NASA CONTRACTOR REPORT

NASA CR-1122

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SYSTEM AND PROCESS DEVELOPMENT FOR SELECTION OF HIGH STRESS TOLERANCE PERSONNEL

by Albert F. Ax

Prepared by
LAFAYETTE CLINIC
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for Ames Research Center

NATIONAL AERONAUTICS AND SPACE ADMINISTRATION • WASHINGTON, D. C. • SEPTEMBER 1968

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Prepared under Contract No. NAS 2-1031 by
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NATIONAL AERONAUTICS AND SPACE ADMINISTRATION

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ABSTRACT

A system has been developed for digital computer processing of psychophysiological data. It employs oscilloscope and oscillograph display, analog magnetic tape storage, A/D conversion, digital tape storage and a large digital computer (IBM 7094). The computing programs developed select all points of interest and compute their type, time of occurence, amplitude and curvature. A summary program computes the mean and standard deviation for the response parameters of amplitude, slope, curvature, duration and interval for any set of epochs selected by the editor. A third program selects pairs of points from any sets of variables on the basis of minimizing the variance in lag for the set. The coincidence coefficient and product moment correlations are computed for any set of response parameters of paired points chosen by the editor. These correlations do not confound coincidence, amplitude and shape of responses as does the classical cross-correlation function and are therefore more suitable for the study of the interdependence of biological subsystems.

Two substantive studies have been completed. The classical conditioning of autonomic responses in schizophrenia and healthy subjects demonstrated a marked impairment in the performance of autonomic conditioning by schizophrenic patients. A pilot study of non-schizophrenic low motivation subjects revealed a disability for autonomic conditioning similar to that found in chronic schizophrenia. These findings suggest that autonomic conditioning may serve as an index for the diagnosis of both schizophrenia and low motivation and permit the speculation that a low aptitude for autonomic learning may be a contributing factor to both schizophrenia and low social motivation. Finally a study of physiological concomitants of psychological differentiation suggests that the

degree of autonomic response differentiation may be correlated with the cognitive style of perceptual discrimination.

It was concluded that these successful demonstrations of the diagnostic power of psychophysiological data and those of digital computer analysis justify further study and development of this approach.

These studies are of value to NASA and the science of human motivation and emotional development by virtue of progressing toward more accurate selection and rapid training of personnel for high stress tasks.

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SYSTEM AND PROCESS DEVELOPMENT FOR SELECTION OF

HIGH STRESS TOLERANCE PERSONNEL

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I. Purposes of the Study.

The primary purposes of this study were to develop a system for processing psychophysiological data and to apply it to the task of developing indices for the diagnosis of human tolerance for stress. It was recognized that aptitudes for learning motives and emotional control were primary components of stress tolerance. In order to contain the scope of the investigation within practicable limits imposed by our resources only the psychophysiological aspects of motivation and learning were considered.

The context of the study has two salient features. The psychophysiology laboratory at The Lafayette Clinic had just completed the development of a processing system for psychophysiological data utilizing and EPSCO data logger consisting of a 29 channel multiplexor and a 10 Kc A/D converter and a Bendix G15-D computer with special programs developed for the purpose. That study demonstrated the approach to be feasible but relatively impracticable because of the limitations in capacity and speed of the computer. The other favorable aspect of the situation was that the state-of-the-art of the psychophysiological methodology was just approaching the level to justify major effort toward massive data processing. Biomedical monitoring was being used with pilots, astronauts and in hospitals. Active research was under way in several score laboratories supported by federal agencies, private industry and at medical schools and hospitals. The Society for Psychophysiological Research had been organized two years previously (1960) and the journal PSYCHOPHYSIOLOGY was being established. Psychophysiology thus appeared to be mature enough for marriage to a high speed data processing system.

Psychophysiology is one of the approaches which seeks to explain the physiology of behavior. It focuses on covert behavior available for measurement at the skin surface. It utilizes electrodes and sensitive transducers to sense physiological processes in target organs of the autonomic and central nervous systems and of the endocrine systems. Its special advantages are: (1) that its methods can obtain quantitative, continuous measurements of vital processes whose changes are often too small or fleeting to observe clinically: (2) the measurements can be made without seriously disturbing the processes being observed by intrusions such as implanted electrodes; and (3) the data obtained are already organized in terms of the target organs.

Psychophysiology has its special problems to overcome. (1) Each target organ response may be an end product of several influences, hence may not be a pure measure of any one. (2) This complexity of determination requires the simultaneous measurement of several variables so as to "triangulate" on the processes of interest. (3) The multiple variable approach necessitates complex recording and data processing equipment.

The study of intact systems without subsystem isolation (often referred to as "closed loop analysis") is sometimes criticized as unproductive for the study of the human organism because the system is so large and complex, the transfer functions so poorly described and the number of available variables so small relative to the complexity of the system that the correct interpretation of findings may be impossible. In a sense the description and prediction of human behavior is like describing and predicting the weather--both are large, complex, open, dynamic systems requiring multiple variable, closed loop analysis. More accurate prediction for both require more variables, more observation points and more sophisticated data processing than has so far been possible.

During the past 20 years large scale computers have been applied to weather prediction enabling marked advances in accuracy. We believe similar progress can be made for limited areas of human behavior such as stress tolerance, motivation and emotional control.

The analogy between weather and behavior should not be pushed too far. There are many obvious differences. One important difference is that weather is determined largely by energy transfer whereas behavior is controlled chiefly by the transfer of information. Hence the principles of information theory rather than energy transfer functions are more appropriate for the study of behavior of living organisms. Signal recognition and signal production with multiple level feedback interactions are characteristic of living organisms. For this reason the experimental design and the data processing must be appropriate to signal manipulation which involve sensory thresholds, adaptation or learning, reinforcement or motivation, differentiation and generalization. We have discussed this psychophysiological position in more detail elsewhere (Ax, 1964). An appreciation of this viewpoint is helpful for the reader to understand certain features of the experimental design, the data processing, hardware and the computer programs, as well as our interpretation of the results.

One limitation which psychophysiology shares with all science (except possibly astronomy) is the "general principle of uncertainty" used in the sense that our observations influence the phenomena under observation. The attempt to measure simultaneously as many variables as possible, to control the local environment and to standardize all procedures and instructions to subjects, etc. may influence the subject's behavior, especially his natural emotions, to such an extent that every effort to increase these laudable scientific controls is defeated by a "law of diminishing return". Good psychophysiologic technique strives to minimize the influence of the observation procedures by employing miniature non-painful sensors and by creating a test situation as natural as possible. The use of telemetry to replace the umbilical linkage is one further step that is being taken to enable psychophysiological observation on the free roaming individual while pursuing his natural activities. This next step in psychophysiological methodology adds a severe burden to the data processing. Much more noise is introduced due to movement artifacts and uncontrolled environmental influences as well as the degradation of the signal by the radio linkage. The problems of noise elimination and pattern recognition problems for machine editing has been discussed previously (Ax, Andreski, Courter, DiGiovanni, Herman, Lucas, and Orrick, 1964)and later in this report. Recording may be carried out over days or weeks which strains both the sensor reliability and the capacity of the data processing system. Sampling rates and programming must be carefully planned to minimize the computing time and cost while at the same time maximizing information obtained. Only just sufficient redundancy of sampling to achieve reliability can be tolerated.

One final general aspect of the psychophysiological approach should be mentioned before plunging into the details of the study. Psychophysiology has certain characteristics, advantages and disadvantages as compared to the classical physiological methods. The chief advantage is its ability to obtain information about physiological system status and process without damage or discomfort to the organism. A second advantage is the organization of the response system provided by the end organs. The vasoconstriction response at a finger tip is often much easier to interpret as a functional response relevant to the organismic intentions than is the neuronal response train from an electrode implanted deep in the brain. Similarly, the current activities of the brain may more readily and understandably be described by a pattern of end organ responses such as arterial tonus, muscle tonus, heart rate, heart stroke force, blood pressures and palmar sweating than it can from the EEGs from 32 electrodes scattered about on the scalp. The "face validity" of the EEG as a prime psychophysiological measure for brain activity has often been overvalued due to its success in helping to locate a gross physical damage of the brain. Actually the neurological examination (a clinical type of psychophysiological examination) is often more definitive for brain malfunction. Many psychophysiological variables other than EEG are excellent indices of arousal or motivational state. EEG is one useful physiological measure but has little special value simply because its sensors are located physically closest to brain tissue. A. T.V. repairman does not diagnose a malfunction by scanning the electric field strength over the cabinet of the T.V.; rather he measures potentials and currents in logically critical circuit points. The sensor and effector organs of the body are logical points for the organism. No criticism is implied of the excellent studies of brain structure and functions by direct examination of brain tissue by neurophysiologial methods. It is emphasized that total organismic processes such as emotion, motivation and "stress tolerance" are much more likely to be monitorable by patterns of end organ responses than by scalp EEG.

II. METHODS

A. Data Acquisition System.

Research employing continuous recording of multiple variables requires high speed computing for two reasons: (1) to transcribe the necessarily large numbers of samples into digital values and (2) to compute the multiple interactions among the variables involved. The transcription aspect for a single one hour session for only 10 physiological variables (not including EEG) may require as many as 36,000 samples to describe the variables. An average study of 5 sessions per subject and 100 subjects would produce 18,000,000 values; and many studies might require more variables, more recording per subject, or faster changing variables (such as EEG) which would greatly increase the amount of data to be transcribed and summarized. The computing aspect merely for means, variances, t-tests, and correlations among the parameters that can be abstracted from a set of 10 physiological variables is quite a large task without the aid of a digital computer. When more sophisticated statistics such as factor analysis and multiple regression are employed the computing multiplies many fold. Any method of processing such data less powerful than the digital computer is impracticable for large scale studies required for exploitation of the psychosychophysiologic approach.

