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Automatic Duress Alarms Through Physiological Response Monitoring

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AUTOMATIC DURESS ALARMS THROUGH PHYSIOLOGICAL RESPONSE MONITORING

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ABSTRACT

Physiological response monitoring equipment for automatic duress detection is being developed and evaluated in an attempt to improve the reliability of the human element in security systems. This paper describes an initial study which was designed to determine the applicability of the basic concept to security problems and to provide a subjective overview of problem areas pertinent to continued monitor development. Experimental results indicated that under controlled conditions, response monitoring may provide an effective means for passive determination of moderate to severe stress levels in personnel.

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AUTOMATIC DURESS ALARMS THROUGH PHYSIOLOGICAL RESPONSE MONITORING

Summary and Conclusions

Physiological response monitoring under controlled conditions can provide an effective means for passively determining if the wearer is under moderate to severe stresses. By monitoring the heart rate (HR) and galvanic skin response (GSR) of an individual, it is possible to detect in real time the increase in heart rate and GSR levels due to physiological reactions to mental duress. With existing physiological monitoring equipment, however, the work load of the wearer must be well defined since it is impossible, without additional data, to distinguish mental duress responses from those resulting from moderate physical exertion. Similarly, environmental conditions should be constrained within set limits to avoid masking increases in GSR levels due to mental stress from those associated with increased perspiration. These constraints should not prove overly restrictive and would allow an integrated security system utilizing physiological monitoring equipment to provide an effective real time, automated early warning system for detection of mental duress or death of the wearer.

Background Information

There is a strong and increasing concern that Special Nuclear Material (SNM) and nuclear weapons might be diverted for illegal uses. An important element of present and future safeguard systems designed to protect the nuclear materials is the personnel involved in the handling, transportation, and protection of the material. In an attempt to improve the reliability of the human element in security systems, Sandia Laboratories is examining means to cope with the inherent danger of disablement or death due to coercion or natural illnesses of SNM couriers and guards. As a result of preliminary investigations, a study was initiated into the feasibility of simple physiological monitoring systems which could be used to identify the stress or duress conditions of a subject without the necessity of active communications. Recent work in the area of telemetry and remote processing of biological information indicated that such an approach was possible¹⁻⁴ and indeed warranted further investigation.

Reference 5 discussed the results of a six month study by the Lovelace Foundation which identified appropriate physiological measures of the reactions of humans to stress and startle situations. It was determined in this study that heart rate^{*} and basal galvanic skin responses

* Derived from the "QRS" pulse frequency taken from Electrocardiogram (EKG) monitor.

(GSR) can indicate stress levels and can also be measured, processed, and telemetered using relatively simple state-of-the-art hardware. Reference 6 proposed a follow-up study by Lovelace to develop appropriate hardware for demonstration of the concept. The prototype monitoring equipment was developed and documented along with some initial test results using the equipment.⁷

Figure 1 displays a functional overview of the monitoring equipment. See Appendix A for a detailed description of the system.

Figure 1. Functional Diagram of Prototype Physiological Monitoring System

Following delivery of the prototype equipment to Sandia Laboratories, a decision was made to conduct a more extensive evaluation of the monitoring concept and to determine the feasibility of using physiological monitors in the transportation safeguards field. This report delineates the capabilities and limitations of physiological monitoring equipment.

Experimental Test Procedure

The feasibility of the physiological monitoring concept was examined by exposing five volunteer subjects to a graduated series of stressful environments while monitoring their heart rate and GSR levels. The experimental situations ranged from the negligible stress of normal activities to the slightly stressful function of driving a one-ton van through light to dense traffic over urban streets. The final segment in the experiment consisted of a moderately stressful prearranged "confrontation" with the local Sandia Laboratories security force.

