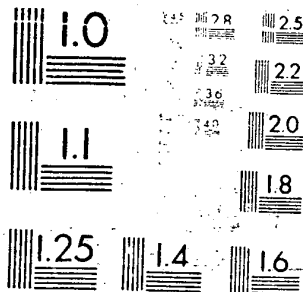


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# Development of an Automated Stress/Duress Detection System Phase II: Field Studies Albuquerque Police Department

Waneta C. Tuttle, Jerry G. Davis

Prepared by Sandia Laboratories, Albuquerque, New Mexico 87185  
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Sandia Laboratories



To be able to understand the situation of people who are covered by the provisions of the United Nations Convention on the Rights of the Child, the United States Government has taken a number of steps. First, the United States Government has taken steps to ensure that the Convention is implemented in the United States. This includes the development of a national strategy for the implementation of the Convention, the establishment of a national committee on the rights of the child, and the development of a national system of child support. Second, the United States Government has taken steps to ensure that the Convention is implemented in the United States. This includes the development of a national strategy for the implementation of the Convention, the establishment of a national committee on the rights of the child, and the development of a national system of child support. Third, the United States Government has taken steps to ensure that the Convention is implemented in the United States. This includes the development of a national strategy for the implementation of the Convention, the establishment of a national committee on the rights of the child, and the development of a national system of child support. Fourth, the United States Government has taken steps to ensure that the Convention is implemented in the United States. This includes the development of a national strategy for the implementation of the Convention, the establishment of a national committee on the rights of the child, and the development of a national system of child support. Fifth, the United States Government has taken steps to ensure that the Convention is implemented in the United States. This includes the development of a national strategy for the implementation of the Convention, the establishment of a national committee on the rights of the child, and the development of a national system of child support. Sixth, the United States Government has taken steps to ensure that the Convention is implemented in the United States. This includes the development of a national strategy for the implementation of the Convention, the establishment of a national committee on the rights of the child, and the development of a national system of child support. Seventh, the United States Government has taken steps to ensure that the Convention is implemented in the United States. This includes the development of a national strategy for the implementation of the Convention, the establishment of a national committee on the rights of the child, and the development of a national system of child support. Eighth, the United States Government has taken steps to ensure that the Convention is implemented in the United States. This includes the development of a national strategy for the implementation of the Convention, the establishment of a national committee on the rights of the child, and the development of a national system of child support. Ninth, the United States Government has taken steps to ensure that the Convention is implemented in the United States. This includes the development of a national strategy for the implementation of the Convention, the establishment of a national committee on the rights of the child, and the development of a national system of child support. Tenth, the United States Government has taken steps to ensure that the Convention is implemented in the United States. This includes the development of a national strategy for the implementation of the Convention, the establishment of a national committee on the rights of the child, and the development of a national system of child support.

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PHASE II: FIELD STUDIES,  
ALBUQUERQUE POLICE DEPARTMENT

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**Jerry G. Davis, BSEE**

Clinical Research Division  
Lovelace Center for the Health Sciences  
Albuquerque, New Mexico 87108

Waneta C. Tuttle  
Waneta C. Tuttle, Ph.D.  
Director, Clinical Research

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DEPARTMENT OF AN AUTOMATED STRESS/DURESS DETECTION SYSTEM  
PHASE II: FIELD STUDIES  
ALBUQUERQUE POLICE DEPARTMENT

ABSTRACT

This report is a summary of the work conducted to date at the Lovelace Medical Foundation, Albuquerque, New Mexico, toward development of an automated stress/duress detection system designed for application to individuals guarding nuclear materials. Detailed information on previous studies may be found in the report for Phase I (Technical and Physiological Studies, SAND78-7015). A more abbreviated version of this report is contained in Phase II Summary Report (Field Studies, Albuquerque Police Department, SAND79-7038).

SUMMARY

In an attempt to improve the reliability of the human element in security systems, physiological response monitoring equipment and high temporal resolution computer analysis of the recorded data have been developed and implemented for automatic duress detection. Twentytwo volunteer police officers were instrumented with small, body-worn electrocardiographic tape recorders. At the program outset, each of these officers underwent laboratory baseline testing using a set of well controlled physiological and psychological stressors. Data were analyzed by an off-line computer. The recorded electrocardiograms were statistically examined for both mean heart rate (MHR) and beat-to-beat variability as represented by the standard error (SE) over the measurement period. For each officer both MHR and SE increased during a pure psychological test, but the SE dramatically decreased during a pure physiological test. This provided the basis for a possible differentiation between responses to physiological and psychological stressors. In field testing, this is necessary to reduce false alarms due to physical activity. These controlled studies provided individualized criteria for alarm algorithms to be tested in the field.

Subsequent to the laboratory tests, the officers were instrumented during their normal daily activities. A total of 247 recording days were obtained and analyzed with twenty second resolution. Each officer maintained a log sheet to independently record the times and severity of any stressful event. In addition, daily call cards were obtained from the police dispatcher. The maximum MHR observed in the laboratory studies for each officer was chosen as the alarm criterion heart rate (CHR), and events were recorded in which the CHR was exceeded.

Using the CHR as a conservative physiological event identifier, a study of the association between "physiological events" and "threatening" field events was made. For this test series, with the selected individual CHR and a highly subjective definition of a threatening situation, false alarms would have occurred on 6 percent of 1,399 no-threat exposures; correct rejection on 94 percent. Again, with the above criteria, 68 percent of the 213 threat exposures would have been identified as such and 32 percent rejected. Improvements in "alarm criteria" and a more consistent definition/understanding of threat exposures can likely improve system reliability. During the police field studies, four major, clearly-defined life-threatening events occurred. During each of these events heart rates exceeded a value 20 percent greater than the CHR and were higher than an absolute value of 150 beats per minute.

The results of the Phase I and Phase II studies suggest the ultimate feasibility of a remote telemetry system to automatically monitor psychological stress/duress. The next essential step in system development will be design and fabrication of an appropriate heart rate sensor.

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I. INTRODUCTION

Many new security devices and techniques have been developed for protection of personnel and facilities in the last several years. Perhaps nowhere has this been more vigorously pursued than in the nuclear safeguards area. While new technologies were being exploited however, it occurred to several investigators that a method of automatically evaluating the psychological status of guard personnel could possibly provide very reliable alarm indications. Assuming that a guard's abnormally high stress level could be quickly and automatically assessed (and



the result telemetered to a central receiving site), help could be summoned without any conscious act by the guard. This would be quite advantageous if the guard were being held at gunpoint. With this goal in mind, we began to investigate methods of detecting psychological stress via physiological measurements. A number of these techniques have been in use for many years and are reviewed by Tuttle and Davis (1978). Among the dependent variables monitored in both laboratory and field tests are many statistical indices of heart rate and skin responses. Special attention has been given to the differentiation of heart rate variability under mental stress as compared to physical exercise (Tuttle and Davis, 1978; Rohmert et al., 1973; Luczak and Laurig, 1973; Mulder et al., 1973; Boyce, 1973; Danev et al., 1971; McSayers, 1973; Opmeer, 1973; Burdick, 1978).

Up to now contradictory results have been reported by these authors using various mental and informational loads as the independent variable and the various indices of heart rate and skin conductance as the dependent variable and indicator of stress. The different scoring methods used by the various investigators may be a partial explanation for these contradictory results. Due to their highly controlled laboratory methodology, the majority of the previous studies were unassociated to the development of an automated stress/duress detection system.

The adaptation of previously described experimental design and instrumentation on freely roving guard personnel imposed unique constraints upon this type of methodology. Of absolute necessity were the requirements that the system be non-invasive, unobtrusive, concealable, easily applied, fast responding and highly reliable. A time lapse from stressor perception to alarm initiation of one minute or less, with a minimum of false positive or false negative alarms, was very desirable. To achieve an acceptable false positive rate, it appeared necessary at the program outset that the method selected for ultimate field use should be able to differentiate between responses to physical and mental stressors. As indicated by previous studies, this differentiation was not assured due to the complex psychophysiological interactions which create unspecific variations in the various indices of heart rate and skin conductance. Consequently, the goals of this Phase II of the development of an automated stress/duress detection system were as follows:

1. To determine if various indices of heart rate and skin conductance could be transduced and recorded with minimal signal artifact in the free roaming subject.
2. To determine if the anticipated increases in the time averaged heart rate and/or skin conductance under life threatening conditions were sufficiently elevated over baseline levels to allow this sole calculation to be sufficient in establishing alarm criteria.
3. To establish if the calculations of additional statistical indices of heart rate (e.g. heart rate variability) were required to increase the efficacy of the alarm system.