A brief preview of some of the problems encountered in developing a high speed system for processing psychophysiologic data may be of interest. Analog computing was considered and rejected as impracticable because an analog computer sufficiently large to handle all variables simultaneously in real time would be too costly. Analysis of single variables or pairs for correlation from magnetic tape storage by a medium-sized analog computer would probably be practicable but still probably slower and require a more costly installation although this approach might have been competitive to the digital system. A further reason for going digital is that automatic computing by the stored program digital computer is very efficient and flexible.

Once the specific digital computer to be used had been identified (for us an IBM 7094), then all design characteristics had to be made compatible with it. The digital tape recorder must meet 7094 specs; the AD converter must produce the specified format, packing density, parity bit, and other specifications. The ADC must have sufficient resolution which for us was 12 bits (1 part in 4096) to cover any range expected. For example if the palmar skin resistance has a range from 30,000 to 1,000,000 ohms and if a GSR as small as 200 ohms change is to be resolved the full dynamic range of 12 bits is needed. The multiplexor must be able to sample at a rate sufficient to sample all variables sufficiently fast to resolve the most rapid changes to be encountered. We judged that 10 samples per minimum expected period would be adequate. For a selection of 30 variables of varying rates of change we chose 160 samples per second real time for all 30 variables (10 at 10 per second, 10 at 5 per second and 10 at 1 per second). A multiplexor with 30 inputs was chosen with an eye to expansion but experience has shown that other difficulties and limitations make it unlikely that more than 10 to 15 variables can be handled, unless groups of subjects are studied simultaneously.

On-line analog preprocessing of most variables in various degrees is required. Nearly all variables require some filtering. Some variables like EKG for our purposes of obtaining heart rate require a cardiotachometer to detect the time of the QRS complex and convert the time between adjacent

QRS complexes into a voltage to be presented to the ADC. The step change, square wave aspect of cardiotachometer data makes it difficult to use. Most sample-and-hold circuits drift slightly and in opposite directions depending on whether the value is above or below zero potential; thus the high or low point to be picked by the computer might be either at the beginning or end of the heart cycle and thus make ambiguous the time of the point. The solution to this problem appears to be to produce a pulse at the time of the QRS whose amplitude represents the duration of the last HP and whose duration is greater than one ADC sample period but less than two, thus assuring a sample as early as possible after the information is available but none at any other time. Between readings the cardiotachometer would assume a value off scale enabling the computer to readily ignore those valueless samples.

Other problems that must be handled for automatic data processing involve solutions to the noise or artifact problem and precise calibration through the entire system from transducer to computer. Filtering and human editing (described in detail in the software section) take care of the artifact problem. Automatic editing seen as a problem of computer pattern recognition is considered a research and development problem. Practicable total system calibration requires excellent stability of component systems both as to gain and base line. A practicable system must be able to be quickly checked and adjusted by the operator and not require an engineer. Finally short term instability should be self checking possibly by supplying frequent calibration signals to the computer which could then modify the output conversion values so as to make them correct.

1. Overview.

The block diagram of Figure 1 shows the plan of the system.

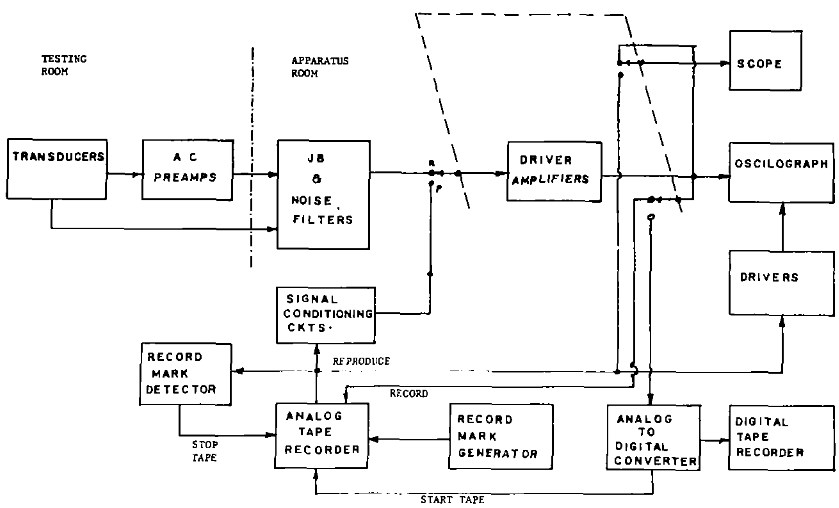


Figure 1

The sensors on the subject and the preamplifiers are in the observation room. The rest of the apparatus is in the adjacent instrument room. During a recording session, the amplified signals are displayed on an 8-channel oscilloscope and recorded on a 24-channel oscillograph and on a 14-channel FM magnetic tape recorder. For computer analysis at a later time, the signals are reproduced from the tape recorder, modified by signal conditioning circuitry, re-recorded on the oscillograph, sampled and digitized by the 29-channel analog-to-digital converter (ADC) and recorded on a digital magnetic tape in IBM 7094 format.

2. Observation Situation.

The subject room is 12x14x8 feet, accoustically insulated and temperature controlled to 25.5 $\pm$ 0.2 C. Humidity is uncontrolled but is recorded as are the outside environmental conditions of temperature, humidity, and barometric pressure. Two one-way observation ports and complete intercom with audio magnetic tape recording are provided. The subject enters directly from a corridor (not through apparatus room) and reclines on the ballistocardiograph bed. Sensors are applied and plugged into jack panels on either side at the head of the bed. Preamplifiers are near the subject for EMG, EEG, EKG, finger pulse and body movement.

3. Sensors.

(a) Electrodes.

Variables sensed by electrodes are the electrocardiogram (EKG), electroencephalogram (EEG), electromyogram (EMG), impedance plethysmogram (IPG), skin potential (SP), and skin conductance (SC). Other electrodes are used for grounding the subject and for applying electrical stimulation.

(b) Transducers.

These are used for sensing skin temperatures (ST), chest and abdominal circumference to measure respiration (CR & AR), the ballistocardiogram (BCG), finger pulse (FP), body movements (BM), and blood pressures (SBP, DBP).

4. Display and Recording.

All signals, except muscle potentials, after preamplification associated with their transducers are filtered and amplified by Offner type 492 DC amplifiers. The signal is then split into three: one branch goes to the 17", 8-channel oscilloscope and is recorded on an oscillograph (24-channel, model 1108 Honeywell) and the third branch goes to the analog magnetic tape recorder (Ampex model CP 100, 14-channel FM). Several signals may be multipexed on the oscilloscope and tape recorder so as to accommodate them all.

During the recording phase, a 1-per-second timing pulse (of 300 CPS for a period of 50 MS) is recorded on the face temperature channel. An electronic counter causes every tenth signal to actuate a marker channel of the oscillograph.

5. Identification Mark for Analog Tape.

Since several experimental sessions may be recorded on one roll of magnetic tape, a system is required for marking and locating the beginning of specified records. This record start mark is recorded on the tape and also displayed on the oscillograph chart, so that precise synchronization can be achieved between the record made during recording and the one made during reproduce which is used for editing. The record mark is a decimal number coded in binary by two voltage levels on each of the 14 channels of the analog tape. Its maximum value is 3999. Each recording session is given a sequential identification number (ID). A particular record may be located on a reel of analog magnetic tape by setting the decimal controls at the desired ID number. The ID numbers are displayed on Nixie tubes as they are passed and the tape stops on the preset ID number. By adding an additional unit any point within a record could be located to the nearest second. We have not found any need for this feature, hence, it has not been added, in line with our general philosophy of keeping the apparatus as simple as possible consistent with required performance.

B. Data Processing System.

1. Signal Conditioning.

Since the ADC sampling switch requires either a synchronized signal or the continuous presence of the signal, the discontinuous asynchronous pulse variables such as EKG, plethysmogram and BCG require transformation before conversion. The EKG is used to generate the heart period (HP), the peripheral pulse amplitude of the finger plethysmogram (FP) is detected by a peak reading hold circuit, and for BCG the IJ wave is measured and held until the next EKG opens the gate for the next BCG signal. The EMG and body movements are integrated, sampled and held. EEG may be analyzed directly in the high-speed mode or it may be divided into several frequency bands and each band displayed as a continuous voltage equivalent to the smoothed average power or voltage of the signal within the band. Any period of EEG record can be analyzed in the high-speed mode of the regular "Points of Interest" program described in the section on software. Since, however, this type of micro-analysis can be quite costly, the more economical, though less detailed method of abstracting the average voltage or power from several broad bands is more practicable.

The DC or slowly changing variables such as temperatures, respiration, palmar conductance and skin potential are reproduced from the analog tape and sent to the ADC essentially unchanged except for amplification and filtering.

The signal conditioning circuitry is the stage where automatic editing for artifacts will be done. At present only filtering, gating by EKG for BCG and PP and the simple pattern recognition of the IJ portion of the BCG are used. More sophisticated pattern recognition circuits are being designed to better distinguish between clean signals and artifacts. Most artifacts caused by subject movements are now removed by the human editor as described in b, (4) of the software section.