Volunteer subjects for the feasibility test were selected by use of a questionnaire (Appendix B). The request form briefly explained the ostensible purpose of the experiment and obtained general background information on the subject, such as age, sex, health, and education. Due to complications involved with physical emplacement of the electrodes, only male volunteers were considered for the experiment. The randomly selected volunteer subjects were briefed on the nature of the equipment and were told that the purpose of the study was to gather normative physiological data during working conditions over a week's time. The subjects were not told that they were to be examined under stress conditions. The subjects were required to wear the monitoring equipment, consisting of four electrodes and a belt-worn preamplifier unit, for a two hour period each day during the experiment. The first two sessions for each subject consisted of two segments: The first, approximately 40 minutes, was spent in the laboratory area with the subject randomly sitting down, walking around, and standing; this segment was used to obtain a data base for the non-stress heart rate and GSR responses. The second half of the sessions required the subject to drive a one-ton van over an 18.3 mile route through Albuquerque (see map in Appendix C). The route was designed to expose the subject to a range of light to dense traffic for approximately forty minutes. The final session of the experiment consisted of an initial 20 minute segment in which the subject was asked to perform some form of moderate exercise in order to raise the heart rate and GSR parameters above their normal levels. Following the exercise section, the subject was directed to complete the session as normal by driving the van over the route through the city. As the unknown subjects attempted to drive out of Technical Area I, they were routinely stopped and searched by the security personnel. Since they were unable to produce an authorized material pass for removal of equipment secreted in the van, the subjects were retained at the guard gate and were interrogated further. During this time interval, the security personnel, through their questions and comments, implied that the subject was attempting to transport stolen government property out of the area or, even worse, was attempting to breach security. At this point, a superior officer was called in to supposedly take charge of the subject. After approximately a minute or two of

continued harrassment by the officer, the subject was informed that the episode was contrived and the full purpose of the experiment was explained with the admonishment that he should not disclose the experiment to fellow subjects. Following the episode, the subject was directed to complete the driving course and to return to the laboratory.

Physiological Monitoring Feasibility Studies

The experimental study described above, although it unfortunately allowed only a brief examination of a broad spectrum of physiological responses to mental and physical stresses, was able to qualify the major limitations and capabilities of the prototype and anticipated follow-on monitoring equipment. Initial investigations and data from the feasibility study pointed out, as expected, that heart rate and GSR levels vary over a large range from individual to individual and from activity to activity. Any serious attempt to institute a warning system must, therefore, first establish a data base of the physiological responses and inherent variations in the levels for every individual to be monitored. This data base should be accumulated during periods when the subject is engaged in activities similar to those monitored.

Examination of the volunteer subject responses (see Appendix D for actual test data) during the daily sessions shows that the mean values of the HR and GSR parameters of an individual are readily obtainable, and, after the initial phase of nervousness, display a reasonable range of variances. The field tests, during which the subjects drove a van, showed that this exercise caused only slight stress and correspondingly only slightly elevated heart rate and GSR levels. The one driver who had no appreciable experience driving large vehicles on public roads would presumably exhibit higher stress and did indeed display a much larger increase in the physiological response levels. Extrapolation of this portion of the experimental results indicate that an experienced tractor driver and/or security guard on the job could normally be characterized by a base line for the two physiological parameters which would vary slowly in time, with relatively small instantaneous fluctuations.

Deviations of the physiological responses from the "norm" during the daily session point out that there exists a potential problem in defining the operating limits of monitoring equipment. The physical environment of the subjects was not well regulated during the driving segments and almost all sessions showed a dramatic increase in GSR levels as the subjects began to perspire. A large increase in the GSR level above the norm could cause a large increase in the false alarm rate or could mask true mental duress conditions. Neither of these consequences are acceptable under realistic operating conditions and would dictate that the temperature and humidity levels to which a subject is exposed would have to be held within well defined limits. In addition, the displayed increase in heart rate and GSR levels during the exercise confirmed that, without additional data, it would be impossible to discriminate between the physiological responses to mental duress and to physical exertion. Due to this fact, the subject must be constrained in the type of physical

activity he engages in while being monitored; this constraint should not be overly restrictive since the experimental data imply that a large range of activities will cause only minimal increases in the observed parameters.

The confrontation session of the experiment did not produce as high a stress level as hoped for, but it was encouraging that in several cases the physiological response of the subjects was dramatic enough to be detectable. All subjects stated that they never felt personally threatened or else experienced only short-lived moments of moderate stress. This fact is supported by the rapid elevation and decay of the heart rate levels at critical times during the confrontation; GSR increases during the episodes were somewhat suppressed by the smoothing provided by a low pass filter included in the hardware. Changes in the physiological responses indicative of mental duress were distinguishable despite the low level of stress, and would imply that the magnitude of duress experienced during an attack should be readily detected.