Clearly, initial controlled laboratory experiments on physiological reaction to various situations on a volunteer population of security personnel were required to establish baseline profile on each individual and the range of responses of the entire population. This analytic approach could subsequently be followed by the more synthetic analysis of responses which occur in the actual life-threatening situation.

## II. METHODS

### A. Laboratory Testing

As a first step toward achieving the above goals, a number of physiological systems were analyzed from the standpoints of response specificity and technical practicality. This analysis provided us with a small number of variables for testing in a controlled laboratory environment. The variables selected as a result of this testing were then utilized in a field setting.

Many responses of the cardiovascular, cutaneous, skeletal muscle, neurologic and respiratory systems were examined in an earlier study (Tuttle and Davis, 1978). Some of the variables studied in each system are outlined below.

1. Cardiovascular
  - a. Heart rate
  - b. Electrocardiogram morphology
  - c. Systolic time intervals
  - d. Stroke volume
  - e. Cardiac output
  - f. Pulse wave velocity
  - g. Blood pressure





2. Electrodermal activity
3. Tonic muscle tension (electromyogram)
4. Neurologic (Electroencephalogram power spectrum analysis)
5. Respiratory
  - a. Respiratory rate
  - b. Tidal volume

Each of these variables was evaluated on its physiological and technical merits. Physiological considerations that influenced variable selection included 1) magnitude of response exhibited by the variable to stress/duress, 2) the variability of the response within and among individuals, 3) the time course of the response, 4) the response of the variable to non-significant stressors (e.g. physical exercise) and 5) the effect of environmental factors on the magnitude and variability of response. Technical considerations included 1) feasibility for transduction from an untrained mobile subject, 2) significance of artifact (all sources), 3) applicability to low power and hybrid packaging techniques, 4) applicability to automatic real-time analysis via microcomputer, and 5) applicability for daily use.

A selected number of these variables met acceptable criteria for further testing and were subsequently evaluated in laboratory tests (see next section). The purpose of this testing was twofold. First, the tests were necessary for collecting baseline data on individual responses to various psychological and physiological stressors. Different individuals respond differently to identical stressors and this test series was designed to allow examination of this variability. The tests also enabled us to look at the intra-individual response differences to psychological and physiological stressors. Secondly, the test series allowed us to develop correlations between physiological and psychological stressor responses. A total of 22 police officers (20 male and 2 female) from the Albuquerque Police Department volunteered for the program. Vital statistics of the population of volunteers is given in Appendix A.

For this test series, we used two laboratory stressors which have been found effective in eliciting clear autonomic responses by previous investigators. These were the cold pressor test and a mental arithmetic task. To introduce a more pure physiological stress, an exercise routine on a bicycle ergometer was utilized as the third test. Each of these tests was conducted with the subject isolated in an

environmental chamber at a nominal temperature of 80°F and 40% relative humidity. Test operators monitored all tests through a window behind the subject. Instructions were standardized, tape recorded and administered to the subject through a headset which he/she wore continuously during the first two tests (Figure 1).



FIGURE 1  
Subject instrumented for cold pressor and mental arithmetic tests in controlled laboratory.

The cold pressor test, as adapted for our series, required that the subject's right foot be immersed in a container filled with approximately four inches of ice water. The foot remained in the water for a full one minute. This test was repeated once after a five minute recovery period. Instructions to the cold pressor test are given in Appendix B.

The mental arithmetic task required that the subject subtract by threes, starting at three hundred, and verbalize the result into a microphone. The subject was to subtract in time with a metronome set at 1.5 second intervals. The subject's voice was delayed approximately 0.15 seconds before being fed back into his headset. This crisp, continuous echo caused obvious confusion in most subjects. In addition, a loud beeper was sounded by a test operator whenever 1) the subject did not enunciate clearly or 2) did not subtract correctly or 3) did not keep time with the metronome. The subject had also been informed that, at the end of the counting period, he/she would receive a very strong shock for each mistake made.



during counting. This was a sham action only. Instructions to the mental arithmetic test are given in Appendix C.

The physiological stress test involved riding a bicycle ergometer at a relatively light work load. The subject did not

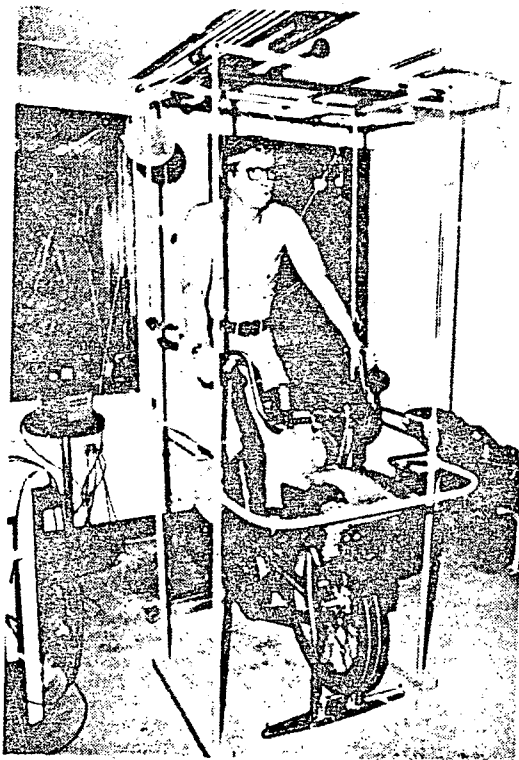


FIGURE 2  
Subject instrumented for physiological stress test on bicycle ergometer.

wear a headset for this test (Figure 2). The subject was told by the test operators before they left the room that he should simply start pedalling when a beeper was sounded and continue until the beeper sounded again. The load on the bicycle was set to 2.0 kilopond-meters/second and the subject was told to pedal at a constant 60 rpm as indicated on the tachometer. The subject exercised for two 3 minute sessions with a five minute rest between.

Protocols of the cold pressor, mental arithmetic, and exercise tests are found in Appendix D.

During a quiet period preceding the initiation of the mental arithmetic task, a startle stimulus was introduced. It consisted simply of a loud noise administered through the headset. The noise was a siren type sound (approximately 100 db) which lasted three seconds.

## B. Data Acquisition and Reduction Systems

### 1. Data Acquisition System

Data collection for this program involved essentially the same system for both laboratory baseline testing and field testing. This system utilized a battery-powered, body-worn, 4-channel tape recorder for recording the electrocardiogram (ECG), skin conductance (SC), skin conductance response (SCR) and timing clock. The ECG preamplifier was an integral part of the recorder while the SC/SCR preamplifier was designed and fabricated by the Biomedical Engineering Department and outboarded on the recorder package. Surface electrodes were utilized for ECG and SC transduction. During laboratory testing signal quality was verified throughout the test by signal monitoring on an oscilloscope. For field testing the signals were initially checked on a strip chart recorder immediately after the officer was instrumented. Each aspect of the data acquisition system is discussed in more detail in the following paragraphs.

#### a. Body-Worn Recorder

The recorder used in this study was the Oxford Medilog model 4-24. (The Oxford system is available in the U.S. through Ambulatory Monitoring, Inc., Ardsley, N.Y.). This recorder measures approximately  $1\frac{1}{2}$ " x  $3\frac{1}{2}$ " x  $4\frac{1}{2}$ " and records on standard Phillips cassette tape cartridges (Figure 3). Using a C-60 cassette allowed up to 12 hours of continuous data recording. This unit was selected because, to our knowledge, it was the only recorder available which allowed three data channel





recording with DC response capabilities (via FM recording). The recorders also utilized a phaselocked servosystem for controlling tape speed. Disposable mercury batteries were used for power.

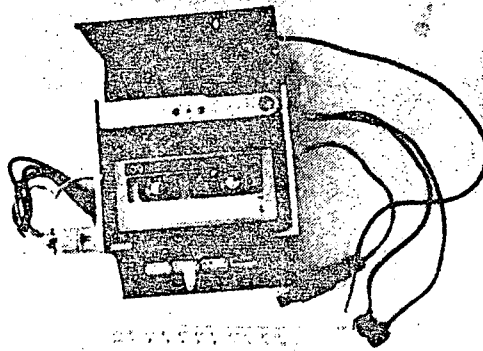


FIGURE 3  
Analog signal tape recorder used in both laboratory and field testing. Note overall length of approximately 10 cm.

The recorders were purchased with four plug-in preamplifiers and/or modulators installed. Each of these units fit on a single PC card measuring approximately  $\frac{1}{2}$ " x 2". The first plug-in unit, designated an EG-2, was a combination ECG preamplifier and pulse width modulator. Although providing only 1 Megohm differential input impedance, this appeared to be adequate when good skin preparation and high quality ECG electrodes were utilized.

Small common mode signals (due to battery operation) also made this rather low input impedance acceptable without introducing excessive 60 Hz interference into the ECG signal. Bandwidth of the recorder system was specified as 0.07 to 100 Hz. (As only rate information was required from the ECG signal, this bandwidth was

usually reduced considerably by utilizing controls on the playback unit).

The second and third plug-in units, designated AM-3, were FM modulators utilized for recording the very low frequency SC and SCR signals. Input sensitivity and offset were adjustable via two trimpots on the PC board. Linearity was better than 1%.

The fourth and last plug-in, designated ATE-1, was a crystal controlled 60 Hz clock generator. This unit also contained an event mark generator which was activated by a push-button on the recorder. The event mark was superimposed on the timing clock using a 30 Hz signal.

#### b. SC/SCR Preamplifier

A preamplifier suitable for skin conductance was not available as a standard plug-in to the Oxford recorder. Therefore it was necessary to design a custom preamplifier. A schematic of this preamplifier is shown in Figure 4.

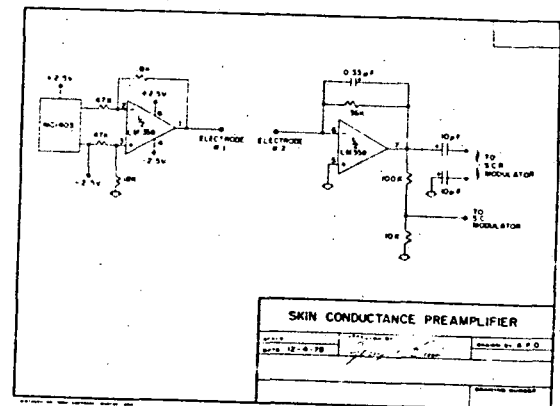


FIGURE 4  
SC/SCR Preamplifier; see text for discussion

Using an MC1403 voltage reference, an electrode excitation of approxi-



mately - 1.0 V was derived at the output of the LM 358. This voltage was applied to the number 1 electrode while the number 2 electrode was connected directly to the inverting input of a current-to-voltage converter stage. Because the non-inverting input of this stage was grounded, the second electrode was held at essentially ground potential. The SCR signal was obtained by simple high-pass filtering (0.04 Hz) of the composite output of the current-to-voltage converter. The voltage excursions of the SCR signal were compatible with the recorder input requirements of approximately 30 mV peak-to-peak. The SC signal, being essentially a DC signal, was considerably greater than this 30 mV level and was therefore divided down appropriately.

#### c. Electrodes

Two types of electrodes were used in this study. Disposable NDM Silvon diaphoretic types were used for ECG transduction while reusable Beckman Silver/Silver-Chloride units were used for skin conductance. The NDM units were pre-jelled with a suitable ECG electrolyte while the Beckman's required that electrolyte be manually applied with each usage. Johnson's KY Jelly was used for this electrolyte.

For ECG transduction these electrodes were placed on the chest in an M-V5 lead configuration for most subjects. Three electrodes were used (as opposed to the minimum two) to ensure good ECG data even in the event that the subject entered a large 60 Hz electromagnetic field. Skin preparation was most important because the subjects tended to sweat profusely due to high ambient temperatures and bulky garments.

Bullet-proof vests were used routinely and continuously by many officers. Acetone, applied vigorously with a gauze square was first used as an oil solvent. Next, tincture of benzoin was applied to an annular area, and after drying, the NDM electrode was firmly applied. This protocol was capable of producing very good long-term adhesion. It should be noted that, after repeating this procedure for 3 to 4 consecutive days, several officers developed moderate skin irritation.

For SC/SCR transduction, two Beckman electrodes were placed on the medial aspect of the ankle. The two leadwires were run through the pants leg to the SC/SCR preamplifier mounted on the belt-worn recorder. Minimum skin preparation was utilized in this case because of possible undesirable alteration of SC caused by this action. A short cleansing of the area with methyl alcohol was the only skin preparation for the SC electrodes. The electrodes were attached using a double sided adhesive collar. SC electrodes could not be attached to those subjects wearing boots due to the size of the electrodes.

#### d. Signal Verification

To verify that good quality data was being transduced and recorded, a model CI-102 coupler/isolator (Research Instrumentation Associates, Cleveland, Ohio) was utilized to demodulate the three signals applied to the recorder heads. In the laboratory tests, the coupler/isolator output was viewed on an oscilloscope. In the field tests, a portable strip chart recorder was used.





## 2. Data Reduction System

The first level of data reduction involved scanning the individual cassette tapes on a high speed playback unit operated at 60 times faster than real-time. The ECG data was processed by a high-speed hardware R-Wave Detector which in turn interfaced to an Intel Microcomputer Development System used as a stand-alone computer (Figure 5).

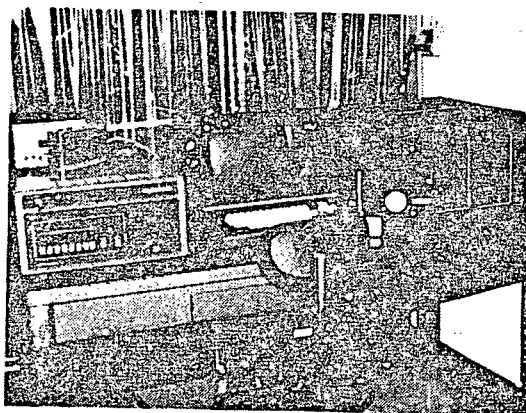


FIGURE 5  
Intel Microcomputer Development System used for data reduction in both laboratory and field tests.

The analog SC/SCR data was written out directly to a strip chart recorder for visual analysis. The various elements of this reduction system are discussed in detail in the following sections and a block diagram of the system is shown in Figure 6.

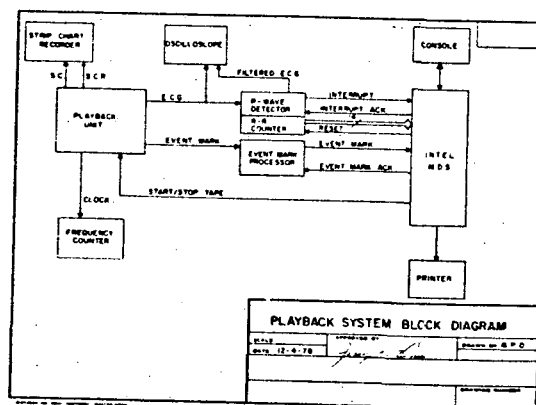


FIGURE 6  
Block diagram of data reduction system;  
see test for details.

### a. Playback Unit

The cassette playback unit was an Oxford Model PB-2 capable of decoding the four channels of data from the cassette tape. The unit operated at sixty times real-time so that a typical 8 hour tape could be played back in 8 minutes. The unit was modified slightly by the Biomedical Engineering Department to enable fine tuning of the playback speed. With this adjustment, overall timing accuracy was well within 1%.

Four plug-in demodulator/processors were used with the basic playback unit. These were a PD-2 for ECG, a PM-2 for SC, a second PM-2 for SCR and a PE-2 for the timing clock/event channel. The PD-2 provided adjustable bandpass and gain. Individual adjustments were available for upper and lower cutoff frequencies and these were adjusted for optimum R-wave detection. The adjustment is described in the next section which deals with the high-speed ECG Processor. The PM-2 demodulator/processors provided adjustable Low-Pass Filtering, Gain and Offset. No High-Pass Filtering was provided as these demodulators were intended for use with DC signals. No adjustments were required on the PE-2 demodulator. As shown in Figure 6, a frequency counter was connected to the clock output. During playback, the 60 Hz crystal controlled clock signal was multiplied up to 3600 Hz assuming an exact 60 times playback speed-up ( $60 \times 60 = 3600$ ). The fine speed adjustment on the playback unit was used to set this frequency to 3600 Hz.



b. High Speed ECG Processor

Schematics of the ECG Processor, consisting of an R-wave detector and an R-R counter, are shown in Figures 7 and 8 respectively. The R-wave detector consists of a bandpass filter, Automatic Gain Control (AGC) circuit, comparator, monostable multivibrator and an R/S Flip-Flop. Operation of the circuit is as follows. The ECG input signal amplitude is set to a nominal 1.5 Vpp using the gain control on the playback unit. The input bandpass filter is centered at 1020 Hz with a Q of 3. 1020 Hz provides bandpassing of the high-energy R-wave component which is centered at approximately 17 Hz real-time ( $17 \text{ Hz} \times 60 = 1020 \text{ Hz}$ ). Using a Q of 3 provides an oscillatory or "ringing" output which thus enables the circuitry to "tach" on either a positive or negative going ECG R-wave. The AGC portion of the processor rectifies and filters the bandpass filter output. This varying DC signal is used to control the resistance of the 2N4860 FET which acts as part of a variable voltage divider. The output of the AGC circuit is set for an 8V positive peak using the amplitude control. The highly filtered and normalized ECG is next fed to the input of a comparator set to trigger at approximately +5V. The output of the comparator is fed to a 74121 monostable multivibrator set for an output pulse width of approximately 2.5 milliseconds. This one-shot thus prevents false retriggering on noise, large T-waves and second or third threshold crossings of the filtered ECG signal. Finally, an R/S Flip-Flop is used to interface the ECG processor to the computer interrupt circuitry through the open collector 2N2222 transistor.

The Flip-Flop is set at the occurrence of each detected R-wave and subsequently reset by the computer generated Interrupt Acknowledge signal.

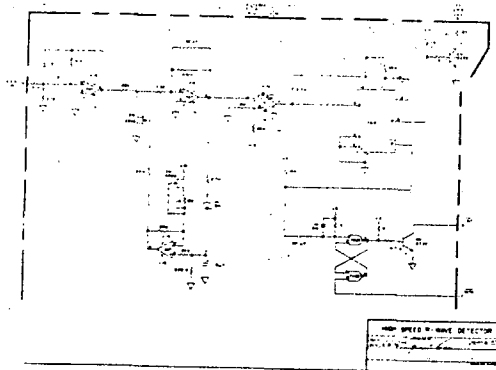


FIGURE 7  
High speed R-Wave Detector designed and fabricated by Clinical Research Division, Lovelace Medical Foundation.

The second portion of the ECG processor consists of a 14-bit R-R counter with a crystal controlled clock. The basic clock frequency, as shown on the schematic, is 1.000 MHz and is divided down to 125 KHz for clocking the counter. A lower clock frequency of 7.8125 KHz is also provided for processing of real-time ECG data. Count inhibit and reset signals are also accepted from the computer.

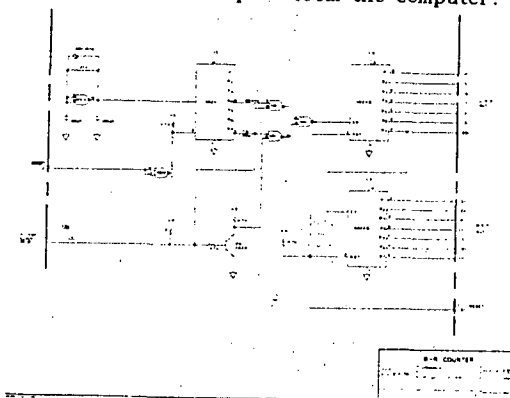


FIGURE 8  
R-R Counter designed and fabricated by the Clinical Research Division, Lovelace Medical Foundation.





c. Skin Conductance Analysis

It was anticipated that analysis of the Skin Conductance and Skin Conductance Response (SR/SCR) data would be first performed in a non-automated manner. This method was expected to be sufficient to allow pattern-recognition of significant changes without the need of costly software development for automated analysis. For this reason, the analog SC and SCR signals were played onto a Brush 260 dual-channel strip chart recorder. The Brush recorder bandwidth was adequate to display the highest frequency components of the SCR signal which were about 2 Hz x 60 = 120 Hz. Because the SC and SCR signals are quite low in frequency content, it was possible to run the strip chart recorder at 100 mm/sec and obtain adequate temporal resolution.

d. Computer System

The computer used for heart rate analysis in this program was actually an Intel Microcomputer Development System (MDS). This system was purchased with the intention of ultimately developing a microcomputer based system for real-time heart-rate processing. The availability of the MDS thus prompted its use in this phase of the program. Although the MDS and peripherals were somewhat slow, they did prove adequate for this analysis. The hardware and software of this system are discussed below.

1) Computer System Hardware

The computer system hardware consisted of an Intel MDS-800 main-frame, an Intel MDS-CRT console, an Intel MDS-2DS diskette operating system and a TI-743 keyboard/printer. The MDS-800 contained an

8080A CPU, 64 KBytes of memory and an 8-level maskable priority interrupt structure. The CRT console was a standard 80 character x 25 lines. The diskette operating system included two single density disk drives, each having 250 KByte storage capacity. The TI "Silent-700" series printer is a thermal printer capable of up to 30 cps print speed. The unit contained internal buffering thus allowing true 30 cps throughput.

2) Computer System Software

System software utilized in this program consisted of the standard Intel ISIS-II package. The programs were written in Fortran IV and compiled using a Fortran compiler written by Realistic Control Corporation for the 8080 microprocessor.

The excellent software developed for this program was written by Mr. Jim Kobs of Sandia Corporation. Because of the speed limitations of the Intel MDS, Mr. Kobs elected to divide the processing into two separate programs. The first program digitized and stored on diskette the basic beat-to-beat heart rates. The second program performed the necessary statistical analysis on the stored HR data.

The first program, called "DGTIZ", reads the R-R counter contents at each R-wave generated interrupt and continuously stores these R-R values in MDS RAM memory. The DGTIZ program continues to accept R-Wave interrupts until 44,000 words have been accumulated. At that time, the MDS memory is full and the data is dumped to diskette. During the transfer period (approximately 10 seconds), processing is halted and the computer stops the cassette playback so that no data is lost.



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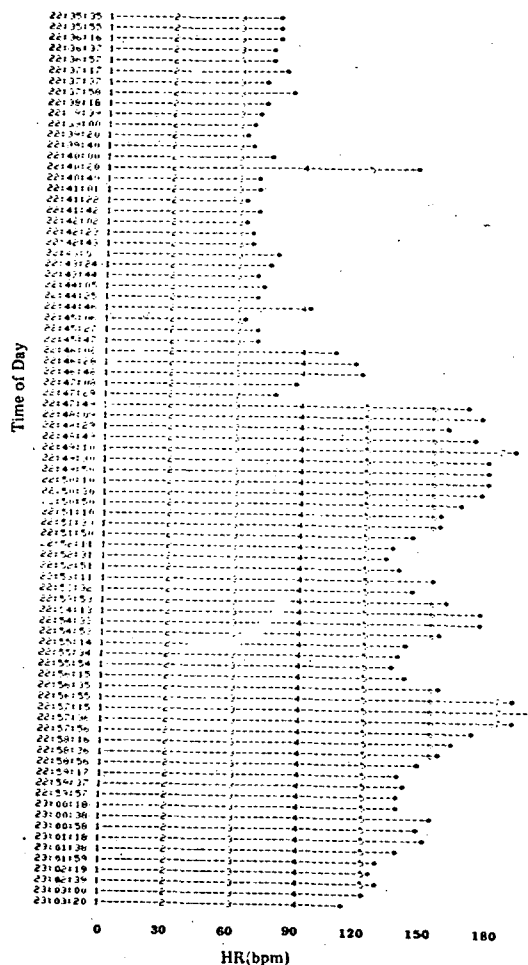


FIGURE 10  
Example of plotted mean heart rate data.

adequate for this application. Ordinates for the plot are entered from the keyboard. An example of plotted mean heart rate data is shown in Figure 10.