2. Digital Magnetic Tape Formats and Sampling Rates.

Economy in digital computation requires the minimum sampling rates consistent with the type of information desired for each variable. It was decided that a sampling rate of 10 samples per minimum interval of variable would provide sufficiently detailed information for our purposes.

Thus if maximum respiration rate were 1 per second, 10 samples per second would enable sufficiently accurate location and amplitude determinations required for computing respiration period and an index of tidal volume. Similary the heart period can change from a maximum of about 2.0 seconds to a minimum of about .33 seconds (30 to 180 beats per minute) in not less than 1/3 second. A sampling rate of 3 SPS would suffice; but because of our desire to correlate the coincidence of changes as well as amplitude changes of heart and respiration periodicity, it was decided to sample the cardiac variables also at 10 SPS so as to make the time of corresponding points on correlated variables equally precise. The slow-changing variables like temperature and those integrated for a definite time of 1 second are sampled 1 SPS. A sampling rate of 5 SPS was chosen for skin potential. In order to provide for the future addition of variables, the ADC sampling switch was designed to provide 10 variables at 10 SPS, 10 at 5 SPS and 10 at 1 SPS including a nonsampled time code generated at 1 SPS. Together these total 160 SPS in real time or 1280 SPS in the reproduce mode as actually used (8:1 speedup). Because of the inherent high-speed sampling and conversion capability of the solid state converter, and an expectation that higher frequency variables such as EEG might sometime be analyzed, a high-speed mode of 6400 SPS is also available. Thus for the high-speed mode there are 10 channels each at 400 SPS, 10 at 200 SPS and 10 at 40 SPS. When this mode is used, the analog record and playback is 1:1 and the digital tape operates at 25"/sec producing the same bit density of 512/inch used for the low-speed mode in which the tape speed is 5"/sec.

a. Density and Sampling Rate.

The raw data is recorded on a digital tape for input to a 7094. The tape is recorded at 512 bits/inch in binary (odd parity) mode. The data is recorded in long physical records with the data samples packed and interlaced. The present system accommodates 30 channels of data sampled at 3 different frequencies.

Channels 1 - 10	Sampled 10 times/second.
Channels 11 - 20	Sampled 5 times/second.
Channels 21 - 30	Sampled 1 time/second.

Channel 30 contains a time code generated by an internal clock in the ADC rather than data.

b. Tape Layout.

Each physical reel consists of 1 or more recording sessions of up to 1.14 hours each. Each session is preceded by a short identification record. The ID record consists of a 12-octal digit ID number repeated 8 times. This ID number is generated by a set of 12 octal switches on the ADC which are manually set.

The 8-word ID record is followed by one or more data records. Each data record consists of 6720 36-bit words representing 126 seconds of real time data. Following the data record is a 1 1/4" interrecord gap. The gap is generated by stopping the ADC without stopping the tape and represents a loss of 2 seconds worth of data out of each 128 seconds of real time.

The last physical record in the session is followed by an end of file mark. The last end of file mark on the reel is followed by an ID block with an ID number of all sevens, (777777777777).

c. Data Sample Packing and Interlace.

Each data sample consists of 12 bits, 11 bits plus a sign bit, thus each sample is a number limited 2048 > sample > -2048. Samples are packed 3 per computer word. Sampling of data channels proceeds in "frames" of 1 second each, the pattern being repeated once per second. A tape record is 126 frames or 6720 words long. Each frame is sampled as follows:

1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
1	2	3	4	5	6	7	8	9	10	17	18	19	20	21	22
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
1	2	3	4	5	6	7	8	9	10	17	18	19	20	23	24
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
1	2	3	4	5	6	7	8	9	10	17	18	19	20	25	26
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
1	2	3	4	5	6	7	8	9	10	17	18	19	20	27	28
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
1	2	3	4	5	6	7	8	9	10	17	18	19	20	29	30

Sampling procedes from left to right. When read into the computer starting in location 1 the following pattern results:

		Samples in Bit Positions	
Word	S-11	12-23	24-35
00001	1	2	3
00002	4	5	6
00003	7	8	9
00004	10	11	12
00005	13	14	15
00006	16	1	2
00007	3	4	5

etc.

4. Time Codes.

The time codes generated by the A/D converter and written on the tape as data samples for channel 30 are slightly different from ordinary samples in that they are unsigned 12-bit intergers. The clock counts in 1-second intervals from 0 to 4095 and counts modulo 4096.

The first time code on the tape in a session is 3, the last time code in the first physical record is 128. The interrecord gap represents two seconds, i.e., 129 & 130, thus the first time code in the second physical record will be 131.

5. Variations From Standard IBM Tape Format.

Tapes produced by the ADC while entirely compatible with IBM

729 Model IV or 729 Model VI tape drives have, none the less, certain variations from standard IBM formats.

(a) Density - Tapes are recorded at 512 rather than 556 bits/inch.

(b) Interrecord gaps - Interrecord gaps between data records are 1 1/4" rather than 3/4". The gap after the 8-word ID block is approximately 79". (The ADC produces only 6720 word records. Even though the ID block is only 8 words long, it writes enough blank tape to make a 6720-word record).

3. Software.

a. Overview.

This section deals with the computer programs*. The programs as described are operational at the General Motors Technical Center computing laboratory. Since, however, their monitor system is unique, the programs as now written cannot be run directly on other 7094 installations. Mr. Singer and Mr. Stahlke in collaboration with the personnel at the NASA Ames Computing Center modified the programs so they can be run at NASA Ames Research Center. To run the programs at other computing centers would usually involve still other modifications as required by each local installation. If the programs were to be applied to different data tape formats, modification of the input routines would be required. The cards and listings for the operational programs may be obtained from The Lafayette Clinic, attention A. F. Ax.

The programs were designed to automate the analysis of physiological

* Programming was done chiefly by Samuel Singer with the help of Rudy Stahlke, Barbara Levin, Robert Hirschfeld, and James Licholat.

data by the use of a high-speed digital computer. A very large amount of data can be accumulated in a very short time in biological experiments in which many variables are studied simultaneously. The data acquisition system for which these programs were designed produces about a half million data samples per hour. Clearly this amount of data must be reduced to something more manageable by extracting only the most significant information, and perhaps equally important, it must be done at a reasonable cost.

With a problem of this magnitude it is important that the system as a whole be fast and efficient, yet it must be flexible to the greatest degree so that a variety of problems can be solved. Data storage was designed with minimum storage space and maximum speed of data retrieval in mind. Where compromises between speed and complexity were necessary, they were generally made on the side of greater speed.

The sections that follow describe the programs in some detail and also the logic involved in the choice of these particular solutions.

b. Points of Interest Program.

(1) The Response Concept.

The data analysis is based on the concept of biologic response (Ax, 1958; Ax, Singer and Zacharopoulos, 1962; Ax, Singer, Zachary, Gudobba, and Gottlieb, 1964), which may be defined for any variable as a significant change in amplitude within a specified time limit. The question which must next be answered is, what is a "significant" change? Since there is a certain amount of "noise" inherent in any system, the amplitude of change must at least exceed the noise level and since there is a certain amount of homeostatic drift in amplitude with time, we may realistically say the significant change in amplitude must occur within a certain time limit. The response is therefore defined in terms of two tolerances, an amplitude tolerance and a time or duration tolerance. A slope could not be used for the tolerance since noise may have high slopes. A response is an amplitude change that occurs within a duration tolerance and exceeds an amplitude tolerance.

A response may be either an increase in amplitude, a rise, or a decrease in amplitude, a fall . It begins when the variable changes amplitude by more than an amplitude tolerance within the period of one duration tolerance and ends when the variable no longer changes amplitude by more than an amplitude tolerance within the period of one duration tolerance. Since one response may immediately follow another, we must also say that a response ends when it changes direction.

(2) Points of Interest.

Responses are identified by their end points which are called Points of Interest (PI). The points are named according to the response they delimit. Examples (Figure 2) are Begin Rise (BR),

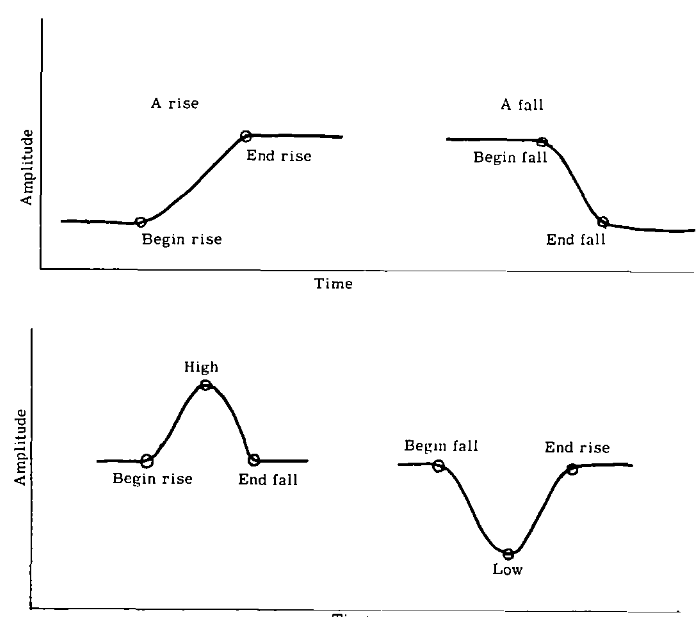


Figure 2

End Rise (ER), Begin Fall (BF) and End Fall (EF). The figures illustrate examples and Table 1 lists all points and their abbreviations.

Types of Points	Abbr.	Comment
Begin Rise	BR	CURV Computed
End Rise	ER	CURV Computed
Begin Fall	BF	CURV Computed
End Fall	EF	CURV Computed
High	HI	CURV Computed
Low	LO	CURV Computed
Drift High	DH	No CURV Computed
Drift Low	DL	No CURV Computed
Begin Epoch	BEP	No CURV Computed
End Epoch	EEP	No CURV Computed
Begin Edit	BE	No CURV Computed
End Edit	EE	No CURV Computed
Begin Short Edit	BSE	No CURV Computed
End Short Edit	ESE	No CURV Computed

Table 1

For the case in which one response does not immediately follow another, the portion of curve between two responses is known as a drift; and if the drift is of less than two time tolerances in duration, it is called a plateau. Examples of these cases are shown in Figure 3.

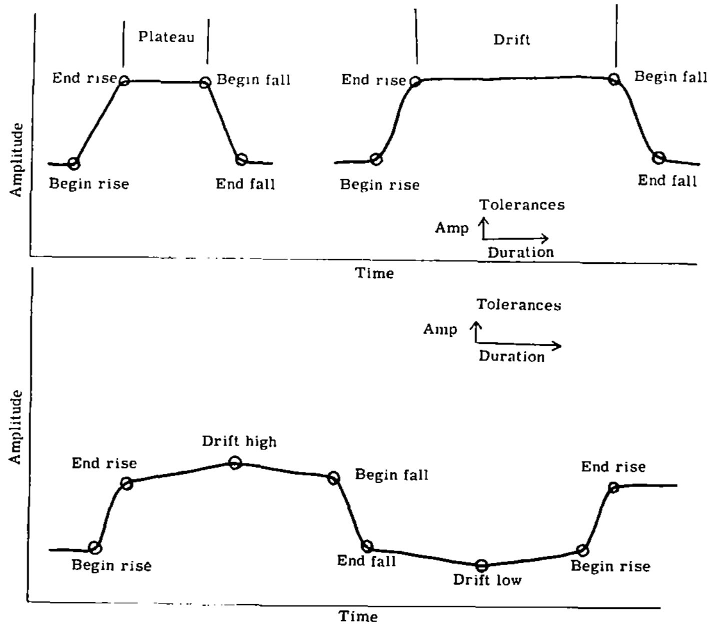


Figure 3

A drift may be of any duration. If during a drift the amplitude exceeds both end points by an amplitude tolerance, the extreme is identified as a Drift High (DH) or Drift Low (DL). A cumulative response consists of two or more discrete responses separated by plateaus (see Figure 4), but not by drifts.

The amplitude of a cumulative response is measured from the first begin rise to the last end rise.

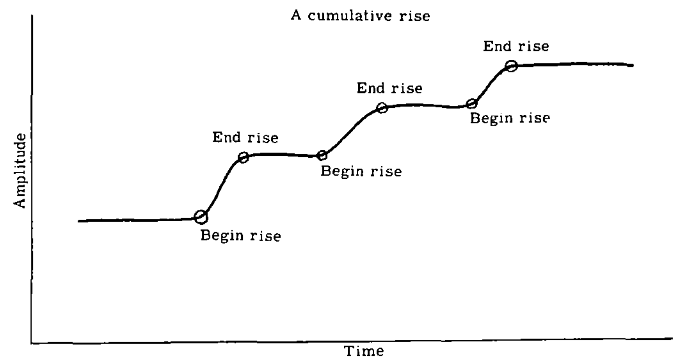


Figure 4

Data are generally recorded within a certain experimental design. The recording period is divided into one or more experimental epochs. It is usually desirable to identify the limits of an experimental epoch. This is done with special points of interest called Epoch Points (EP). These may or may not coincide with one or the other points of interest.

The points of interest are written on magnetic tape ordered by variable number in ascending time sequence. Each P.I. consists of (1) variable number, (2) amplitude, (3) time, (4) type (Hi, Lo, ER, etc.) and (5) curvature. These 5 values for each P.I. are packed into two words on the P.I. tape.

(3) Curvature.

We have now arrived at a set of parameters called Points of Interest which describe a curve. They have the virtue of being easy to obtain rapidly and of describing many important features of the data concisely. One disadvantage of the Points of Interest is that they describe responses (our primary interest) only at their ends and say nothing about what happens between. Further information can be obtained as is illustrated by the cases shown in Figure 5.

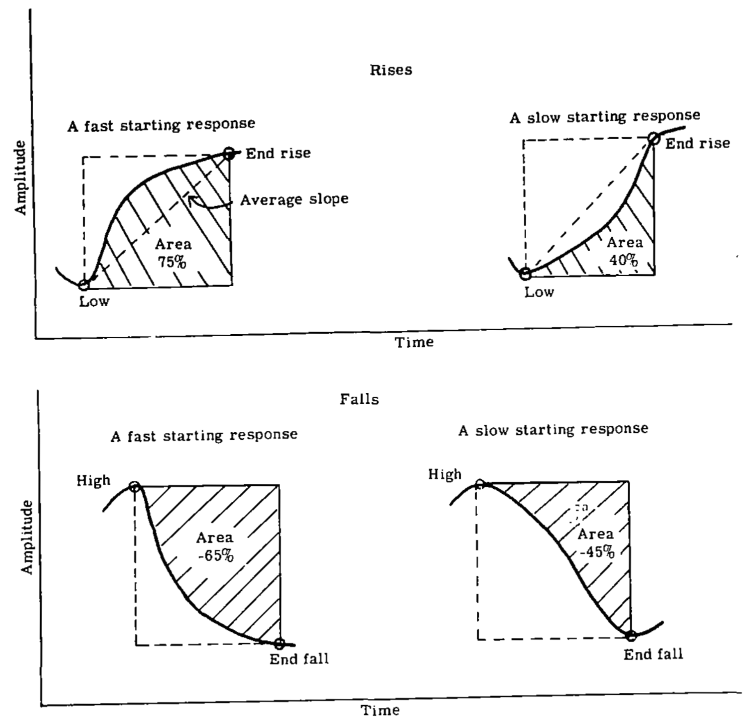


Figure 5

The first two responses shown have similar end points but different behavior in between. In one sense we might call the first a big response or fast-starting response and the second a small or slow-starting response. The area under the response, shown cross-hatched, is a good index of the difference between the two responses. A fast-starting response has a large area. The area is a way to describe the average curvature. Areas larger than the triangle enclosed by the average slope line indicate a generally convex curve produced by a "negative acceleration" over most of the curve. Conversely areas less than the triangular area indicate a generally concave curve. To preserve this property of a fast-starting response being associated with a large area the complimentary area, or area over the curve, is computed for falling responses. In order to give the area or curvature concept a standard meaning regardless of amplitude, duration or area of the particular response, the percent of the rectangle encompassed by the amplitude and duration of the response is computed as illustrated.

(4) Artifacts and Editing.

Unfortunately real data generally contain a number of artifacts (noise) which must be handled in the data analysis. Indeed, to be generally useful the analysis system should be able to process data that are mostly artifactual and extract what good data are present.

Artifacts may be divided into two groups, those which can be recognized and interpolated or skipped by the computer and those which must be deleted by a human editor. In this system the computer recognizes as artifact those data which exceed either a specified amplitude or a specified slope. These two artifact tolerances are provided by the editor and provision is specified by a third editing tolerance, the <u>edit duration tolerance</u>. An edit of duration less than the edit duration tolerance is linearly interpolated. An interpolated edit is called a <u>Short Edit</u> (SE) while a longer non-interpolated edit is called simply an <u>Edit</u> (E). Their end points are special points of interest and are named <u>Begin Edit</u> (BE), <u>End Edit</u> (EE), <u>Begin Short Edit</u> (BSE), <u>End Short Edit</u> (ESE), as is appropriate. Examples of editing are shown in Figure 6.

We have now briefly described the essential features of the first part of our data analysis system, the part called the <u>Points of Interest Program</u> (Figure 7). This program which comprises the major part of the system can process several experimental recording sessions sequentially. It can handle 29 different channels of data simultaneously at 3 different sampling frequencies. It has provisions for scaling and converting data to physiological units as well as the features already described. Running time on the IBM 7094 for processing an hour's worth of data (about 500,000 samples for 29 variables) is about five minutes. A sample of

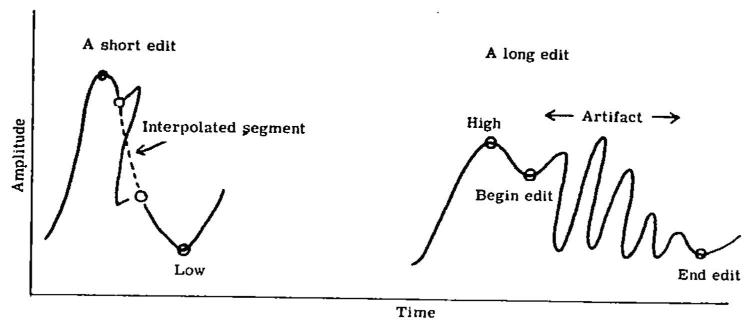


Figure 6

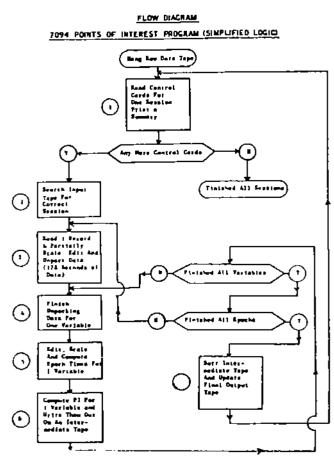


Figure 7

the polygram (Figure 8).

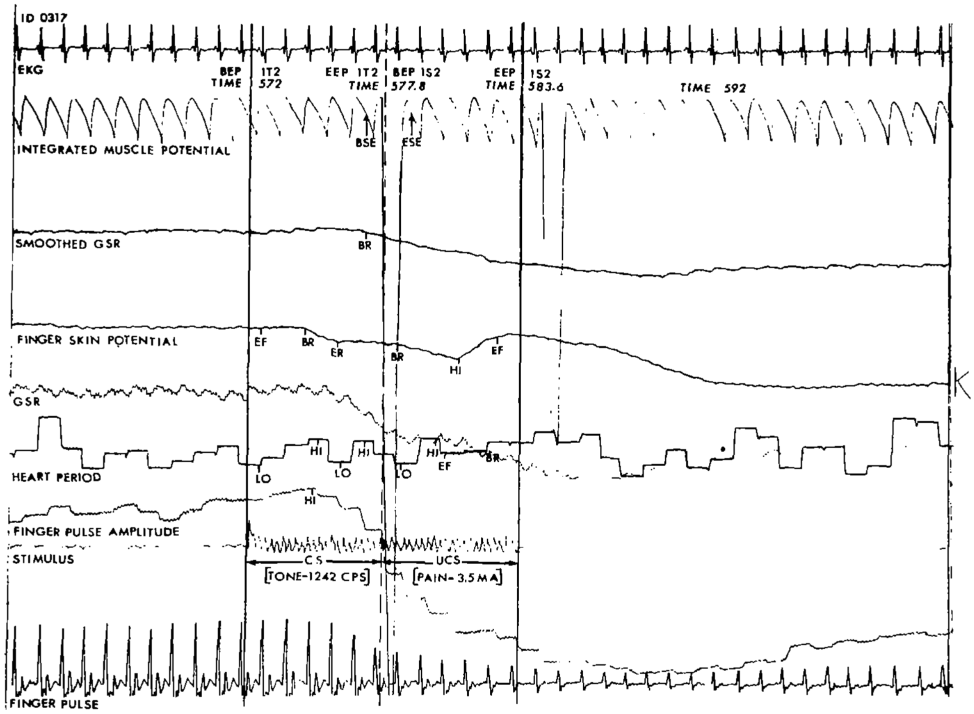


Figure 8

The raw data for all variables (Table 2, appendix) and Points of Interest and summary listing for the sampling of the variables are shown in Tables 3 to 12, appendix..

c. Summary Program.

The Points of Interest Program describes the data in terms of responses. While this considerably reduces the amount of data, the information is not yet organized into a form that is easily assimilated. The summary program is designed to perform the part of this function that does not require elaborate statistical analysis.

The summary program summarizes data by the experimental epochs which were set up in the design of the experiment. It allows easy comparison of one epoch with another by summating the data. The summary tabulates separately three general categories of data: (1) general information about the epoch, (2) information about the first few responses in the epoch, and (3) a summary of various aspects of all responses for the entire epoch (Table 12a).

POINTS OF INTEREST SUMMARY

SESSION NO 274071210001 _ NAME ______ PT. ID 0188 TESTED 11-13-63 INTERVIEW 1 REASSURANCE, STRESS

VARIABLE 1 HEART PERIOD IN MILLISECONDS SUMMARY NO 1 148 POINTS OF INTEREST

EPOCH 3 REASSURANCE 2

BEG EPOCH	597.7	END EPOCH	898.0	DURATION	300.3
BEG AMP	959.99	AT TIME	597.7		
END AMP	1061.65	AT TIME	896.9		
MAX AMP	1180.09	AT TIME	894.0		
MIN AMP	971.79	AT TIME	671.1		
MEAN AMP	1000.36	STAN DEV	72.05		

98.2 PER CENT GOOD DATA 1.8 PER CENT LONG EDIT PER CENT SHORT EDIT

	INIT AMP	INCREMENT	DURATION	SLOPE	AREA	LATENCY	PREC DRIFT
FIRST INTERVAL	999.59	-21.07	2.3	-9.29		0.	
RESPONSE 1	978.42	-96.46	2.0	-48.23	-0.42	2.3	0.
RESPONSE 2	882.17	210.01	2.3	91.31	0.30	4.3	0.
RESPONSE 3	1071.42	-105.62	1.6	-66.01	-0.41	8.8	2.2
RESPONSE 4	978.02	148.96	2.1	70.93	0.47	12.4	2.0
RESPONSE 5	1125.98	-216.73	4.1	-52.86	-0.38	14.5	0.
LAST INTERVAL	0.	0.	0.	0.		0.	

SUMMARY OF RESPONSES, PLATEAUS, AND DRIFTS

	NO.	INCREMENT		DURATION		SLOPE		AREA		INTERVAL	
		MEAN	STD	MEAN	STD	MEAN	STD	MEAN	STD	MEAN	STD
DISC RISES	59	109.91	66.025	2.0	1.00	56.63	58.225	0.46	0.120	4.7	2.22
CUM RISES	0	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
DISC FALLS	62	-101.84	54.856	1.8	1.08	-78.13	41.743	-0.45	0.152	4.6	1.88
CUM FALLS	0	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
PLATFAUS	0	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
DRIFTS	19	1.93	13.917	2.7	0.92	1.25	5.474	-0.00	1.206	0.	0.

DISC RISES PER CUM RISE MEAN = 0. STD = 0.

DISC FALLS PER CUM FALL MEAN = 0. STD = 0.

Table 12a

Each variable is summarized separately. The Summary categories are discussed in more detail below. (See Tables 4, 6, 8, 10, 12, appendix, for computer listing of the summary output for the data whose P.I. were illustrated.) Table 12a is an example of a standard summary output, but of different data.

(1) General Information Section.

This tabulation permits identification of the epoch and quick evaluation of the range of variation of the variable. It also gives some idea of the amount of useful information extracted by listing the number of points of interest in the epoch and the amount of editing. The following information is listed:

(a) Variable Number.

(b) Data Information Number.

(c) Number of P.I. in Epoch.

(d) Epoch Number.

(e) Epoch Duration.

(f) Epoch Beginning Time and Amplitude.

(g) Epoch End Time and Amplitude.

(h) Maximum Amplitude and its Time.

(i) Minimum Amplitude and its Time.

(j) Mean Amplitude and its Standard Deviation.

(k) Percent Good Data.

(l) Percent Long Edits.

(m) Percent Short Edits.

(2) First Responses Section.

Experimental epochs are usually set up to study responses to specific stimuli. The largest and most significant responses often occur immediately following the start of the epoch. In order to be able to examine the first part of the epoch indetail, the first few responses are tabulated individually. Up to 10 responses may be tabulated for a given epoch as well as the first and last intervals in the epoch. The first interval is the period between the start of the epoch and the beginning of the first response and the last interval is the period between the end of the last response in the epoch and the end of the epoch. For each response and interval the following information is tabulated:

(a) The initial amplitude.

(b) The amplitude of increment or decrement.

(c) The duration.

(d) The mean slope.

(e) The curvature index.

(f) The latency time from start of the epoch.

(g) The preceding drift time between the end of the last response and start of the present one. The last item, preceding drift, is included to permit ready identification those responses that follow other responses immediately and those separated by drifts.

(3) Summary of Response Parameters Section. (Table 12a.)

This third section of the summary listing (which was not printed out in the preceding examples) tabulates the means and standard deviations of several aspects of the responses in an epoch. Data are tabulated separately for rises, falls, plateaus and drifts. The program also computes cumulative responses if they are present. Cumulative rises and cumulative falls are tabulated separately as well as the mean and standard deviation of discrete responses, including those in cumulative responses, for each cumulative response. For each discrete response, cumulative response, drift or plateau, the number of each type plus the means and standard deviations for the following parameters are tabulated: (a) increment or decrement; (b) duration; (c) slope; (d) curvature: (e) interval between responses.

4. Program Input and Output.

The input to the program consists of the session identification numbers for the sessions to be processed, the variable numbers and the begin and end times for each epoch. The data input is the points of interest magnetic tape produced by the Points of Interest Program. Output is printed with an option of writing most of the printed output on tape for future statistical analysis.

d. Correlation Program.

(1) Unconfounded Parameter Correlation.

A method has been developed for correlation of the primary parameters of selected pairs of responses from a single variable or from pairs of variables. It does not employ the conventional auto- or cross-correlation approaches which utilize arbitrary equal interval samples; but rather this novel approach utilizes the time, amplitude, slope and curvature of the responses matched on the basis of <u>minimal variance in lag</u>.

This approach is not only parsimonious in computing time, because a highly selected and much reduced set of points is used, but also it has theoretical value. Consider these two variables in

Figure 9.

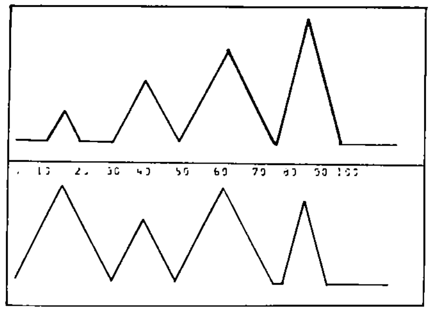


FIGURE 9

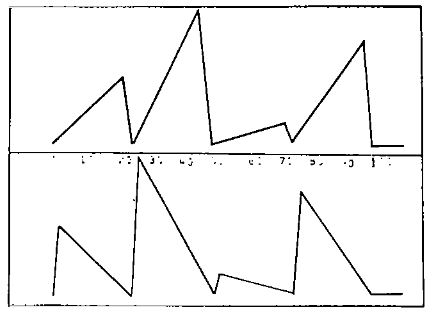


FIGURE 10

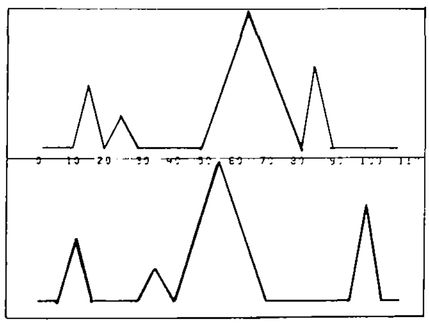


FIGURE 11

Figure 9. Synthetic responses to illustrate high coincidence and slope correlations, moderate cross correlation, and zero amplitude correlation.

Figure 10. Synthetic responses to illustrate high coincidence correlation, high response amplitude correlation, and low slope and cross-correlation.

Figure 11. Synthetic responses to illustrate high amplitude and slope correlations and low coincidence and cross-correlations.

Figure 9

Would you say these two variables are correlated? Note that every time one variable rises to a peak, so does the other, reaching the maximum at exactly the same time. Thus, in the most primitive sense they are perfectly correlated by virtue of their perfect coincidence. We note also that the corresponding responses have exactly similar shapes; in each case the slopes of rise are the same and the slopes of fall identical on the two variables. Thus, their slopes are perfectly correlated. Their maximum amplitudes, however, are completely uncorrelated; the product moment correlation coefficient of their maximum values is exactly zero. The standard cross-correlation over time applied to these two variables produces a maximum correlation of approximately 0.57 for a lag of zero and less for all other lags. Since a correlation of 0.57 represents about 32 per cent of common variance, we could conclude they are weakly correlated by this classical correlation function; their maximum amplitudes are completely uncorrelated but they are perfectly correlated by indices of coincidence and slope. In the next example (Figure 10) the two variables, when adjusted for lag, have perfect product moment amplitude correlation of their maxima, perfect consistency in lag, but by virtue of their differing shapes produced by differing rise and fall slopes the maximum cross correlation is a minute 0.35 with an optimum time lag of 15.

Finally in Figure 11 the two variables again have responses of perfectly proportionate amplitudes, itendical shapes but this time inconsistent lags. The maximum cross-correlation whuch occurs at lag 10 is only 0.20.

These examples should make it clear when dealing with variables which have irregular intervals and variable shapes due to different rise and fall slopes, that none of the conventional methods of correlation gives a full and unambiguous measure of their correlation. The standard cross-correlation function based on equal interval samples correlated over a mean time lag (Tau) clearly produces some cort of average, confounded of all three aspects of coincidence, amplitude and slope. In biological systems it may be important to measure any one of these three aspects of correlation independently according to its own internal principles of response. Classical cross-correlation in this situation would reveal only a weak relationship, whereas control may be absolute with regard to <u>occurrence</u> and <u>timing</u> of the dependent systems' response. The neural impulse which starts the heart beat is this type of response.

In attempting to apply standard cross-correlations to respiration produced heart period variability called "respiration simus arrhythmia" we have often found small "zero-order" correlations in respiration and heart rate records which by visual inspection, appeared to have strong sinus arrhythmia. These inconsistent findings stimulated us to seek better ways to measure cross-correlation among physiological variables.

Our approach keeps entirely separate the aspects of coincidence, amplitude, and shape. It retains the concept of a response as the primary entity. The first problem is to identify the corresponding responses on a pair of variables.*

(2) Phases of the Correlation Programs.

The correlation of response parameters proceeds in two distinct phases (Figures 12, 13, 14).

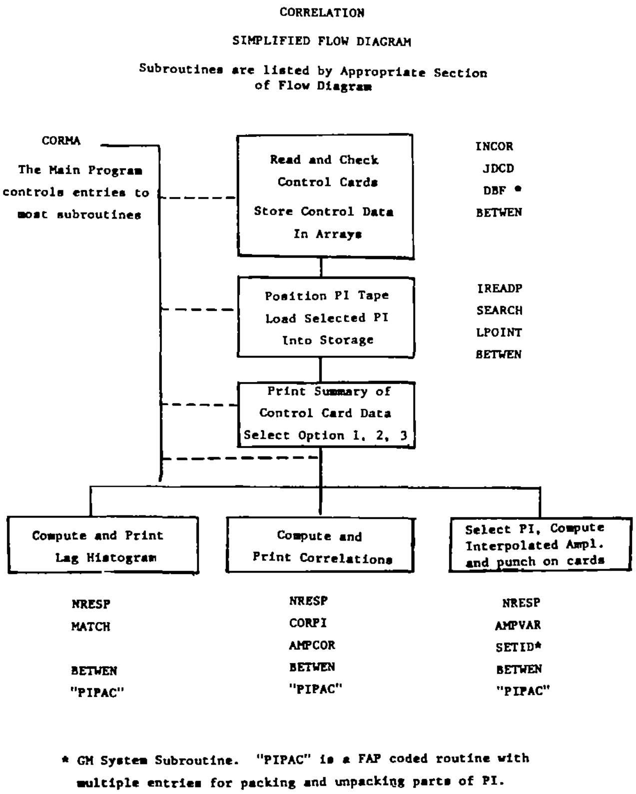


Figure 12

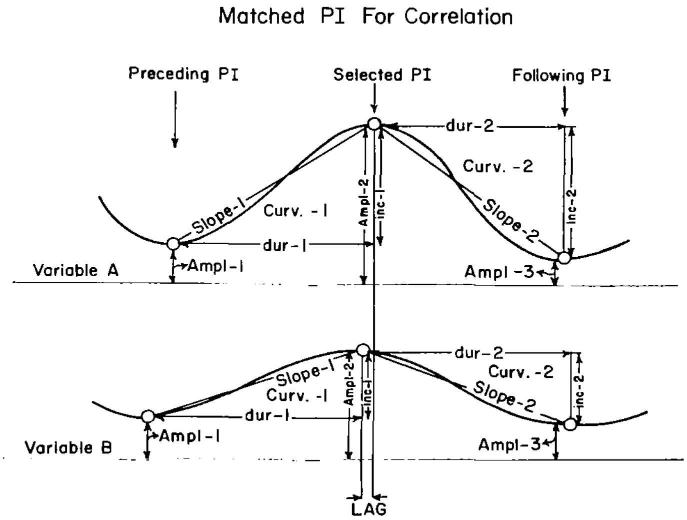
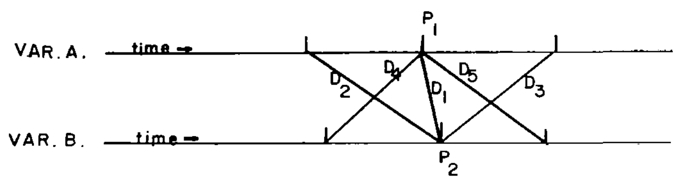


Figure 13

* Ax, A. F.; Zachary, G.; Gudobba, R. D.; Gottlieb, J. S. Psychophysiological data retrieval and utilization. Ann. N. Y. Sci., Vol. 115: 2, pps. 890-904, 1964.

CORRELATION MATCHING METHOD



The PI are indicated by short vertical lines on the time scale of the two variables. P_1 will be matched with P_2 if the time differences D_1 through D_5 meet the following test: D_1 must be less than D_2, D_3, D_4, or D_5.

Figure 14

During the first phase, the times of selected P.I. are matched and a histogram of the lags between samples for the pairs of variables being matched is printed out. This enables the user to select the characteristic lags for the P.I. he desires to correlate. During the second phase these lags are used as input. The selected P.I. are matched and the subset of those points closest to the specified lags is used for the actual correlations. Matching may take place on either the beginnings or ends of responses as desired.

The input to the program is similar to the P.I. and summary programs previously described and consists of a set of program control cards specifying the desired program parameters and a tape containing the points of interest in the format produced by the P.I. program. Output consists of a summary of control card information plus identification data such as epoch and variable names from the P.I. tape. This is followed by the lag histograms for phase 1 and correlations for phase 2 in convenient tabular form. The program contains extensive optional printout of intermediate data for use in checkout and during early program usage.

III. APPLICATION OF ACQUISITION SYSTEM.

The data acquisition system became operational long before the data processing system did. During this time, considerable data were recorded by oscillogram and analog magnetic tape. Three physiological variables were analyzed by hand on two studies. The first of these studies has been partially reported previously. (See Ax, Beckett, Fretz, Gottlieb, 1965.)

A. Classical Conditioning of Autonomic Responses in Humans.

1. Rationale.

The notion underlying this study is the concept of <u>learned motivation</u>. It is well established that the motives which the individual develops by interaction with his social environment are learned, (Hull, 1943; McClelland, Atkinson, Clark, & Lowell, 1953; Hebb, 1958; Brown, 1961; Miller, 1951; Miller, 1961). The individual learns his motivational pattern uniquely according to his particular endowments and experiences. Since there is almost always more than one motive present, it is necessary to conceive of motives as being organized into a hierarchy in reference to <u>current need</u>, <u>opportunity</u>, and <u>long term consequences</u>. Current need, opportunity and long-term consequences, are very interdependent variables which may interact strongly as illustrated by emotional behavior and impulse buying which after the act may be seen as very inappropriate behavior and to result in undesirable long-term effects. The motivational hierarchy which enables the decision to act (presumably by some sort of reciprocal inhibition) is largely unconscious and may have little relationship to the verbalized conscious "hierarchy of values".

One who tends to be overweight may have placed dieting high on his verbalized hierarchy of values but continue to overeat. The motive to diet is obviously not very high on his hierarchy of motives. This common difficulty in human motivation can be seen to be largely due to the relatively low potency for some people of long-term--as contrasted to short-term--reinforcements. An immediate threat to health is usually quite successful for dieting. Clearly to predict and understand behavior the true hierarchy of motives rather than the deceptive verbal "hierarchy of values" must be studied. It is for this reason that the unconscious involuntary physiologic processes are used to study motivation.

The motivational aspect of behavior is believed to be managed by the limbic system of the brain which regulates the autonomic nervous system (ANS). The physiological functions controlled by the ANS thus are prime targets to study with regard to their role in learning motives.

The concept of an aptitude for learning the hierarchy of motives seems strange to some people. Yet few would doubt that the establishment of the hierarchy is learned. Wherever there is learning, we may postulate, there must be an aptitude for the learning. All aptitudes that have been measured appear to be widely distributed in the population and are in general only moderately correlated with each other. Thus we do not expect fo find musical talent, verbal ability and athletic ability to be highly correlated; similarly the aptitude for learning the social motives need not be well correlated with the well-studied aptitudes mentioned above.

Just as educators know that they must adapt their procedures to the intellectual abilities of the student and adjust their expectations for him in terms of his I.Q., so must we learn to recognize and measure the aptitude for learning the social motives and to adapt our social incentives to the person's motivational aptitude and to adjust our expectations of his achievements in terms of his aptitude for learning the social motives.

The aptitude for learning the social motives has a general effect on all achievement, since motivation is a prime factor in all behavior. No matter how great the talent, if motivation is low there can be little achievement. It would appear that motivational learning is influential for its own acquisition in a regenerative, positive feedback way, thus playing a power factor role. From early childhood relatively small differences in initial motivational aptitude may have profound effects on achievement.

Successful demonstration that these physiological measures of learning correlate with motivational aspects of important life activities such as education, work and family responsibilities would contribute to better scientific description of the mechanism of motivation and to the practical application in selection and training of personnel.

2. Method.

This was a study of clinical group differences rather than one of conditioning per se, hence identical procedure was used on all subjects rather than a procedure employing methodological subgroups for control of stimulus order, pseudo-conditioning, etc. This orientation to clinical group differences makes the study less than ideal for the analysis of the nature of the conditioning obtained. Subsequent studies will be required to clarify these interesting problems.

a. Experimental Procedure.

The experiment was done on each subject over a 5-day period (Figure 15 next page). Five 1-hour sessions of physiological testing were done on consecutive days. The first session was habituation to the laboratory during which 3 different pitched tones were sounded each for 12 seconds for each of 5 trials. The second and third sessions were for conditional training during which two of the tones were reinforced by two different intensities of pain stimuli each 5 times per session. The fourth session

CONDITIONING PARADIGM

DAILY SESSIONS

Habituation	Ist cond.	2nd cond.	Extinction	Cold Pressor

A CONDITIONING SESSION

Rest.	Instruction	15 stimuli	Inst.	Rest.	
5'	2'	34'	1'	5'	=47 min.

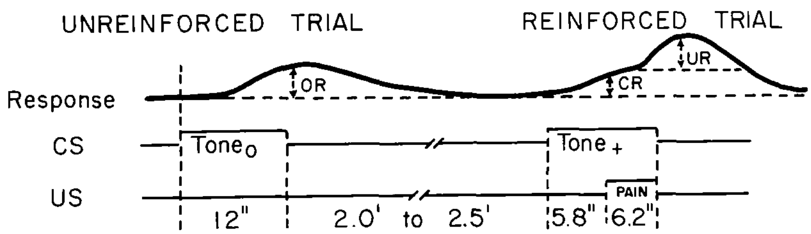


Figure 15

was extinction during which only the tones were given as on the first day. At the completion of the extinction series, the pain electrodes were once more attached and 4 intensities of stimulation (2.5, 3.5, 4.0, and 4.5 ma) were administered at about 3.0-minute intervals so as to enable the determination of the subjects' responsiveness to the pain stimuli when the response was not complicated by a preceding CR elicited by the CS. It was hoped that these responses could be used in a regression equation to adjust for individual differences in response sensitivity so as to reduce the between-subject variance. The pain stimuli can also reveal the systematic discrimination of the response system to incremental pain stimuli.

On the fifth day the cold pressor test was done and 3 I.V. blood samples taken for biochemical analysis being done by Dr. Frohman. The experimental procedure for each session was preceded by at least 5 minutes recorded undisturbed rest and followed by a 5-minute rest period.

The conditional stimuli used in this experiment were tones of 3 different pitches (470, 770, and 1240 Hz) interrupted (50% on - off 4 times per second at about 75 db loudness. Each tone was presented for 12 seconds for 5 repetitions at pseudo-random intervals (from 2.0 to 2.5 minutes) in 4 sessions on consecutive days. The unconditional stimuli were direct currents applied to the toe pads via zinc sulphate wetted circular sponge electrodes. The direct current values were 2.5 and 3.5 ma; that is, 6.50 and 9.10 ma/cm^2. An electronic current regulator maintained precisely these current values regardless of skin resistance changes beneath the electrodes. During the first or habituation session each of the 3 tones without the pain was presented 5 times. During the second and third sessions the smaller (2.5 ma) pain stimulus always accompanied the last 6.2 seconds of the middle pitched tone (770 Hz) and similarly the higher pain stimulus (3.5 ma) was always paired with the highest pitched tone (1240 Hz). The lowest pitched tone was never reinforced by pain. On the fourth or extinction session no pain stimuli, only the tones, were presented. This session was identical with the habituation session. Thus during the two conditioning sessions each of the two higher-pitched tones was reinforced a total of 10 times.

Each subject was told for the habituation session that he would hear some tones but he need do nothing. For the two conditioning sessions he was told that some of the tones would be accompanied by a brief pain in his toe which would feel like heat. For the 4th or extinction session he was told that there would be no pain stimuli--that the pain electrodes were not applied to his toe. This true information was given to the subject in the hope that it would eliminate the random variance caused by varying hypotheses of the subects as to when they might be given pain stimuli. The involuntary autonomic response was of more interest than the conscious expectations.

On the fifth day the subject was required to immerse his foot in continuously stirred ice water for 1 minute. I.V. blood samples were taken before, during, and after the ice water stimulus. During the 10 minutes of stimulation, the maximum rise and fall from the prestimulus resting levels were scored for each variable.

b. Subjects.

Three types of subjects were tested:

(1) The clinical group consisted of 28 male chronic schizophrenic patients with an age range of 27-41 with a mean age of 31.9 years. The mean duration of the illness was 7.6 years with a minimum of over 2 years. They were maintained in a special research ward and kept off all drugs for a year or more prior to the time of testing. They were on a good diet and required to participate in a daily program of exercise. According to the diagnosis by a single psychiatrist on a single occasion, their subdiagnoses were distributed as follows: Paranoid 36%, Hebephrenic 18%, Catatonic 14%, Simple 14%, and Undifferentiated 18%. During the 8 years most of these patients have been studied, there have been changes in psychiatric opinion about their subdiagnostic categories; all clinicians agreed, however, that all 28 patients were indeed chronic schizophrenics.

(2) The control group consisted of 18 healthy employed persons. Each was interviewed by a psychiatrist and rated on the same psychiatric scales on which the patients were rated. In addition the control group was given the Minnesota Multiphasic Personality Inventory, the Wonderlick

Personnel Test, a reversed digits test, and weight and auditory discrimination tests. If any control subject was judged to be unhealthy physically or psychiatrically by the psychiatrist, he was excluded from the control group. The age range was 19 to 44 with a mean age of 28.1 years. There was no attempt to match the two groups on I.Q. Within the control group there was no significant correlation between the GSR conditioning score and the Wonderlick index of I.Q.

c. Physiologic Response Scoring.

Manual analysis was done on skin conductance (SC), skin potential (SP) and finger pulse (FP). The analysis of heart rate, respiration, frontalis muscle tension, face temperature, and ballistocardiogram was postponed until computer analysis could be done.

(1) Base Level.

The palmar conductance and potential were measured prior to the onset of each stimulus and also at five selected points of each (a) During the last minute of the first rest period.

(b) Between the 5th and 6th stimulus (at the lowest SC point and point of least activity of SP).

(c) Between the 10th and 11th stimulus.

(d) Between the 15th stimulus and the instructions for rest.

(e) Near the end of the final rest period.

Since finger pulse had no calibration, the base level was not considered a useful measure.

(2) The Conditional Responses (CR) to tones (T_0, T_1, T_2) were measured during the habituation and extinction sessions within the 12-

second period while the tone signal was on. During the conditioning sessions the CR was measured only during the 5.8 seconds of the tone prior to the onset of the pain stimulus. The responses to T_0, T_1, and T_2 were each measured in the same manner during the conditioning sessions, except those for FP for which the T_0 (unreinforced tone) was measured over the full 12-second tone interval as it was for all variables during habituation and extinction sessions. The purpose of this change was to enable, for one variable, a proper comparison between the unreinforced and reinforced sessions which is not possible when the periods of analysis are of different length. The more obvious solution to this problem would appear to have been to have measured all responses to tones for all sessions only during the first 5.8 seconds of the tone. If this had been done comparisons between tones and between sessions would have all been possible. The reason it was not done was because many of the responses, especially those of FP, had rarely reached their full amplitude at the end of the 5.8 second period; hence, the value obtained at the 5.8 second cutoff was not the best representation of the response amplitude. The data should be rescored both ways to test this hypothesis and to enable all comparisons. Another experimental design which employed unreinforced trials for the usually reinforced tones, T_1 and T_2, would, of course, also have provided a solution. This was not done because we feared that less than 100% reinforcement would produce inadequate conditioning in this experiment where the total number of reinforcements was only 10 per tone. Finally it must be reiterated that our primary purpose was the group comparisons rather than a study of conditioning.

(3) The unconditional response (UR) was measured during the 6.2-second period while the pain stimulus was on. In order to make the CR and UR comparable the UR analysis period was not carried beyond the offset

of the pain even though many responses continued to rise after the US offset. The UR are being rescored to examine the full response.

Another problem in comparing the CR and UR is the fact that the UR is nearly always occurring during some phase of CR response or recovery. As mentioned earlier the "Law of Initial Values" is not sufficiently sophisticated to enable correction for this aspect. For some variables and for some stages of the just previous response, the second response may be augmented; for other variables and stages, it may be diminished in amplitude. John Gorham working in our laboratory is investigating this problem.

All responses are calculated by subtracting the amplitude just prior to the beginning of the response from the value either at its maximum or at the end of the analysis epoch as described above.

Skin potential (and heart rate when it is analyzed) presents special problems because it has four typical patterns of response: (a) positive uniphasic, (b) negative uniphasic, (c) positive diphasic (positive portion first), and (d) negative diphasic (negative portion first). The polarity of the response is the potential at the palmar surface referenced to the arm electrode. Normally the palm is negative to the arm reference. No special procedures (such as skin drilling) were used to decrease the resistance at the arm site except the usual washing and rubbing in of electrode paste (Redux). Variable resistance effects between the electrodes and loading was prevented by using an electrometer coupler having over 1000 megohms input impedance. We have determined that at least 10 megohms input impedance is necessary to prevent loading and resistance effect.

The SP measures were taken as follows: (a) frequency of each type, and (b) amplitude of the increments and decrements from both types of responses whether from uni- or di-phasic responses. In order to avoid scoring as responses the recoveries, only that portion of the secondary wave which exceeded the beginning amplitude was utilized as illustrated below in Figure 16.

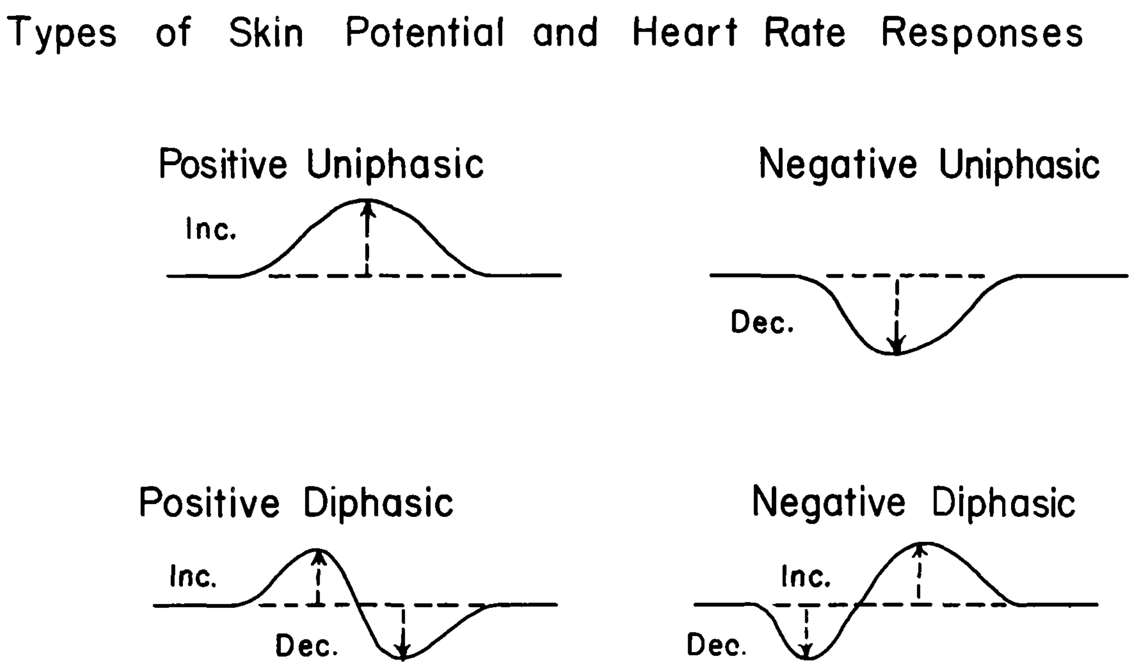


Figure 16

There are problems which require arbitrary solutions. (1) For a response to be counted the change for this study must be at least 0.2 mv in amplitude within 1.0 second. For SC the change must be 0.05 micromho within 5 seconds. (2) If the recovery of a response is not completed when another response of the same polarity occurs the second response must be treated as another response. If the second response reaches a greater value than the first one (all within the specified analysis epoch), the maximum value of the second response may be used as the minuend from which the amplitude of the variable at the beginning of the first response is subtracted to produce the response amplitude. Such a response is called a cumulative response. (3) The remaining arbitrary consideration is the maximum interval between the maximum or end rise of the first response and the beginning of the second response so as to distinguish between discrete and cumulative responses. This value has been set at twice the time tolerance. For SP it is 2.0 seconds and for SC it is 10 seconds. It should be emphasized that neither frequencies nor amplitude distributions are meaningful nor comparable unless such scoring standards are followed and stated.

There is as yet no clear understanding of the significance of these different types of skin potential responses. Chester Darrow (1964), Robert Edelberg and David Wright (1964), and R. C. Wilcott (1964) have presented tentative explanations but at present no generally acceptable explanation has been presented.

3. Results.

a. Base Levels.

The tendency for the schizophrenic group to have significantly ($p < .05$) higher average base levels of palmar conductance over all four sessions suggests a higher level of activation (Table 14).

BASE LEVELS*

Variable	Habituation		First Conditioning		Second Conditioning		Extinction		4 Sessions		Cold Pressor	
	C	S	C	S	C	S	C	S	C	S	C	S
SC	2.71	4.18	3.29	4.29	3.54	4.27	2.54	4.03	3.03	4.19	2.63	3.57
SP	-2.6	-14.3	-17.2	-14.9	-18.0	-15.0	-15.8	-12.9	-14.11	-14.16	-	-
SBP	119.7	118.9	120.8	116.3	120.8	120.3	117.8	116.7	119.8	118.1	116.4	113.2
DBP	77.3	78.8	77.0	77.3	77.8	80.8	74.9	77.4	76.5	78.5	73.3	73.0

* Middle three samples for each session.

For controls Base Level $r_{sc.sp} = .26$ $p > .05$ (4 sessions)

For Schiz Base Level $r_{sc.sp} = .28$ $p > .05$ (4 sessions)

Table 14

The two groups do not differ significantly on SP or BP. It is not known whether higher or lower skin potentials are associated with arousal. But since SP and SC for mean base levels have only insignificant correlations for both control ($r = .26$) and schizophrenic ($r = .28$) groups it would appear that SP is not an indicator of the same aspect of arousal that SC is believed to be.

Without valid base level measures for such additional variables as heart rate, peripheral plethysmogram, muscle tension, and EEG desynchronization it would be hazardous to say how the two groups compared on activation or how they adapted over the sessions. As Lacey (1966) has recently pointed out and Darrow (1942), Ax (1953), Sternbach (1960), Lazarus (1966), and others have shown, the physiological indices of activation do not correlate very well. We conclude that activation or arousal is too global and undifferentiated a concept accurately fit the facts. Individuals manifest their activation in unique patterns and do so differently in different situations. Much more research is needed to relate patterns of physiological activation with well described emotional and motivational patterns in many types of individuals.

The correlations between base levels and the various indices of response show a similarly variable pattern. Of the correlations computed on individuals for SC between base levels and response, the range was from zero to .74. For SP they are equally variable. Such wide individual differences and variability within individuals in regression of response amplitude on base level makes questionable any attempt to remove the base level contribution from response amplitude. There is little to be gained by attempting to apply the "law of initial values", until studies are done which sufficiently control for the other determinants of response amplitude. The determinants other than base level include individual response specificity, type of arousal and contribution of other variables. Many studies must be done to reveal the true, probably curvilinear, relationship between response amplitude and base level for each variable, each type of stimulus and each "type of subject" (if indeed each individual is not a type unto himself). We come to this lamentable conclusion even though we believe that the contributions of psychophysiology to the study of stress tolerance, motivation and emotional development can be greatly enhanced by the full exploitation of the true "laws of initial values." Much research needs to be done in this area.

b. Orienting Responses.

An important consideration for classical conditioning is for the conditional stimulus originally not to elicit much of an orienting response, or at least to be relatively habituated, before conditional training is begun. Minimal response to the CS prior to conditioning makes it easier to show unambiguously that enhancement in response amplitude or frequency of response has been achieved by the training procedure. There is uncertainty as to exactly what role the amplitude of the OR has for the course of conditioning. Often it is found that for pseudo-conditioning control groups where there is no pairing of CS with UR the OR habituates whereas for the conditioning groups the OR does not habituate and is said to have become the CR. