measurements, make sure all the instruments are operating and set up for the specific participant. Verify that the equipment is recording the record data to the appropriate files. The following list is the equipment that must be verified:

1) Fit2000
2) PVT
3) Digit Cancellation Task
   - Verify the appropriate number of tests and the correct instructions have been printed and assembled
4) Waypoint
5) OASIS/COPILOT
   - Participant will be sat in simulator cab; assessment of how well OASIS is able to work on particular participant's eyes
6) Train Simulator
7) Actiwatch
8) Motionlogger Light Sensor Watch
9) Sleep Logs

Make sure their Information/Instruction packet is ready.

Day 1:
Subject will come to the lab for a formal introduction to the experimental procedures. During this period they will be provided with a packet of materials, including written instructions on how to use and perform the various pieces of equipment and tests, and sleep log forms. The experimenter will review all materials in detail with the participant. Participants will be assigned an Actiwatch and a MotionLogger, asked to sign a form acknowledging that they have received these devices, and shown how to use the devices in conjunction with the daily log. The experimenter will also provide information on the CoreTemp ingestible thermistor to the participants in order to obtain their consent

A. Screen participant on OASYS
B. Provide and review information packet with participant
   a. Explain purpose/provide overview of experiment
   b. Explain each device to be tested
   c. Explain simulation tasks and scoring scheme (give sample printout)
C. Assign Actiwatch and Motionlogger to participants
   a. Have participants sign acknowledgement form
   b. Explain how to use devices
D. Provide participants with daily log form packet

a. Explain how to use forms

E. Explain CoreTemp thermistor/try to enlist support

F. Begin filling in Data Record on participant

G. Participants given a tour of equipment; baseline data begins to be collected

1) Fit2000 (first time) If the subject fails, have them repeat this test until we can get a baseline data.
2) PVT
3) Fit2000 (second time)
4) Digit Cancellation Task
5) Fit2000 (third time)
6) Waypoint
7) Fit2000 (forth time)
8) OASIS/COPILOT (when subject goes into train booth, check if OASIS can take readings of the subject's eyes)
9) Train Simulator (short, 5 minute run) Expose him to
   a) Arithmetic Task
   b) Train Sentry Alerter Task
   c) Speedometer Tracking Task
   d) LED Tracking Task
10) Fit2000 (fifth time)

Participant will be given an appointment card, reminding him to return on the third day to repeat the above 10 data collection and familiarization tasks. Participants will be reminded to immediately call the experimenter if they encounter any problems, either in scheduling or failures in equipment of log forms. They will be reminded to bring in their completed log forms during their next scheduled lab visit.

After the participant has left:

A. Download all data from collection instruments

B. Copy all data onto second floor computer in the appropriate directory

C. Complete paper data record for that day

Day 2:
Email a thank you note to the participant for joining the study. Also, remind them about completing the sleep log and wearing the Actiwatch, and confirm the time they will return on Day 3 for baseline tests. Also remind them to bring in their completed daily logs for day 1 and 2 on day 3.

Day 3:
Take the Actiwatch and Motionlogger Light Sensor Watch from the subject and download the data. Review data to ascertain:

a) instrument is working properly
b) participant is wearing the device

Return the watches to the participant. Collect his daily log and discuss any anomalies that occurred in the past two days. Copy forms, filing one in data record, and preparing the second one for entry into a database. Have the participants repeat the baseline testing as outlined in Day 1, except collect twice as many FIT2000 data points.

Day 4:
Email a thank you note to the participant for continuing on with the study. Also, remind them about completing the sleep log and wearing the Actiwatch, and confirm the time they will return on Day 5 for their 4 or 8 hour simulation run. Also remind them to bring in their completed daily logs for day 3 and 4 on day 5.

Day5:
Experimenters are to come in 1 hour prior to the scheduled simulator run, participants 30 minutes prior to run. Set up and check the testing equipment (as specified in Day0), and make sure snack food and drink are available. Verify that the equipment is recording the data to the correct files. The train simulator should be set up so that the participant needs only to press enter to begin the simulation run. If the participant has agreed to take the CorTemp pill, initialize the pill and the CorTemp recorder.

Thirty minutes prior to the simulator run, meet participant in Building 1 and sign him in. Bring participant back to Building 6 and have him complete the following tests:

1) If the subject has agreed to take the CorTemp pill, have them swallow the pill and verify that the recorder is picking up the signal. (have extra batteries on hand)
2) Fit2000 (first time) If the subject fails, have them repeat this test until we can get a baseline data.
3) PVT
4) Fit2000 (second time)
5) Digit Cancellation Task
6) Fit2000 (third time)
7) Waypoint
8) Fit2000 (forth time)
9) Subjective measures
10) Fit2000 (fifth time)
11) Train Simulator (session 1, 110 minutes)
    a) Fit the participant with the Novalert watch and finger sensor.
    b) Check if Oasis/Copilot is positioned correctly and can take readings of the participant's eyes.
    c) While the participant is working with the train, make sure all the Fit2000, PVT, and Waypoint data have been downloaded and are under the correct file names.
    d) Record any anomalies that occur during run; especially during time of performance tests (alerter go on?)
12) Break (10-15 minutes)
    a) Fit2000 (second time)
    b) PVT
    c) Digit Cancellation Task
    d) Waypoint
    e) Subjective measures
    f) Bathroom/stretch/food/water/etc...

g) Turn off the current OTW Display and start a new 2hr OTW display.

13) Train Simulator (session 2, 110 minutes)

a) Fit the participant with the Novalert watch and finger sensor.

b) Check if Oasis/Copilot is positioned correctly and can take readings on the participant's eyes.

c) While the participant is working with the train, make sure all the Fit2000, PVT, and Waypoint data have been downloaded and are under the correct file names upstairs.

14) Break or End of Simulation...

If the subject is doing the 4hour simulator: End of Simulator Run, perform:

- Fit2000 (third time)
- PVT
- Digit Cancellation Task
- Waypoint
- Subjective measures
- End of session administrative/paper work
  a) If night run, call a taxi to pick everyone up in 10-15minutes
  b) Have participant return the Actiwatch and Motionlogger Light Sensor Watch and sign form with experimenter. Make copy of form for participant.
  c) Download the data from the watches, simulator, equipment (and CorTemp recorder), and store on second floor computer.
  d) Back up data file on CD.
  e) Collect activity log from participant, make a copy, filing one under his paper data record.
  f) Copy the sleep log and return it to him. Remind him to continue to fill out the sleep log and to bring it to the last simulator run.
  g) Check his bonus payment worksheet but do not let him know what his bonus earnings is.
  h) Have him sign the payment consent form.
  i) Turn off the Train Simulator and OTW display. If night run, lock up and wait for the taxi in the lounge.

If subject doing 8hr Simulation Run: Break (10-15 minutes)

- Fit2000
- PVT
- Digit Cancellation Task
- Waypoint
- Subjective measures
- Bathroom/stretch/food/water/etc...
- Turn off the current OTW Display and start a new 2hr OTW display.

If subject is doing the 8hour simulator run:

15) Train Simulator (session 3, 110 minutes)

a) Fit the participant with the Novalert watch and finger sensor.

b) Check if Oasis/Copilot is positioned correctly and can take readings of the participant's eyes

c) While the participant is working with the train, make sure all the Fit2000, PVT, and Waypoint data have been downloaded and are under the correct file names

d) Record any anomalies that occur during run; especially during time of performance tests (alerter go on?)

16) Break (10-15 minutes)
   a) Fit2000 (fourth time)
   b) PVT
   c) Digit Cancellation Task
   d) Waypoint
   e) Subjective measures
   f) Bathroom/stretch/food/water/etc...
   g) Turn off the current OTW Display and start a new 2hr OTW display.

17) Train Simulator (session 4, 110 minutes)
   a) Fit the participant with the Novalert watch and finger sensor.
   b) Check if Oasis/Copilot is positioned correctly and can take readings on the participant's eyes.
   c) While the participant is working with the train, make sure all the Fit2000, PVT, and Waypoint data have been downloaded and are under the correct file names upstairs.

18) End of Simulator Run, perform:
- Fit2000 (fifth time)
- PVT
- Digit Cancellation Task
- Waypoint
- Subjective measures
- Bathroom/stretch/food/water/etc...
- End of session administrative/paper work
   a) If night run, call a taxi to pick everyone up in 10-15minutes
   b) Have participant return the Actiwatch and Motionlogger Light Sensor Watch and sign form with experimenter. Make copy of form for participant.
   c) Download the data from the watches, simulator, equipment (and CorTemp recorder), and store on second floor computer.
   d) Back up data file on CD.
   e) Collect activity log from participant, make a copy, filing one under his paper data record.
   f) Copy the sleep log and return it to him. Remind him to continue to fill out the sleep log and to bring it to the last simulator run.
   g) Check his bonus payment worksheet but do not let him know what his bonus earnings is.
   h) Have him sign the payment consent form.
   i) Turn off the Train Simulator and OTW display. If night run, lock up and wait for the taxi in the lounge.

Day 6:
Check all the data we collected and try to graph them. Send thank you email to subject and remind them to keep filling in the daily log. Verify time and date he is to return to complete the second simulator run.

Day n-1: Day before the Second Simulator Run
Email participant and remind him to come in to do the second simulator run. Also remind him to bring his daily log forms.

Day n: Second Simulator Run
Repeat procedures of Day 5. At the end of the simulator run, debrief the subject.

Day n+1: Day after the Second Simulator Run
Email to thank the subject for his participation and to let him know that the check is on its way.

Appendix H: Equipment Procedures for Experimenters

Equipment Procedures for Experimenter

SYNCHRONIZE TIMES ON EVERY COMPUTER IN THE EXPERIMENT
NOTE: Before doing any other procedure, you must synchronize the computers with the network's local time. Also synchronize the VCR/CAMERA MONITOR time.

For all PCs

1. Click on the <Start> button on the desktop.
2. Select <Run> in the menu that pops up.
3. In the "Run" window, type:
   systime
4. A window will open showing the network's local time. The time on the desktop task bar (in the lower right hand corner) should now show this network local time. If so, the PC is now synchronized with the network time.
5. Close the window.

For the UNIX computers (Harry and Impact)

1. login as the super user by typing
   su
2. Enter the super user password
3. To get the current system time, type
   date
4. To change the system time so that it matches the Novell times on the PCs, type
   date MMDDHHMM.SS
   For example to set time to April 19, 2001, 4:30:15pm, you would type
   date 04191630.15

FIT 2000 PROCEDURES

How to Startup the Screener

If system is not on or not working, start with step 1. Otherwise, start at step 3.