The insight provided by this study shows that under controlled situations, physiological response monitoring equipment could provide a fairly reasonable means to passively and automatically monitor the stress levels experienced by personnel. The automatic discrimination of moderate to severe stress conditions probably would not be accurate enough to provide a stand-alone alarm system, but physiological monitoring should prove to be a valuable asset to an integrated security or safeguards system.

Recommendations for Future Studies

Since it is felt that there is a large potential benefit from the monitoring concept versus the relatively small expected cost of further investigation, it is recommended that work involved in the development of the physiological monitoring equipment and its integration into existing security systems be continued. It is recommended that future work areas include the following.

1. Miniaturization - The current body-worn equipment is bulky and is extremely awkward to use. The size of the belt-worn pack and the need to physically attach electrodes to the chest area make it unreasonable to use the monitoring equipment during normal work periods. Discussions with commercial companies indicate that there exists monitoring equipment on the market that could be adapted from their present function of monitoring animal behavior to meet the requirements of a security monitor.
2. Advanced Field Studies - The current study utilized volunteer subjects selected at random from Sandia employees and tested them in an uncontrolled environment. A more extensive field test using professional guards and drivers on actual trucking routes would provide a much more accurate view of the feasibility of the monitoring equipment.

3. Monitoring of Severe Stress Levels - As stated earlier in this report, the stress level experienced by the volunteer subjects would only be regarded as moderate. Future studies should attempt to expose subjects to much higher levels of stress in order to determine if the expected increases in physiological responses are indeed present.
4. Sensor Response - The sensor response to true stress will be dependent upon both its design and its location on the body. Additional investigation is needed to optimize these parameters and to achieve greater validity in stress measurements.

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APPENDIX A

System Description

System controls, connectors, indicators, and the like are described in the following sections.

Body-Worn Unit

There are two alternate breadboard units of body-worn equipment associated with this system. The first unit is for hardwire usage and contains only the battery-operated EKG and skin conductance (SC) preamplifiers. The EKG and SC outputs of this unit are connected directly to the FM data recorder or, for lab testing, directly to the central processing system. The second unit, in addition to the EKG and SC preamplifiers, contains a telemetry transmitter to enable real time field usage.

Hardwire Unit

The hardwired breadboard unit is contained in a small chassis that is approximately 3 x 4 x 5 inches in size with a bracket for attachment to the subject's belt (Figure A-1). The unit has only one control, the ON/OFF switch. There are four input jacks, two each for the EKG and SC leads. Finally, there are two coaxial output connectors for the EKG and SC analog signals.

Figure A-1. Breadboard Body-Worn Hardwire Unit

Central Processing System

The central processing system (Figure A-2), is contained in a standard rack cabinet that is approximately 23 inches high. External to this cabinet are the video monitor and the telemetry receiver. The front panel features are numbered on Figure A-2, and the function of each is detailed below.

1. CATHODE RAY TUBE, CRT: This display is a monitor for the analog EKG or SC signals. The signal is presented in memory scope fashion with the trace progressing smoothly from right to left. Digital storage (shift registers) is utilized.
2. EKG/SC SWITCH: This switch selects the analog waveform to be displayed on the CRT.
3. FREEZE SWITCH: This pushbutton switch, when depressed, causes the trace presented on the CRT to become stationary, or freeze its position in time, until released.
4. HEART RATE DISPLAY: This numeric display indicates the instantaneous (beat-to-beat) heart rate in beats per minute.
5. SKIN CONDUCTANCE DISPLAY: This numeric display indicates the present value of skin conductance in micromhos per square centimeter.
6. QRS LAMP: This lamp lights momentarily with each heart beat at the occurrence of the "QRS" complex.
7. HEART RATE ERROR LAMP: This lamp lights momentarily if there is an erroneous EKG waveform. Most common causes of heart rate error are either an extremely noisy EKG signal or complete lack of signal. More than four heart rate errors per minute will cause the letter "E" to be output to the video display.
8. HEART RATE ALARM LAMP: This lamp lights if the average heart rate deviates outside either the high or low heart rate limits.
9. SKIN CONDUCTANCE ALARM LAMP: This lamp lights if the average SC value exceeds the high SC limit.
10. RESET SWITCH: This pushbutton switch is used for resetting (restarting) the microcomputer. Depressing this switch clears all data in the computer and on the video histogram display.