The occurrence of an event mark is also stored in the DGTIZ data set and printed out whenever encountered during the REDUCE program.

#### e. Data Scanning Procedure

Because of the large amount of time required to reduce and print out the entire portion of every data set, a scanning process was instituted so that the amount of data to be printed could be reduced to a manageable quantity. This scanning process was based on the premise that a heart rate elevated above a conservatively selected level would signal a data segment possibly useful for in-depth analysis.

Based on this premise, criterion heart rates were selected for each individual and were in fact the highest heart rate levels achieved during the base-line laboratory testing. The ECG was continuously monitored on an oscilloscope during initial data playback (during the DGTIZ program) and, by triggering the oscilloscope on the ECG R-Wave, it was easy to visually determine when the heart rate exceeded the threshold level by noting when the R-R interval shortened. Whenever this occurred, the time of day, as displayed on the playback unit, was noted. Finally, each of these "events" was individually reduced and printed by instructing the REDUCE program to start reduction 20 minutes before and end reduction 10 minutes after the event. This process reduced the actual printing time markedly.

#### C. Field Testing

Subsequent to the laboratory testing, the 22 police officers from the Albuquerque Police Department underwent field testing. Each of these officers was instrumented on an average of 12 days during a five-month period from June through October, 1978. The officers were instrumented upon reporting for duty and wore the instrumentation continuously during the entire duty period. Normal duty period was approximately 8 hours. A maximum of 8 officers were instrumented on any given day.



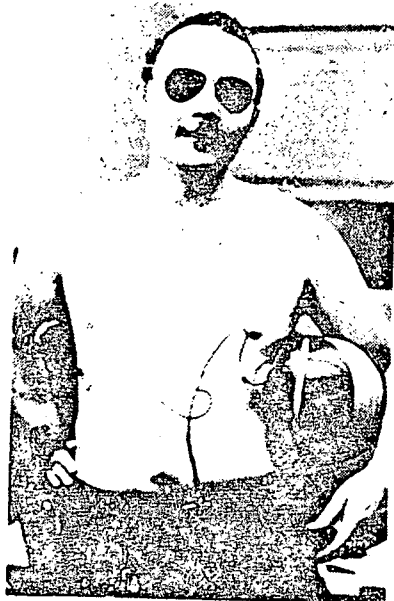


FIGURE 11  
Instrumented police officer showing placement  
of electrodes and recorder on officer's belt.



FIGURE 12  
Fully instrumented officer.  
Note portability of recording unit.

Each officer was also requested to provide a retrospective evaluation of his/her feelings during any event perceived as stressful. To minimize requirements on the officer, a very brief questionnaire was provided for this purpose (See Appendix E). This subjective evaluation was then correlated with the physiological response seen during the event. Other corroborative data available were call cards obtained from the police dispatcher. (See Appendix F).

The instrumentation consisted of all equipment necessary to transduce and record the electrocardiogram (ECG) and the skin response as indicated by skin conductance (SC) and skin conductance response (SCR). The tape recorder selected for this program (see previous section) provided four continuous channels for up to 24 hours utilizing standard cassette tapes. The recorder was very small and light-weight and was attached to the officer's belt (Figure 11). In practice, the officers quickly forgot that they were wearing the system (Figure 12).

In practice, the ECG quality provided by this system was very good. In all but a few instances the signal was entirely adequate for cardiostachography. In the field testing however, the SC/SCR transduction proved to be unfeasible on a routine basis. This was because of both the excessive amount of time required to apply the electrodes properly and less than adequate signal quality due largely to motion artifact.

### III. RESULTS AND DISCUSSION

#### A. Laboratory Stress Testing

Studies early in the initial project indicated that of all the variables previously listed, heart rate (HR) via the electrocardiogram and skin conductance (SC) were most appropriate for transduction in a system designed to remotely detect physiologically manifested psychological stress or duress. The final phase of the initial project was designed to further evaluate heart rate and skin conductance responses to stress. For this purpose, ten male volunteers, aged 24 to 35 years, underwent the combined laboratory stress test described previously. The results of these tests provided the basis for analysis of the physiological data subsequently collected in the police testing.

Analysis of HR and SC data collected during the initial laboratory tests was limited to manual calculations and was conducted as follows. Twenty second





TABLE 1				
MEAN HR CHANGE				
Four Stressors, Initial Study (n=10)				
	Cold Pressor	Exercise	Mental Arithmetic	Startle
Mean (bpm)	+ 9.8	+28.2	+30.5	- 4.3
S.D.	+3.68	+6.21	+7.59	+0.94
P	<.005	<.005	<.005	NS

"response" segments of HR and SC data were analyzed for each subject for the exercise (E), cold pressor (CP), and mental arithmetic (MA) tests, as well as for the startle stimulus (S). These "response" segments were identified as the first 20 seconds after the beginning of each test. For each segment the linear regression of heart rate with time was calculated.

Changes in mean heart rate (MHR) during the response segments are shown in Table 1 along with the appropriate t statistic and its significance for the average response for each test. The larger the t statistic for the difference between the mean baseline heart rate and the mean 10 second response, the greater the significance of the response. The p value indicates the probability that the recorded mean responses for the ten subjects may have occurred due to chance. (NS=non-significant).

The increases from baseline in CP, E and MA were all statistically significant. The data show that the largest increases in MHR occurred with E and MA. The startle resulted in a non-significant decrease in MHR. The significant changes in mean heart rate show that a continuing psychological stress can be identified by evaluation of a 20 second segment of heart rate data. In addition, these data demonstrate that the HR responses to the psycho-physiological stressors could be clearly differentiated from the HR response to a startle stimulus.

Although the data in Table 1 show a good separation of the startle response from the other stressor responses, they do not demonstrate sufficient discrimination between HR responses to physical exercise (E) and the psychological stressor, mental arithmetic (MA). However, subjective evaluation of the cardiometer records resulted in appreciation of differences in the pattern of heart rate response to the mental arithmetic and cold pressor tests when compared to the pattern of heart

rate change during physical exercise. After an initial, rapid beat-to-beat HR increase at the beginning of exercise, the cardiogram was smooth, showing little beat-to-beat variability in heart rate. Heart rate variability is common at low resting heart rates due to sinus arrhythmia and is known to decrease at elevated heart rates during exercise (Burdick, 1978). During MA, however, it was noted that a relatively high beat-to-beat variability was maintained during elevated MHR's. This observation sug-

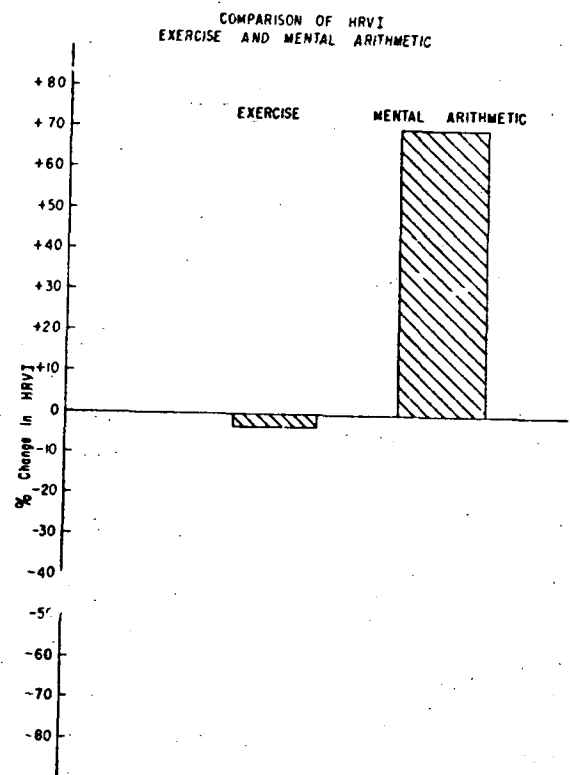


FIGURE 13  
Comparison of HRVI during exercise and mental arithmetic.

gested that heart rate variability might serve as a discriminator between physiological and psychological stress in an alarm system (Rohment et al., 1973). In an attempt to translate these qualitative observations into quantitative data, mathematical treatment of the data was approached as follows. For the E and MA tests the standard error (SE) of the linear regression was calculated during 1) a selected 20 second segment during the



second minute of E and 2) the 20 second segment following the onset of counting during MA. Calculated in this manner, SE reflected beat-to-beat heart rate variability (Opmeer, 1973).

To assess the usefulness of combining the heart rate and heart rate variability data, a heart rate variability index (HRVI) was calculated as  $MHR \times SE$ . These data, expressed as a fraction of baseline HRVI, are shown in Figure 13.

The HRVI data confirmed the qualitative observations of higher HR variability during mental as opposed to physical stress. While mean heart rate was 17% higher during exercise as compared to mental arithmetic, the HRVI was 75% higher during mental arithmetic. It was appreciated, however, that these differences in HR variability occurred in controlled laboratory studies where the exercise involved a constant work load. It may be more likely that physical exercise in the field would provide more intermittent stimulation to the autonomic nervous system and potentially produce an HRVI that might be confused with that produced by mental stress, particularly over the short time period (20-60 sec) required for response in an automatic alarm system.

The initial laboratory studies also showed an increase in SC and SCR during the several stress tests. However, measurement of skin conductance was discarded early in the subsequent field studies because of technical impracticality and the promising results of heart rate analysis.

Each of the twenty-two police officers who participated in the field testing also underwent the combined laboratory stress test. Performance of these tests provided individualized physiological response profiles that would be used 1) as a basis for analysis of data in the field and 2) as an evaluation of the practicality of using a simple laboratory stress test to establish individualized alarm criteria. Automated data processing as described previously in this report was developed for application to the results of the laboratory tests performed on the police officers. This more comprehensive analysis of the data confirmed the findings from the first series of laboratory tests. Comparison of HR and SE data from the three tests showed a pattern of increase in heart rate and decrease in standard error during E that was distinct from the increases in both heart rate and standard error observed in the MA tests. In other words the baseline data from the police officers

confirmed the observation in the earlier studies of a high HRVI during mental arithmetic and low HRVI during exercise. Aside from its implication for an automatic alarm system, this ability to distinguish physical from psychological stress in the laboratory through the HRVI is a contribution to basic understanding of the cardiovascular responses to stress. The results of these studies confirm the well-known decrease in beat-to-beat variability during physical exercise but contradict the findings of Blitz, et al. (1970), and Luczak and Laurig (1973), who found a negative correlation between HR and HR variability during a mental task.

#### B. Field Testing

Each officer completed an average of 12 eight hour taping sessions (range 9-15) during normal field operations. A total of 247 tapes were collected that included approximately 2,000 hours of recorded heart rate data.

As a preliminary means of identifying physiological responses, a physiological event identifying criterion based on HR alone was established for each officer on the basis of HR recorded during the laboratory baseline testing described earlier in this report. The criterion HR was chosen as the maximum HR achieved during any of the laboratory tests (E, CP, or MA). This initial procedure for identifying events was chosen because the three laboratory stressors were known to create mild to moderate physical or psychological stresses. Physiological event criteria determined in this manner were felt to be very conservative as the hypothesized threat in the field would be expected to represent a much greater stress. For most of the officers the maximum HR (criterion HR) occurred during the bicycle exercise. This finding was of practical importance since it supports the idea that a simple exercise test may be useful in setting individual alarm criteria.

Using the criterion heart rate (CHR) determined for each officer, the tapes were screened for "physiological events." Screening was accomplished by visual estimation of heart rate from the analog ECG R-R interval as displayed on an oscilloscope during the high speed (60 x real-time) playback. The same individual screened all tapes and accuracy was confirmed by periodically repeating the screening of selected tapes. The visual screening procedure was a means of reducing the volume of raw data to a quantity that would be manageable for statistical analysis.



Computer analyses were performed only on data tape segments where heart rate exceeded the CHR. The analyses spanned the period from 10 minutes before to 5 minutes after the segment where the elevated heart rate was observed. Arithmetic manipulations of the HR and SE data for each of the 20 sec intervals comprising the 15 minute span were performed and all recorded and calculated data was printed. In addition, MHR was plotted in histogram fashion. The plotted MHR data provided a graphic display of the acceleration of HR during periods of excitement experienced by the police officers as illustrated by the example in Figure 10.

In Figure 10 mean heart rate is shown for 20 second intervals from 22:35:35 hours to 23:03:20 hours for a police officer involved in quelling a riot at a local night club. It is interesting that the initial increase in heart rate occurred at 22:46:08 when the officer received the radio call regarding this disturbance. The increase in heart rate at this point reflects anticipation of a threatening event. A similar anticipatory physiological response may occur in a hypothetical field situation in which a subject initially perceives the existence of a possible threat rather than immediately recognizing an actual threat. The maximum heart rate during the event in Figure 10 was in excess of 180 bpm which is near the predicted maximum heart rate achievable for a man of the officer's age. The sustained heart rate response in excess of 150 bpm indicates the magnitude of the heart rate response to be expected in a life threatening situation.

The first approach to analysis of the total data base was to identify a "physiological event" as any three consecutive 20 second intervals with MHR above the CHR which were preceded by six consecutive intervals with MHR below CHR. This procedure identified a total of 434 physiological events. This total was higher than the number of life-threatening events expected to be experienced by a group of 22 police officers during the total hours of duty involved. Application of a more stringent event-identifying criterion defined as 1.10 times the CHR reduced the number of events to thirty. Increasing the event-identifying HR to 1.20 times the CHR reduced the number of events to five.

Two other algorithms for identification of physiological events were applied along with the CHR + 10% and CHR + 20% methods to a total of sixteen tapes chosen at random from the total of 247. These 16 tapes were analyzed in their entirety. These algorithms identified physiological

TABLE 2	
NUMBER OF EVENTS DETECTED BY VARIOUS ALGORITHMS (16 Randomly Selected Tapes)	
ALGORITHM	NUMBER OF EVENTS
CHR + 10%	9
CHR + 20%	1
HR > 150 bpm	0
HR ↑ > 30%	4

events as 1) three consecutive segments with MHR in excess of 150 bpm or 2) three consecutive segments where MHR was 30% higher than the mean of the preceding six segments. For the 16 selected tapes the number of physiological events chosen according to all four algorithms (total = 9) are shown in Table 2.

For each of the physiological events identified by the initial screening procedure, the standard error (SE) for each of the 20 second segments comprising the event was tabulated. Percent change in SE was also calculated. The data suggest that increases in HR accompanied by high heart rate variability (as indicated by high SE's) may reflect psychological stress during events lasting longer than a few minutes. However, the data show that HR variability may not be reliable as an alarm criterion in a system which requires response in less than sixty seconds. This is probably due to the more variable stress intensity in the field as compared to the laboratory. Even in the sixty second time frame, however, SE remains a useful tool for rejection of artifact in the HR data.

#### C. Correlation of Field Experiences with Physiological Events

Independent corroboration of physiological events by documented field experiences in a study of this type is difficult for several reasons. First, the availability of corroborative data is dependent on the cooperation of the police officer who may experience such severe demands on his time that his completing the log sheets is precluded. Second, use of dispatcher call cards for this purpose depends on uniform day-to-day availability of accurate



call information. Third, classification of logged events or call card information as threatening or non-threatening must be somewhat arbitrary.

The validity of the relationship of the call data to physiological events is compromised by the differences among the individual officers in the degree of subjective strain experienced as a result of receiving various types of calls. At best, the call cards provide imprecise descriptions of the nature of the event. In an attempt to identify those calls perceived as most stressful by the policemen, six officers were asked to grade all possible calls on a scale of 0 to 3 representing increasing levels of stress. The calls in Table 3 received all "2" and "3" ratings and, on this basis, were identified as most stressful.

TABLE 3

POLICE CALLS CAUSING INCREASED STRAIN

Bomb Threat	Murder or Homicide
Sniper	Rape
Civil Disturbance/Riot	Shooting
Cover Assistance	Stabbing
Officer in Trouble	Fight in Progress with Shots

In order to evaluate the accuracy and sensitivity of the stress/detection system based on heart rate alone, physiological events identified by the CHR were associated with log and call card data. The data show that for all of the events classified as threatening (total=213) a physiological event was identified by the CHR in 68% and not identified by the CHR in 32%. The incidence of "misses" (32%) is explained largely by the problems related to the documentation of threatening situations. Interviews with the police officers indicated that it is likely that the absence of a physiological event at the time of a documented "threatening" event was due to the fact that the event was not truly significantly stressful and reflects the somewhat arbitrary classification of "positive documentation". For all of the non-threatening events occurring during the recording periods (total=1,399) a false alarm would have occurred in 6% of the cases and a correct rejection would have occurred in 94%. For all of the recorded events (total=1,612) the stress detection system made a "correct" decision in 90% of the cases and was incorrect in 10%. For clarity, correlation between

physiological data and recorded events are shown in Table 4.

More objective identification of threatening events (which could only have been accomplished by continuous personal real-time monitoring of the police officer's daily activities by contract personnel) would have reduced the number of "misses" (no alarm in a threatening situation) by reclassifying them as correct rejections. Application of a higher alarm criterion heart rate would have reduced the number of "false alarms" by transferring them to the correct rejection category but would also have reclassified some "correct alarms" as "misses." Our subjective evaluation of the data again suggests that the majority of the reclassified "misses" would be explained by unreliability of the supporting field event data.

As will be seen in the ensuing discussion, application of a higher alarm criterion heart rate (which intuitively seems logical) reduced the alarm situations to a number that does not lend itself well to exhaustive analysis. For this reason data obtained from application of the stricter alarm criteria will be discussed in descriptive terms. Application of the more stringent CHR + 10% and CHR + 20% to the data from the police officers reduced the total number of physiological events to 30 and 5 respectively. One-half of the 30 physiological events identified at the CHR + 10% level were corroborated by a recorded significant event. All of the five identified at the CHR + 20% level were correlated in time with a threatening event.

The physiological events identified on the selected tapes (Table 2) by the four algorithms (CHR + 10%, CHR + 20%, HR > 150 bpm and HR + > 30%) were also analyzed for positive correlation to the serious field events as identified by call card data or the officers' log sheets. For the sixteen selected tapes, only one of the nine physiological events identified in Table 3 was corroborated by available information. Heart rate for that event exceeded the CHR, CHR + 10%, CHR + 20% and also represented a heart rate increase greater than 30%.

Extremely threatening situations were experienced by four instrumented officers during the field testing. These involved the riot call represented in Figure 2 and a gun raid involving three officers. Physiological events were identified during all of these situations using CHR + 20% and HR > 150 bpm standards. The 30% increase in MHR did not identify two of





the events because there was a gradual, rather than an abrupt, increase in heart rate in response to the stress during those two events.

#### IV. CONCLUSIONS AND RECOMMENDATIONS

This study has shown that remote analysis of heart rate has potential as an effective means for automatic detection of stress in guards. The analysis of the data suggests that a heart rate greater than either  $CHR + 20\%$  (as established in the exercise test) or 150 bpm is the best criterion for initial establishment of alarm criteria. This algorithm may be refined greatly through application of more extensive computer analysis.

The potential usefulness of this system is more apparent if one considers that the magnitude of the psychological stress expected to accompany a significant threat to a guard will probably approach that level accompanying the most serious threats experienced by police officers who are relatively adapted to fear-type psychological stress.

While this study has shown the utility of HR analysis for automatic stress detection in policemen, the system still requires optimization for the ultimate goal of chronic usage on a guard population. To attain this refinement, it is felt that further work in this project should encompass at least three major activities.

The first, and most important, requirement for optimization of the system is the development of a more suitable heart rate sensing system than the electrocardiographic approach. Transducing the ECG signal requires that chest electrodes be firmly attached to the subject. In the present study, skin irritation developed in several officers after a few days of electrode application and removal. This was attributed to the very aggressive adhesive used on the electrode. Additionally, the application procedure required several minutes for completion. It is desirable that a system be developed which can be applied very quickly by essentially untrained personnel and can be utilized continuously with no adverse effects. A miniature transducer for heart rate that may be worn comfortably over a long period of time is needed for this purpose.

The second item to be studied and further developed in future work is the alarm algorithm itself. More extensive computer analysis of police and guard personnel data bases should provide a well-defined algorithm which can be used with high confidence.

Third, it is necessary to evaluate the system on a group of guard/security personnel similar (or identical) to the population to which the system will ultimately be applied.



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## APPENDIX A

Name	Age	Sex	Height cm	Weight kg	Shift	VOF	No. years on Force	Exer.	Med. History	
B., R.	27	M	181	81	3	—	4	SL	S: ulcer	
B., R.	41	F	162.5	61.75	2	—	1	SL	Recent surgery	
B., L.	35	M	174.6	80.9	3	—	—	SL	S: arterial disease	
B., M.B.	27	M	194	105.3	3	—	6	3	SL	S: hypertension
C., W.	33	M	183	89	3	—	—	—	SL	Smoker
C., D.D.	27	M	191	84	3	—	2	1	SL	
C., B.H.	25	M	173	64.2	4	—	5	10	RP	S: ulcers
H., S.	29	M	185	97.4	4	—	8	4	RP	
J., J.E.	31	M	175.3	87.1	2	—	—	1	RP	
J., J.M.	35	M	179	80	4	—	—	2	RP	
K., D.	24	M	181	75.5	1	—	4.5	4	RP	
L., J.	29	M	182	83	4	—	—	2	RP	Smoker
L., J.	25	M	174	86.5	3	—	5	3.4	SL	
M., R.J.	31	M	178	114	3	—	10.5	—	SL	S: Kidney disease
O., M.	30	M	178	71	3	—	9	8	RP	
R., R.A.	37	M	177	88.5	2	—	—	—	SL	S: angina
H., R.B.	32	M	170	77	3	—	3	4	RP	
S., R.	31	M	179	65.8	4	—	—	—	RP	
S., R.	26	M	176	76	1	—	6	2	SL	Smoker
S., P.J.	31	M	181	87.3	3	—	8	1	RP	S: Heart Murmur
W., K.	25	F	158	45	3	—	—	—	SL	Smoker
W., G.	32	M	185.6	88.6	3	—	—	1.2	SL	Smoker

### CODE:

Shift: 1 - night (11/7)

2 - day (7/3)

3 - evening (3/11)

4 - special operations

### Exercise:

RP - Regular Pro: m

SL - Seldom

### Misc:

S - Smoker

VOF - Years on Force

## APPENDIX B

### Instruction - Cold Pressor Test

The test which is about to be administered is called the Cold Pressor Test. This is a very simple test which has routinely been used for many years in psychophysiological research.

A container of very cold water has been placed next to your right foot. When you are signalled to do so, you should immediately raise your foot and completely immerse it in the container of cold water. You must keep your foot in the water for a full one minute before removing it.



In a few minutes, the red light on the table will be turned on. This is your signal to immediately put your foot into the water. Put your foot all the way to the bottom. The light will remain on for one minute. When the light goes off, you may remove your foot from the water. During the time when your foot is in the water, do not move any more than absolutely necessary. After removing your foot from the water, continue to keep motion to a minimum. Do not attempt to dry your foot. We will enter the room shortly and do this for you.

During the next several minutes we will be calibrating our instruments. You will not receive any further instructions before the test. So for the next few minutes, relax as much as possible and watch for the red light. When it appears, put your foot in the water and rest it on the bottom and keep it there until the light goes out.

#### STOP (10 SECONDS)

We will now repeat the Cold Pressor Test. This will be the second and final administration of this test. In a few minutes, the red light will be turned on. As before you should then put your foot fully into the water and keep it there until the light goes out.

#### APPENDIX C

##### Instructions Mental Arithmetic Test

##### Psychological Test - Written Instructions

You are about to receive a group of psychological tests. The tests have been designed to be mentally stressful. Each test will be fully explained by this recording. You should listen carefully and follow the directions exactly. If at any time you do not understand a particular instruction, raise your hand for assistance.

The instruments before you are a metronome, a red signal light and a microphone. Later in the test the metronome will be started and the white light on it will begin to flash. The red signal light is controlled from outside the room and can be turned on as it is now. The purpose of the metronome and signal light will be explained later. The microphone is connected both to your headphones and a speaker outside the room.

Several sensors and electrodes have been placed on your body. These will allow us to monitor your responses during the

stress tests. The two electrodes on your left hand are for a different purpose, however. These electrodes will be used to deliver an electric shock. An electric shock device is located outside the room and is attached with wires to the hand electrodes. The intensity of the shock has been preset to a very high level. The purpose of the electric shock will be explained later. You will not receive any shocks until the end of the test period.

For the next few minutes we will be making final adjustments. During this time you should relax as much as possible. Until further instructions are given, please sit quietly and rest. The microphone will not be turned on until later in the test.

##### Final Instructions

The test will now continue.

During this test you will be counting aloud into the microphone. You will hear your voice in the head phones.

When you start counting, start with the number 300 and begin counting downward by threes, that is 300, 297, 294 and so on. Do not shorten the number by saying "two-ninety-seven, two-ninety-four", and so on. This will be counted as a mistake. Say "two hundred ninety-seven, two hundred ninety-four, two hundred ninety-one", and so forth. Say one number each time the metronome light flashes. It is important that you keep pace with the metronome.

You should be aware that your voice, which you hear in the headphones, will be electronically delayed by a slight amount. For this reason, counting may be somewhat difficult. Each time you count incorrectly or do not pronounce the number smoothly, the red light will flash. These mistakes will be counted and totalled. One minute after you stop counting, you will begin to receive very strong shocks. You will receive one shock for each mistake. The shocks will begin one minute after you stop counting and will be spaced 5 seconds apart.

The test will begin after this recording ends. You should start counting when you see the red light blink. This will occur about 5 seconds after the recording ends. Put your mouth close to the microphone and speak very clearly. Continue counting until the microphone is disconnected and you cannot hear your voice.



Remember, when the red light blinks, start subtracting threes from 300, speaking one number each time the metronome beats. If you do not keep step with the metronome, this will also be counted as a mistake.

#### APPENDIX D

##### Protocols - Cold Pressor, Mental Arithmetic and Exercise Tests

###### Cold Pressor Protocol

Elapsed Time	Event
0:00	Begin baseline recording
3:00	Start recorded instruction
6:00	Immerse foot in ice water
7:00	Remove foot from ice water
8:00	Operator enter room with warm water, dry foot
11:00	Start recorded instructions
12:00	Immerse foot
13:00	Remove foot
14:00	End of test

###### Mental Arithmetic Protocol

Elapsed Time	Event
0:00	Start baseline recording
3:00	Start recorded instructions
8:00	Noise startle (3 seconds)
10:00	Resume recorded instructions
12:00 (±)	Counting begins
14:00	Counting stops
16:00	End of test

###### Exercise Protocol

Elapsed Time	Event
0:00	Begin baseline recording
3:00	Start exercise
6:00	Stop exercise
11:00	Start exercise
14:00	Stop exercise
16:00	End of test

#### APPENDIX E

##### Questionnaire Times and Subjective Evaluations Of Events During Each Recording Session

NAME \_\_\_\_\_

DATE \_\_\_\_\_

Time of Event or Call \_\_\_\_\_

Time Left Scene \_\_\_\_\_

Type of Event (give police code) \_\_\_\_\_

Enroute to or upon first arrival at the scene of the event, to what extent did you feel personally in danger?

Not at all \_\_\_\_\_  
Somewhat \_\_\_\_\_  
Very much \_\_\_\_\_

During the event, to what extent did you feel personally in danger?

Not at all \_\_\_\_\_  
Somewhat \_\_\_\_\_  
Very much \_\_\_\_\_

Were you physically threatened in any way (with weapon, assault)?

No \_\_\_\_\_  
Yes \_\_\_\_\_

Were you physically active (running, climbing stairs)?

No \_\_\_\_\_  
Yes \_\_\_\_\_

#### APPENDIX F

##### Police Dispatcher Radio Code Signals

###### Radio Code Signals

10-1	Receiving Poorly
10-2	Receiving Well
10-3	Stop Transmitting
10-4	OK or Message Received and Understood
10-5	Relay Message
10-6	Busy, But Available For Calls
10-7	Out of Service on a Call
10-8	In Service Available for Calls
10-9	Repeat Transmission
10-10	General Administrative Assignment
10-11	Animal Call, Disturbance or Injury
10-12	Check Driver License Revocation List
10-13	Advise Weather and Road Conditions
10-14	Escort
10-15	Family Fight
10-16	Prisoner in Custody or Pick up at
10-17	Pick up Papers or Items at
10-18	Drunk Person
10-19	Return to Station
10-20	Location or What Is Your Location?





10-21 Call By Telephone  
 10-22 Request for Blood Alcohol Technician  
 10-23 Sex Offense, Exposure or Molesting  
 10-24 Direct Traffic  
 10-25 Do you have Contact with or Contact  
 10-26 Request Auto Registration from MVD  
 10-27 Investigation of:  
 10-27-1 Murder or Other Homicide  
 10-27-2 Rape  
 10-27-3 Robbery, Armed or Unarmed  
 10-27-4 Aggravated Assault or Battery  
 10-27-5 Burglary  
 10-27-6 Theft, Fraud, Embezzlement  
 10-27-7 Auto Theft  
 10-27-8 Shooting  
 10-27-9 Stabbing  
 10-27-10 Forgery or Bogus Check or Credit Card  
 10-28 Missing Person  
 10-29 Check for Wanted or Broadcast Wanted  
 10-30 Juvenile Call  
 10-31 Suspicious Person(s) or Cars  
 10-32 Fight in Progress  
 10-33 Fire Call-Direct Traffic at the Scene  
 10-34 Officer or Meet Officer  
 10-35 Prowler or Peeper  
 10-36 Correct Time  
 10-37 Shoplifter Complaint  
 10-38 Vandalism  
 10-39 Disturbance or Disorderly Person(s)  
 10-40 Mental Patient  
 10-41 Neighbor Trouble  
 10-42 Request Case Number and Times  
 10-43 Rescue Call or Request for Rescue  
 10-44 Traffic Accident no Injuries  
 10-45 Traffic Accident Injuries  
 10-46 Wrecker Requested  
 10-47 Drunk Driver  
 10-48 Use Caution  
 10-49 Any Traffic?  
 10-50 No Traffic  
 10-51 Message for Delivery  
 10-52 Message for Delivery  
 10-53 Silent Alarm  
 10-54 Have Car Stopped or Will Be Stopping Car  
 10-55 Ambulance Call or Request for One  
 10-56 Have Arrived at Scene  
 10-57 Narcotics  
 10-58 DOA or Suicide  
 10-59 Bomb Threat  
 10-60 Coffee Break

10-61 Lunch Break  
 10-65 Kidnapping, Abduction, Hostage  
 10-69 Sniper  
 10-80 Demonstration  
 10-81 Civil Disturbance or Riot Call  
 10-82 Cover Assistance  
 10-83 Officer in Trouble



**- END -**

**DATE FILMED**

**04/01/80**