1. Close the "Admin" and "Hub" applications windows.
2. Turn off the screener (There is a switch on the back of the machine.)
3. Start "Admin" (double click on the "Admin" icon on the Windows desktop)
4. Start "Hub" (double click on the "Hub" icon on the Windows desktop)
5. Turn the screener power on.
   (It may take about 50 seconds for the screener to boot up. Then it should display "Enter ID Number". At the same time, the Hub will display "Ready")

Notes: If the screener doesn't boot up the first time, turn it off and on again.

How to Use the Screener

1. Enter ID # on the screener
2. Rest your forehead on the Forehead Rest. Try to hold steady during the test.
3. Adjust the Forehead Rest Assembly up and down to position ONE EYE in front of the eyepiece. Make sure you can see the green light in the center of the sighting tube. ALWAYS USE THE SAME EYE.
4. Press and release either of the green buttons.
5. The screener will beep. The center green light will start moving side to side. Follow the green light with your eye without moving your head. (The green light will move side to side 3 to 6 times)
6. The green light will return to the center and pause for 5 to 6 seconds.
   You can blink your eye during this pause.
7. After the pause, 4 green lights will begin to flash 4 to 7 times. Look straight at the center light and try not to blink.

8a. A beep will indicate that the test is complete. "Complete" will be display.
8b. OR a buzz will indicate that the test will run again and you will repeat steps 5 through 8.

How to Enter a Subject's Info into a Database at the Admin Terminal

1. Click on the pull down menu on the "Admin" window
2. Enter the appropriate password if prompted (i.e. database or admin)
3. Click on the Database pull-down menu and select Employee
4. The "Edit Employee Data" dialog box will pop up and may already have values.
5. Click on <Add> button to enter a new subject's data.
6. Enter the subject's data in the required fields:
   a) Name (last, first, middle initial [optional])
   b) Social Security Number
   c) Employee ID# (it can be from 2 to 10 digits, but all ID#'s MUST be the same length)
   d) Department (select from the department pull-down menu)
   e) Job Class (This defines how often a subject should be screened. Select it from the job class pull-down menu)
   f) Testing Enabled From (enter the time range a subject can test)
   g) Testing Enabled On (Click on which Hub # 1)

7. Click <Add>, then <OK> when done. (If an already existing subject record was changed, click <OK> only.

Notes:

To edit an existing subject record, instead of step 5, click the arrows at the bottom of the window to find and edit the existing record.

To delete a subject record, select the appropriate record number and click <Delete>

To exit the "Edit Employee Data" window without any changes, close the window.

How to View Data/Results of a Screening:

1. On the main Admin window, click on the "Report" menu item.
2. Choose the type of report you want
3. Enter the pertinent subject and test date info that you want a report for
4. A report will be pop up.
5. To print a report, click on the Options/Print menu of the report window

How to Get Analyzed Results of FIT 2000

1. Double click on the "ReportGenerator" icon
2. A Menu Pops up detailing the possible types of reports you may want.
   a. Faults & Conclusions – Detailed analysis of faults and conclusions, by department and by employee over a specified time period.
   b. Employee Analysis Detailed Data – i.) Individual employee data showing FIT Index and readings ii.) Individual employee summary showing all readings.
   c. High Risk and Baseline Unstable – i.) Listing of employees with "high risk" and data over specified time. ii.) Listing of employees who are Baseline Unstable.
   d. Exception Report – i.) A listing of employees who did not take the test over the time period.
      ii.) Complete summary of all tests along with exceptions
   e. Screener Report – Detailed analysis of results from each Screener over a specified time period.
3. Choose the type of report you want.
4. Enter the pertinent subject and test date info that you want a report for
5. A report will be pop up.
6. To print a report, click on the Options/Print menu of the report window

OASIS PROCEDURES

How to start OASIS:

1. Click on the "perclosapprelease" icon on the COPILOT DATA computer desktop window.
2. A window will pop up and prompt you for a file name to save the data to. Enter a name and press <ENTER>
3. The Copilot will start collecting data.
4. To end data collection, press <Ctrl-c>

How to Get the Data:

1. Click on the START button in Windows and Select Find, then Files or Folders
   Note: currently, the default place where the data file is saved is on the desktop.
2. Once you find the data file, ftp the file or save it to a disk to transfer to a computer that has EXCEL
3. Run the EXCEL macros to process the data (this is to be created.)

How to Look at the Data Right Away:

1. Double click on the data file on the desktop of the Copilot computer.
2. Open the file with Wordpad when the window pops up asking which application you want to use to open it. The following are the variables being recorded:
   a. Timedate – shows date and time "04/04/01 18:21"
   b. PERCLOS – show the perclos value. (High number such as 95 means there is no on in the train booth.)
   c. EyeX-1
   d. EyeY-1
   e. Eyeh-1
   f. EyeX-2
   g. EyeY-2
   h. EyeH-2

NOVALERT PROCEDURES

How to Start:

1. Plug the thin black wire that is connected to the Novalert computer in the proctor room to the waist box (CB s/n 604) in the train simulator room. There are 2 of these wires, but plug in the one that is connected to the small Novalert box (PCA s/n 704) that is near the projector screen.
2. Plug the waist unit box (CB s/n 604) wire into the wrist unit (NSF-102 s/n 304).
3. Attach wrist unit to inner surface of subject's clean and dry wrist. Attach the finger sensor assembly to inner surface of a clean and dry thumb base.
4. To operate the system, activate the Novalert PC in the NOVASENSE mode by clicking on "Nova/Novasense" icon on the desktop.
5. Choose Setup from the main menu.
6. In the window that pops up, make sure COM1 is selected for Data Port and that NONE is selected for Stimulus Port.
7. Click on <Okay>
8. Choose View from the main menu and select View from Real Time
9. The graph will appear.
10. Turn wrist unit ON by pressing the ON button on wrist unit. The LED should flash green.
11. On the graph display, click <record off>
12. A window will pop up asking for a file name to which to save the data. Enter a name.
13. Click on Okay. The <record off> button now turns read and is replaced by the words <record on>
14. To stop recording, click on the <record on> button. The button will return to its original <record off> state and data collection will end.
15. To exit the program, choose exit from graph menu and then from main Novasense menu.
16. Turn off the wrist unit by pressing the on/off button. The LED will turn red right before the unit goes off.

How to get data:

1. Open Novalert window on the Novalert PC (step 4 above).
2. Choose View from the main menu and select <from file>
3. Click on Display File (Note: Data Files are saved in directory, C:\Program Files\novasense)
4. If you'd like to transfer the data elsewhere, copy the file to a disk or ftp it to another computer.

ACTIWATCH PROCEDURES

To Setup the PC

1. Make sure the Actiwatch reader is connected to the PC,
2. Make sure the COM ports are properly set. (If they're not, the Ready LED will light up.)
3. Open main Actiware-Sleep window by double-clicking on the application icon on the desktop.
4. Select Reader and then select Com Port
5. Select COM port to which you have connected the Actiwatch reader (which is COM2)
6. Check if the correct COM port was chosen by
    a. If correct, the Ready LED will only illuminate when device is positioned correctly.
    b. Turn Actiwatch face down and place it in the region of the reader (p2-5) shown below. The small dot on Actiwatch must be n the same corner as the small dot on the reader.

To Setup the Actiwatch on the PC

1. Double click on "Sleepw" icon on PC desktop. A window called "Actiware-Sleep" will open.
2. Remove straps from the Actiwatch unit.
3. Invert Actiwatch unit so that the metal side faces up.
4. Place the unit (with the metal facing upwards) on the "Actiwatch Reader" box.
5. Align the dot that is on one corner of the Actiwatch with the dot in the drawing on the "Actiwatch Reader"
6. Verify that the LED on the "Actiwatch Reader" illuminates. The LED will illuminate only when the Actiwatch is correctly aligned.
7. Select Options in the Main Menu of the "Actiware-Sleep" window.
8. Verify that there is a checkmark next to "Full Menus" under Options. If there is no checkmark, select "Full Menus" and the Full Menu will appear.
9. Select Reader → Write in the Main Menu
10. Select <OK>in pop-up window once communication between PC and Actiwatch is established.
11. Select <OK> in the next window that pops up.
12. A window with the current setup for Actiwatch will appear where you will enter the following info:
    a. Subject's ID#
    b. Subject's Age and Sex
    c. Start Date
    d. Start Time
    e. Epoch Length – enter 1minute
    (Notes: The current PC clock time is used to calculate the starting time. Unless you have specified a starting time, Actiwatch will begin collecting data 2 minutes from the time setup was received. The Epoch Length is the period of time Actiwatch will accumulate activity counts before saving the sample and resetting the counter to zero. For sleep analysis, the Epoch interval should be one minute or less.)
13. Click <SEND> once the settings are entered.
14. Click <OK> in the pop up window.
15. Click <OK> in message window that says the PC/Actiwatch communication was successful.
16. Remove the Actiwatch from the "Actiwatch Reader" and close the application window.
17. Close the "Actiware-Sleep" window.

18. Replace the straps on the Actiwatch unit.
19. Have the subject wear the Actiwatch around the wrist of the dominant hand.

To Download Data from the Actiwatch to a PC

1. Double click on "Sleepw" icon on PC desktop. A window called "Actiware-Sleep" will open.
2. Remove straps from the Actiwatch unit.
3. Invert Actiwatch unit so that the metal side faces up.
4. Place the unit (with the metal facing upwards) on the "Actiwatch Reader" box.
5. Align the dot that is on one corner of the Actiwatch with the dot in the drawing on the "Actiwatch Reader"
6. Verify that the LED on the "Actiwatch Reader" illuminates. The LED will illuminate only when the Actiwatch is correctly aligned.
7. Select Options in the Main Menu of the "Actiware-Sleep" window.
8. Verify that there is a checkmark next to Full Menus under Options. If there is no checkmark, select Full Menus and the Full Menu will appear.
9. Select Reader → Read in the Main menu.
10. Select <OK> in the window that pops up.
11. When download is finished a window will pop up, select <Yes> to save the file.
12. Name the file and direct it to the folder C:\Minimitter\Actiware\tbs and click <OK>
13. To look at the file, select Sleep Analysis from the main menu. A window with the graphical data representation will open.
14. Click on <Calculate> in the upper left corner of the graphics window.
15. You can print the graph by choosing the File → Print in the Main menu.
16. To close the graph, click on "x" in the upper right corner of the graphics window.

To See a Previously Saved Data File

1. Double click on the "Sleepw" icon on the PC desktop.
2. Select File → Load from the Main Menu
3. In window that pops up, go to the directory C:\Minimitter\Actiware\tbs to find the data file.
4. Select the file you want to see and click <OK>.
5. Select Sleep Analysis from main menu. A window with the graphical data representation will open.
6. Click on <Calculate> in the upper left corner of the graphics window.
7. You can print the graph by choosing the File → Print in the Main menu.
8. To close the graph, click on "x" in the upper right corner of the graphics window.

ACTIWATCH ALERTER PROCEDURES

To Setup the Actiwatch Alerter on the PC

1. Double click on the "ALWATCH" icon on the PC desktop. The software window will open.
2. Remove straps from the Actiwatch Alerter unit.
3. Invert Actiwatch Alerter unit so that the metal side faces up.
4. Place the unit (with the metal facing upwards) on the "Actiwatch Reader" box.
5. Align the dot that is on one corner of the Actiwatch Alerter with the dot in the drawing on the "Actiwatch Reader"
6. Verify that the LED on the "Actiwatch Reader" illuminates. The LED will illuminate only when the Actiwatch Alerter is correctly aligned.
7. Change the information in the software window:
   User Identity – enter subject ID#
   Epoch Length – enter 1 minute
   Threshold – enter Low
   Alarm Delay – enter 1 minute
   Volumc – enter low
8. Click on <Send Setup> button. The Actiwatch Alerter unit and PC will communicate and the Actiwatch Alerter unit will be updated for a new subject.

How to Download Data

1. Double click on the "ALWATCH" icon on the PC desktop.
2. Remove straps from the Actiwatch Alerter unit.
3. Invert Actiwatch Alerter unit so that the metal side faces up.
4. Place the unit (with the metal facing upwards) on the "Actiwatch Reader" box.
5. Align dot that is on one corner of Actiwatch Alerter with dot in drawing on Actiwatch Reader
6. Verify that the LED on the "Actiwatch Reader" illuminates. The LED will illuminate only when the Actiwatch Alerter is correctly aligned.
7. Click <Read Data> button in the window.
8. In the window that pops up, click <Yes>
9. A window will prompt you to enter the filename and directory to which you want to save data. Save the data in C:\Minimitter\Actiware\alarm_tbs and then click <OK>.

To Look at Analyzed Data

1. Double click on the "ALWATCH" icon on the PC desktop.
2. Select File → Load to open the data file you want to see. The file should be in C:\Minimitter\Actiware\alarm_tbs
3. Select Actogram in the main menu. A graph will appear.
4. To print the graph, select File → Print.
5. Select Alertness in the main menu to get a different graph.
6. To print this graph, select File → Print.

PVT-192 OPERATION PROCEDURES

NOTE: The LEFT button on the PVT is used to move the cursor.
The RIGHT button on the PVT is used to select the option.

To Set up test parameters on the PVT (or can set up with a PC - look at section after this one)

1. Switch on the PVT.
2. Select Setup on the display by pressing the LEFT button to get to it and then pressing the right button to select it.
3. PVT will prompt you for an Access password. The default password is 123. To enter the password: Use the LEFT button to move the cursor to the first number,
   then press the RIGHT button to accept the digit,
   continue until the whole password is displayed on the top line of the LCD display,
   then move the cursor to Q (stands for quit) and press the RIGHT button.
   If you make a mistake, select E (erase) to wipe out all the characters you've selected And begin again. If you mistakenly entered this Access mode, select R (return) to display the previous Menu (Select Setup).
4. In Select Setup Menu, choose PARAM to set up preliminary information for the test subject.
5. In PARAM, the following will be displayed and you will be enter the following:
   a. Study - enter 2-8 letters to identify the study about to be recorded. You can select + to see more of the alphabet segment. Once you've entered this data, select Q.
   b. Mood - Enter any word or phrase up to 8 letters. This will be displayed on the pre and post test analog mood scale. Once you've entered this data, select Q.
   c. E Initials - Enter up to 3 letters to identify the Experimenter or test administrator. Once you've entered this data, select Q.
   d. S Initials - enter 3 letters to identify the Subject. Once you've entered this data, select Q.
   e. Subject - enter up to 4 digits to further identify the person to be tested. Once you've entered the data, select Q.
   f. Trial - Enter up to 3 digits to identify the Trial sequence number for a particular subject. Once you've entered this data, select Q.
   g. ISTmin ms - Enter the minimum or lower boundary of the Inter-Stimulus Interval, in milliseconds. The smallest value permitted is 1second (1000ms). Since the LED stimulus display remains illuminated after a response for about 1second, it is necessary use a long enough value to allow distinguishing one stimulus from the other, e.g. at least 1500 ms. Once you've entered this data, select Q.
   h. ISTmas ms - Enter the maximum or upper boundary of the Inter-Stimulus Interval, in milliseconds. This value must be larger than the MIN IST. Once you've entered this data, select Q. (The PVT will randomize its presentation of stimuli between these min and max values.)
   i. TTT sec - Enter the Total Test Time for each trial, in seconds. A typical value is 600 seconds (10minutes). Once you've entered this data, select Q.
   j. Task Code - enter visual, auditory or both. The standard test is visual only.

Once you've entered this data, select Q.

k. Handedness - enter the subject's dominant hand. Once you've entered this data, select Q.

Once this section is completed, the PVT will revert to the Select Menu.

To Setup Test Parameters on the PC (Do NOT do this because software doesn't work for it)

1. Once the PVT is well charged, connect it to the computer's serial port via the 9-pin male to 9-pin female cable. (To check the PVT charge, click on the PVTCommW icon on the PC desktop.
2. In order for the PVT and PC to communicate , the PVT must be in Supervisory Mode, so At the Main Menu, Select Setup.
3. Enter the **Supervisory Mode** access code:
    a. Select 31267 (Note this code cannot be changed)
    b. Then select Q.
4. On the PC, in the "PVTCommW" window, Select Initialize. The PC will begin to move through a series of interactive screens. Follow the instructions on the screens.

To begin a series of reaction-time trials

1. Turn on the Power.
2. When the Select Menu appears, Select TEST
3. Select REAL. The test will start with the parameters entered above.
4. The MOOD WORD will be displayed. Have the Subject move the cursor on the 10-position line between YES and NO.
5. The Display will now read, "Ready to test... Press any button to start". Once the subject presses the LEFT or RIGHT button, the test starts.
6. At the end of the test time, the MOOD WORD will be displayed. Have the Subject move the cursor on the 10-position line between YES and NO.
7. Once the Mood scale response is entered, there will be a short blank pause and then the Main SELECT menu will appear.
8. Now the PVT can be turned off.

NOTES: The PVT will increment the Trial Number, ready for the next test. If you want to test a different subject, the PVT test parameters must be changed. See the above sections on how to do this.

WARNING: If the power goes out DURING a trial, then ALL data in that trial will be LOST and the trial number will not increment. The PVT power should be left on until the Main Menu appears (which will occur after completion of the trial).

To Download Data from the PVT to a PC

1. On the PC desktop, double click on the "PVTCommW" icon.
2. Select PVT → Download from the main menu on the window that pops up. A window will appear asking you to ensure the PVT is in "Supervisory Mode".
3. To get the PVT in Supervisory Mode,
    a. Turn on the PVT
    b. In the PVT Main Menu, select Setup.
    c. In the Access mode, select the numbers of the Supervisory Mode Access Code: 31267

d. Select Q. The words “Supervisory Mode” should appear on the PVT.
4. Click <OK> on the pop up window from step 2.
5. Click <OK> in the next pop up window.
6. The PVT and PC will start to communicate to retrieve data. Process Completed Click <OK> in the pop up window named “Download Finished”.
7. A window will prompt you for what to name and where to save files. Save the file in C:\Program Files\Ami\PVT\tbs

To Look At Data Files

1. On the PC desktop, double click on the “PVTReact” icon.
2. Click on <Load and Parse PVT Files> button in the window that appears.
3. A window pops up asking what file to open. Select file you want to open. It should be in C:\Program Files\Ami\PVT\tbs
4. Choose <Detail> or <Summary> in the window that appears. Detail will give you a detail of the data. Summary will give you a summary.
5. Click on the <Analyze> button.
6. Some graphs will appear. To print them, click <Print Report> button.
7. Click <OK> in the window that pops up. The files will now be printed.

CORTEMP PROCEDURES

To Setup Test Parameters from the PC

1. Make sure the battery in the CorTemp recorder (the unit that needs to be near the waist area) is sufficient by taking the battery out and testing the battery's voltage on a voltmeter.
   The voltmeter is in the proctor lab. Connect the red and black wires of the voltmeter to the ends of the battery and make sure the voltage on the voltmeter display is at least a 9. If it is less than 9V, replace the battery.
2. Make sure the recorder (the CorTemp waist unit) is turned off. (The on/off switch for CorTemp is inside the box where battery goes, so you have to remove the battery first.)
3. Attach the serial cable from the PC to the recorder unit.
4. Once the CorTemp recorder unit and PC are serially connected, turn on the recorder.
5. Using the CorTemp recorder keyboard,
   a. Press <ENTER> to reach the STBY screen
   b. Press <MENU>
   c. Press <READ> until you arrive at PC LINK option
   d. Prcss <F2> to open the PC link.
6. Double Click on "CT2000" icon on the PC desktop. The CorTRACK window will open.

7a. If the software does not recognize a connection with the recorder, follow instructions on the screen to correct the problem.

7b. Once connection is established between the PC and the recorder, the CorTRACK software will identify which version of firmware is operating on the recorder. (In the upper right corner of the window, a green button should be labeled "Unit Connected".)

8. On the window that pops up, click <UPDATE PARAMETERS> to set up the following testing parameters:
   a. In the ID Number box, enter the subject's ID #. Alphanumeric ID's are allowed.
   b. In the Time Settings box, click the PC Time <ON> button to synchronize the recorder unit
      And PC time.
   c. In the Options box,
      i. Click the <ON> button for Detect Battery,
      ii. Click <ON> for Detect Signal,
      iii. Select 1 for Active Sen.
   d. In the Temperature Settings box, select the unit of temperature measurement. We'll use Celsius.
9. When the above parameters have been set, click <LOAD PARAMETERS>
10. To enter sensor pill serial and calibration numbers, click <EDIT SENSORS>.
11. The sensor edit screen will display. Click on the inside of the first cell to the right of "1" to begin entering sensor information.
12. Once all sensor information is entered, press <DONE>.
13. Click <EXIT PC LINK>
14. Exit from CorTRACK by closing its window.
15. Turn off the recorder before disconnecting it from the PC.

To Use and Monitor the CorTemp

1. Turn on the recorder.
2. Press <ENTER> to get to the STBY screen.
3. Press <MENU>
4. Press <READ> until you arrive at the SENSOR TEST option.
5. Press <F2> to select SENSOR TEST.
6. Remove the pill from it's wrapping and remove the magnet.
7. Place the pill near the recorder. The Recorder should display SENSOR ON. If it doesn't, make sure the magnet has been removed and that the pill is near the recorder. If it continues to display SENSOR OFF, replace the pill with another and repeat the test. If a pill needs to be replaced, make sure that you do steps 10-12 in the above section.
8. Have the patient swallow the sensor with tepid water.
9. Press <ENTER> to get to the STBY mode
10. Press <READ> to allow the system to take a temperature reading. (Make sure the recorder is close enough to the subject to take a reading.
11. Once you see the initial temperature reading, press <RUN/STOP> to start recording data.
12. Have the subject wear the recorder around his waist.
13. To end data collection, press <RUN/STOP>
14. Press <F1> to EXIT the operating software.
15. Turn off the unit.

To Transfer Data from the CT2000 to a PC

1. Double Click on "CorTemp" icon.
2. Make sure the recorder (the CorTemp waist unit) is turned off. (The on/off switch for the CorTemp is inside the box where the battery goes, so you have to remove battery first.)
3. Attach the serial cable from the PC to the recorder unit.
4. Once the CorTemp recorder unit and PC are serially connected, turn on the recorder.
5. Using the CorTemp recorder keyboard,
   a. Press <ENTER> to reach the STBY screen
   b. Press <MENU>
   c. Press <READ> until you arrive at PC LINK option
   d. Press <F2> to open the PC link.
6. Double Click on the "CT2000" icon on the PC desktop. The CorTRACK window will open.

7a. If the software does not recognize a connection with the recorder, follow instructions on the screen to correct the problem.

7b. Once connection is established between the PC and the recorder, the CorTRACK software will identify which version of firmware is operating on the recorder. (In the upper right corner of the window, a green button should be labeled "Unit Connected".)

8. Click <Download Data> button on the CorTrack window.
9. A window will pop up asking you where to save the file and under what name. Save file in C:\ct2000\data\tbs and click <Save>.
10. The window called "Download Data" will start saving the data. When the CorTemp is finished downloading, it will return to the DATA TRANSFER/PC LINK screen.
11. Exit from CorTRACK by closing its window.
12. Turn off the recorder before disconnecting it from the PC.

ACTIGRAPH MOTIONLOGGER PROCEDURES

To Use the Motionlogger

1. On the Motionlogger PC, double click on the "ACT2000" icon.
2. Remove the straps from the wrist unit.
3. Insert the wrist unit into the PC Interface box.
    a. The unit should go in face-down.
    b. Align the six gold contacts with the six gold pins of the interface receptacle.
    c. Lower the other end of the unit into the receptacle as far as it will go without forcing it.
4. On the PC, select Actigraph → Initialize from the menu of the ACT2000 window.
5. In the windows that appear, set
    a. Current Time- to set your own time, enter it and click <Set Current Time>
       To use the computer time, click <Continue> (We'll be doing this option.)
    b. Actigraph Type – select Sleep Watch and click <OK>
    c. Sleep Watch Selections – select Sleepwatch-R and click <OK>
    d. Actigraph Sampling Modes – select LIGHT and click <OK>
    e. Events – select Record Events and click <OK>
    f. Epoch Length – click <OK>
    g. ID – enter the subject's ID #
    h. Startup Conditions – select IMMEDIATE and click <OK>
    i. Run Time – Select Transmit
    j. Preview Header – Select <OK> if the settings are correct.
    k. Overwrite – select <YES> (Note this will erase any previously recorded data.)
    l. Actigraph Initialization – this box will disappear and be replaced by a message that Initialization is completed. Click <OK>
6. Remove the wrist unit from the Interface box.
7. Close Act2000 window.
8. Put the straps back on the unit.
9. Have the subject wear the watch _______(on shirt like a broach?)

To Download Data
For every type of unit except the MicroMini:

1. Place the unit into the interface box.
2. On the PC, double-click on the "ACT2000" icon.
3. On the ACT 2000 window, select Actigraph → Download. The software will verify whether the unit and PC can communicate and then start to download data.
4. In the pop-up window that appears, click <YES> to save the data file.
5. Save the data file in C:\Program Files\Ami\Act2000\tbd\<datafilename> and click <OK>
6. Once the file is saved, a pop up window will appear. Click <OK>
7. A graphical representation of data will appear.
8. You can print the graph by clicking on the Printer icon on the icon bar.

To Look at Previously Saved File

1. On the PC, double-click on the "ACT2000" icon.
2. Select File → Open from the Main Menu of Act2000.

3. Double click on the desired file icon. A graphical window will appear.
4. You can print the graph by clicking on the Printer icon on the icon bar.

WAYPOINT PROCEDURES

To Start Waypoint
1.Double click or double touch the "Waypnt" icon on the Microtouch Monitor.
2. Follow the instructions on the series of screens that will appear. Here is what you will be asked to do.

a. Press <Continue> on the screen to continue

b. In the window that pops up, enter the subject # and then touch <Continue> This is where you should stop and allow the subject to take over to begin the test.

c. In the next screen, press <Continue>

d. The next screen will explain the task, which is to touch boxes of letters in numbers in the following
order: 1 – A – 2 – B – 3 – C – 4 – D , etc. You will be given two practice trials.

e. To begin the real test, Press <1> button in the next screen.

f. Once the test is over, a screen will appear telling you the test is over and what your high risk odds
ratio is.

To Analyze Data
We don't. This data will be sent to the developer to be analyzed.

TRAIN SIMULATION OPERATION PROCEDURES

To Start the Train Simulation

NOTE: If testing the add/sub mode, you must disconnect the cord for the lighted reset switch from the large power control white box on the side of the train cab. (This will disable the reset button used for the Train Sentry Alerter.)

1. Login to Harry as viengvil.
2. Turn on the Projector by
   a. Pressing <STBY> on the remote.
   b. Then pressing <EXIT> on the remote to bypass the warm-up (bypassing warm-up will do no harm according to Barco.)
3. The projector will show the desktop on Impact. Login to Impact as viengvil.
4. Open a winterm window on each machine by going to the main menu on the upper left corner of the desktop. Click on Desktop → Unix Shell.
5. On Harry, go to the veh-5-dash directory by typing in the winterm window:
   cd rail-sim/vehicles/veh-5-dash
6. On Harry, type the following and then press <ENTER>
   dash -mode <m> -id <i> -o <o> -pay <p> -dur <d>
   NOTE: that <m> should be 1 for addition/subtraction or 2 for Trainsentry Alerter.
   <i> should be the subject ID #
   <o> should be the data output file name
   <p> should be the payment file name
   <d> should be the test duration: 4 for 4hrs or 8 for 8hrs.
   also note that there is a space between the option (e.g. -mode) and the choice (e.g. 2)
   For example, to run in the Trainsentry alerter mode on subject #39, to save data to file subj1night, to save results to payment file subj1pay, and to input the test duration of 8hrs, you would type:
   dash -mode 2 -id 39 -o subj1night -p subj1pay -dur 8
   Once these commands are entered, Harry will start connecting to Impact. You will see a series of messages scroll up in the window.
7. On Impact, go to the veh-5-otw directory by typing on the winterm:
   cd rail-sim/vehicles/veh-5-otw
8. On Impact, once "heartbeats" messages appear on Harry window, type the following:
   veh-5-otw
   and then press <ENTER>:
9. The out-the-window view and the instrument panel view will pop up in about 2-3minutes.
10. Disconnect the standard keyboard attached to Harry and replace it with the numeric keypad.
11. A few seconds before the subject presses <ENTER> on Harry's #pad to start driving the train, press <POWER> button on the sound woofer that is next to the train cabin and under the main power connection box. This will start the train sound.

BIG NOTE: During the first session break, a couple of minutes before the subject returns to the train,

1. Quit the veh-5-otw simulation by hitting the <pause> button on Impact's keyboard.
2. Open a new winterm window.
3. Type: cd rail-sim/vehicles/veh-5-otw
4. Type: veh-5-otw

5. When the new “otw” display pops up, bring the winterm window up front. You will see the state of the train (time, seg, dist, dir, and desired speed) in the winterm window.
6. Press the <↑> key on Impact’s keyboard to increase the train speed until the desired speed on the winterm window is 28.9 m/s.
This will start a new veh-5-otw session that will last approx 2hr and 10mins.
Repeat this process during each session break. (This is a temporary measure that we’ll use for the test bed study until the veh-5-otw tracks are fixed.)
NOTE: To turn off the projector, press <STBY> on the remote
To pause the simulation due to an emergency, flip up the switch next to instrument panel monitor in the proctor room. To end an emergency pause and restart the simulation, flip the switch back down.

To Get Train Simulator Data Files:

NOTE: All data files are saved on Harry in the directory
rail-sim/vehicles/veh-5-dash/data
To get the files and transfer them to a different computer, you will have to ftp them. (Harry has no secondary storage device. Also, harry cannot telnet to computers other than Impact.)
There are 3 types of files you can look at:

a. datalog file (has more explanations),
b. statdatalog file (file to use in an Excel spread sheet for analysis),
c. payment file (file that has the summary of bonus money calculations.

To ftp the files:

1. In the Harry Winterm window, type
   telnet impact
2. Enter guest and then press enter at the password prompt
3. Once you're connected to impact, type
   ftp harry
4. Repeat step 2
5. Once you're connected to harry from impact via ftp, type
   cd rail-sim/vehicles/veh-5-dash/data
6. Type
   get <your data filename>
7. Repeat 6 for all your data files.
8. Once everything is successfully transferred, close the connection to harry by typing
   close
9. Now connect to the computer you the data to be transferred to by typing
   open <your computer name or IP address>
10. Continue as you would a normal ftp process and then close that connection.
11. To end the ftp process, type
    bye
12. You can use Wordpad or Excel to look at the data.
    If you open the data file with Excel, the data file is space delimited.