11. STOP LAMP: This lamp lights momentarily at the end of each minute when the video display is updated. The lamp lights steadily when the video display is fully filled and the computer is in a halt mode.
12. HEART RATE HIGH LIMIT SWITCHES: These thumbwheel switches select the high heart rate alarm limit, which is entered into the computer by depressing the reset switch.
13. HEART RATE LOW LIMIT SWITCHES: These thumbwheel switches select the low heart rate alarm limit, which is entered into the computer by depressing the reset switch.
14. SKIN CONDUCTANCE HIGH LIMIT SWITCHES: These thumbwheel switches select the SC high limit, which is entered into the computer by depressing the reset switch.
15. AUDIBLE ALARM: This unit produces a steady tone whenever the HR or SC exceeds their respective alarm limit.
16. ALARM VOLUME CONTROL: This potentiometer sets the audible alarm volume.
17. POWER ON/OFF SWITCH: This switch controls primary line voltage to the system.
18. FUSE: This is a 3/4 amp slow-blow fuse in the primary power circuit.
19. HARDWARE/TELEMETRY SWITCH: This switch selects the system input source. In the hardware position, system inputs are from the front panel EKG and SC inputs. In the telemetry position, the inputs are from the telemetry receiver.
20. EKG INPUT CONNECTOR: This BNC connector accepts the analog EKG waveform from either the body-worn hardware unit or a portable data recorder.
21. SC INPUT CONNECTOR: This BNC connector accepts the analog SC input from either the body-worn hardware unit or a portable data recorder.
22. VIDEO MONITOR: This monitor presents the histogram display of the averaged HR and SC values for a total period of approximately one hour.

Note: See text for description of numbered items.

Figure A-2. Central Processor System

APPENDIX B

Request for Volunteers for a Feasibility Study of a Physiological Duress Indicator

As you may know, there is a strong and increasing concern about possible safety hazards when transporting nuclear materials. A potential problem in the highway transportation of materials is the jeopardization of the safety of the transport due to the disablement of the driver. As part of the nuclear safety program, Sandia Laboratories tasked the Lovelace Foundation to develop an early warning system which would allow for remote, real time monitoring of the electrocardiogram responses of freely roving subjects. Sandia is now conducting feasibility studies of the body-worn monitoring equipment and is attempting to build a data base of the physiological responses of normal healthy adults.

Volunteers for the physiological study will be asked to "wear" the monitoring equipment two hours per day for a week. During the daily sessions, the subjects will be asked to perform normal activities and, in addition, will be asked to drive a vehicle over a predefined route through the general Albuquerque area. The driving route will be designed to expose the subject to light to heavy traffic and will be about forty to fifty minutes in duration.

The monitoring equipment consists of four electrodes, placed on the chest by means of double sticky tape, a belt worn preamplifier unit, and a portable cassette recorder to record the sensor outputs.

Prospective volunteers should complete the attached form and return it to S. C. Roehrig - 1712, by 6 August 1976.

DATE _____

Name _____ Age _____ Ht _____ Wt. _____ Sex _____

Organization _____ Phone _____

Education (Indicate highest level)

PhD _____ Masters _____ Bachelors _____ Associate _____ Other _____

Major field of study _____

Current Sandia job assignment _____

Rate your physical condition

Excellent _____ Good _____ Average _____ Fair _____

Describe your routine physical exercise program, if any _____

How long have you maintained this program? _____

Other sports activities in which you regularly participate _____

Do you have a U. S. Government motor vehicle operator's license? _____

APPENDIX C

Test Driving Route

The driving route depicted in Figure C-1 was designed to expose experimental subjects to light-to-heavy traffic conditions over urban streets and freeways. The route is a closed loop covering approximately 18.3 miles and requiring 40-50 minutes to drive. Major intersections on the route through Albuquerque include:

1. H Street and Wyoming
 - Exit from Sandia Laboratories Secured Area
2. Wyoming and Lomas
3. Lomas and Louisiana
4. Louisiana and Menaul
5. San Mateo and Interstate 40
6. Interstate 40 - Interstate 25 interchanges
7. Interstate 25 and Central
8. Central and Wyoming

Figure C-1. Experimental Driving Route Through Albuquerque

APPENDIX D

Individual Physiological Response Evaluations

The following sections present typical responses and values for the physiological parameters of five volunteer subjects. All displays are histograms plotted as a function of time (minutes). Heart rate is plotted in beats/min. averaged over a minute. Skin conductance, GSR, is the resultant output conductance of a low pass filter with a time constant of 15 seconds and is plotted in units of micro-mho/centimeters². Except as noted, a plotted value of zero indicates loss of data due to excessive noise, bad connections, etc.

Preceding each series of plots is a short section discussing the individual responses of the subjects to the experimental sessions.

D-1 Subject Number 1

Subject 1 was the oldest of the volunteers and has been employed at Sandia for a considerable length of time. The subject's long term employment is probably responsible for the calmness displayed during the contrived incident; the jump in GSR levels at two crucial times, would, however, be indicative of worry or frustration at being stopped and interrogated by the guard force. Written comments by the subject following the experiment suggested that the subject never felt personally threatened, but was indeed annoyed at having been stopped and harrassed.

The extremely high GSR values during the last portion of the driving route were caused by profuse sweating due to the high temperatures within the van.

Figure D-1 shows the data obtained from Subject Number 1.

Subject 1: Typical plot for daily session, normal activity segment

$$\bar{X}_{HR} = 83.6 \text{ beats/min}$$

$$\bar{X}_{GSR} = 6.6 \text{ m mho/cm}^2$$

Significant events:

t = 1-2 min Subject standing and putting on shirt

t = 7-9 min Subject standing to permit checking of GSR electrodes

t = 1-9 min No GSR data

Note: Subject's initial nervousness is evidenced by large jump in HR when asked to stand for examination of electrodes.

Figure D-1.1. Subject 1: Typical Plot for Normal Session

Subject 1: Typical plot for daily session, driving segment

$$\bar{X}_{HR} = 80.1 \text{ beats/min}$$

$$\bar{X}_{GSR} = 4.536 \text{ m mho/cm}^2$$

Significant events:

None

Figure D-1.2. Subject 1: Typical Plot for Driving Session

Subject 1: Exercise session

$$\bar{X}_{HR} = 83.4 \text{ beats/min}$$

$$\bar{X}_{GSR} = 5.8 \text{ m mho/cm}^2$$

Significant events:

t = 4-5 min Subject doing knee bends

t = 8-9 min Subject sitting

t = 21 min Subject doing toe touches

Figure D-1.3. Subject 1: Exercise Session

Subject 1: Confrontation session and final driving segment

$$\bar{X}_{HR} = 85.1 \text{ beats/min}$$

$$\bar{X}_{GSR} = 14.7 \text{ m mho/cm}^2*$$

Significant events:

- t = 4 min Initial halt and questioning at security gate
- t = 6 min Entry of superior officer
- t = 8 min Taking subject's name and social security number
- t = 12 min Call subject's department head
- t = 15 min Told true purpose of experiment and episode

* Note: GSR data after 34 minutes not included in average. Subject was sweating profusely and the data was considered not comparable with the rest of the session.

Figure D-1.4. Subject 1: Confrontation and Final Driving Sessions

D-2 Subject Number 2

Subject 2 has been employed with Sandia approximately seven months, and although the subject had become acquainted with a large majority of the rules and regulations, he was apprehensive all through the tests about taking the van through the security gate. The large jump in the HR and GSR levels at the arrival of a security lieutenant at the scene would indicate that the subject was undergoing at least moderate levels of stress. This level of gains in the physiological parameters would be sufficient to trigger automatic alarms.

It is interesting to note the rise in values accompanying the subject's entry and exit from the freeway system on Figure D-2.4 due to the subject's nervousness at the earlier confrontation. The rise in GSR levels during the last of the segment is again due to the temperature increase inside the van.

Figure D-2 shows the data obtained from Subject Number 2.

D-3 Subject Number 3

This subject's physiological responses were very unusual in that the recorded GSR levels were below the detection threshold of the monitoring equipment for all of the normal activity sessions; GSR levels for the driving segments were detectable only in the last half of the session when the subject had begun to sweat. Considering this subject's apparent normal range for GSR values ($\bar{X}_{\text{GSR}} \approx 0$), the peaks in the heart rate and GSR levels during the confrontation and the continued elevated GSR values following the episode appear quite significant.

Review of the driving segment (Figure D-3.2) reveals that the subject's heart rate varied a great deal along the route, and, after sweating commenced, was correlated with the GSR levels. Spikes in the levels were due to turning corners, entering freeway system, etc., which would not be considered moderately stressful. Discrimination between the elevated levels in the driving segment and the values observed at the confrontation by an automated process should be possible, but at this sensitivity could result in a high false alarm rate.

Figure D-3 shows the data obtained from Subject Number 3.

Subject 2: Typical plot for daily session, normal activity session

$$\bar{X}_{HR} = 69.9 \text{ beats/min}$$

$$\bar{X}_{GSR} = 4.3 \text{ m mho/cm}^2$$

Significant events:

- t = 1 min Subject standing
- t = 2-7 min Subject sitting
- t = 8 min Subject standing and adjusting chair
- t > 8 min Subject sitting
- t = 15-22 min No obvious reasons for dramatic change in GSR levels

Figure D-2.1. Subject 2: Typical Plot for Normal Session

Subject 2: Typical plot for daily session, driving segment

$$\bar{X}_{HR} = 75.3 \text{ beats/min}$$

$$\bar{X}_{GSR} = 10.6 \text{ m mho/cm}^2$$

Significant events:

$t = 3-5 \text{ min}$ Subject standing and walking

$t > 5 \text{ min}$ Subject driving van

Figure D-2.2. Subject 2: Typical Plot for Driving Session

Subject 2: Exercise Session

$$\bar{X}_{HR} = 75.3 \text{ beats/min}$$

$$\bar{X}_{GSR} = 10.6 \text{ m mho/cm}^2$$

Significant events:

- t = 1-2 min Subject doing knee bends
- t = 3-5 min Subject walking
- t = 6 min Subject sitting
- t = 7-10 min Subject walking
- t = 11 min Subject doing knee bends
- t ≥ 12 min Subject walking

Figure D-2.3. Subject 2: Exercise Session

Subject 2: Confrontation session and final driving segment

$$\bar{X}_{HR} = 85.3 \text{ beats/min}$$

$$\bar{X}_{GSR} = 9.2 \text{ m mho/cm}^2$$

Significant events:

- t = 2 min Arrival at security gate
- t = 3 min Questioning about absence of material
removal pass
- t = 6 min Entry of superior officer
- t = 7 min Told true purpose of experiment
and episode
- t = 21 min Entry to I40 Freeway
- t = 28 min Exit from I25 Freeway

Note: Data at t = 4-5 min was lost when the tape recorder was inadvertently turned off at the scene.

Figure D-2.4. Subject 2: Confrontation and Final Driving Sessions

Subject 3: Typical plot for daily session; normal activity segment

$$\bar{X}_{HR} = 67.3 \text{ beats/min}$$

$$\bar{X}_{GSR} = 0; \text{ below threshold level}$$

Significant events:

t = 1-2 min Subject standing and walking

t = 15 min Subject standing

t = 31 min Subject standing

Note: There was no apparent equipment failure for GSR parameter.
All of Subject 3's normal activity segments appear to show
GSR values below equipment thresholds.

Figure D-3.1. Subject 3: Typical Plot for Normal Session

Subject 3: Typical plot for daily session; driving segment

$$\bar{X}_{HR} = 82.2 \text{ beats/min}$$

$$\bar{X}_{GSR} = 11.0 \text{ m mho/cm}^2$$

Significant events:

t = 7 min Subject leaving Sandia Base

t = 23 min Subject GSR level greatly increased
due to temperature rise inside van

Figure D-3.2. Subject 3: Typical Plot for Driving Session

Subject 3: Exercise Session

$$\bar{X}_{HR} = 90.9 \text{ beats/min}$$

$$\bar{X}_{GSR} = 7.4 \text{ m mho/cm}^2$$

Significant events:

- t = 1-2 min Subject walking
- t = 3-5 min Subject doing knee bends
- t > 6 min Subject walking and standing

Figure D-3.3. Subject 3: Exercise Session

Subject 3: Confrontation session and final driving segment

$$\bar{X}_{HR} = 85.4 \text{ beats/min}$$

$$\bar{X}_{GSR} = 24.5 \text{ m mho/cm}^2$$

Significant events:

- t = 1 min Initial arrival at security gate
- t = 3 min Security personnel state they will have
to file security violation report be-
cause of no material removal pass.
- t = 7 min Arrival of superior officer
- t = 9 min Told true purpose of experiment
and episode

Figure D-3.4. Subject 3: Confrontation and Final Driving Sessions

D-4 Subject Number 4

Subject Number 4 was definitely the most nervous of the volunteers; the subject appeared uneasy throughout the experiment and seemed especially apprehensive when driving the test van. Postexperiment debriefing indicated that the subject was very nervous about driving the van, as he had never driven a vehicle anywhere near this size on public streets.

Heart rate levels during the confrontation segment were quite high when compared to normal activity and driving segments and would be representative of a stressful situation; the GSR level, however, was only slightly above "normal" GSR-driving values. An automated procedure using both HR and GSR increases for alarm probably would not be capable of detecting this incident because of the low GSR levels.

Figure D-4 shows the data obtained from Subject Number 4.

D-5 Subject Number 5

Subject number 5 was the most responsive subject to the confrontation episode. The subject, at the time of the experiment, had only been employed at Sandia for a month and was ignorant of any rules for removal of materials from the secured area. Due to his ignorance, this subject probably experienced the highest level of stress. The extreme elevation in heart rate and GSR levels during the episode would have been readily detectable by a scheme for monitoring the physiological parameters.

As noted in Figure D-5.1, the fluctuations in the GSR level were very large compared to other subjects, but were noted on other occasions with this subject. These responses were probably a result of the subject's nervousness during the experiment.

Figure D-5 contains the data obtained from Subject Number 5.

Subject 4: Typical plot for daily session; normal activity segment

$$\bar{X}_{HR} = 77.4 \text{ beats/min}$$

$$\bar{X}_{GSR} = 3.3 \text{ m mho/cm}^2$$

Significant events:

$t = 5 \text{ min}$ Subject standing and moving chair

$t = 20-41 \text{ min}$ Subject randomly standing and sitting

Figure D-4.1. Subject 4: Typical Plot for Normal Session

Subject 4: Typical plot for daily session; driving segment

$\bar{X}_{HR} = 100.7$ beats/min

$\bar{X}_{GSR} = 17.8$ mmho/cm²

Significant events:

None

Note: Subject appeared very nervous when asked to drive van. HR and GSR levels are very erratic and are difficult to correlate with any significant events.

Figure D-4.2: Subject 4: Typical Plot for Driving Session

Subject 4: Exercise Session

Subject 4: Confrontation session and final driving segment

$$\bar{X}_{HR} = 106.3 \text{ beats/min}$$

$$\bar{X}_{GSR} = 18.2 \text{ m mho/cm}^2$$

Significant events:

- t = 2 min Initial halt of subject at security gate
- t = 5 min Entry of superior officer
- t = 7 min Continued harrassment concerning
lack of material removal pass
- t = 8 min Told true purpose of experiment and
episode

Note: At the beginning of the session, subject appeared somewhat calmer than on previous session but was still nervous.

Figure D-4.4. Subject 4: Confrontation and Final Driving Sessions

Subject 5: Typical plot for daily session; normal activity segment

$$\bar{X}_{HR} = 78.8 \text{ beats/min}$$

$$\bar{X}_{GSR} = 20.6 \text{ m mho/cm}^2$$

Significant events:

None

Note: There was no obvious external reason for the large fluctuation in the subject's GSR level, although this same behavior was also observed on other occasions. Behavior could probably be due to nervousness during the sessions.

Figure D-5.1. Subject 5: Typical Plot for Normal Session

Subject 5: Typical plot for daily session; driving segment

$$\bar{X}_{HR} = 84.2 \text{ beats/min}$$

$$\bar{X}_{GSR} = 24.4 \text{ m mho/cm}^2$$

Significant events:

- t = 3 min Leaving Security Gate
- t = 15 min Turning left onto Menaul and subject
"cutoff" by another driver
- t = 21 min Entering 125 freeway
- t = 36 min No obvious reason for sudden drop
in HR level.

Figure D-5.2. Subject 5: Typical Plot for Driving Session

Subject 5: Confrontation session and final driving session

$$\bar{X}_{HR} = 95.1 \text{ beats/min}$$

$$\bar{X}_{GSR} = 52.6 \text{ m mho/cm}^2$$

Significant events:

- t = 2 min Initial halt at security gate
- t = 6 min Refusal to leave security area
- t = 8-9 min Arrival of superior officer and intensified questioning
- t = 12 min Subject told will have to be reported
- t = 13 min Told true purpose of experiment and episode

Figure D-5.3. Subject 5: Confrontation and Final Driving Sessions

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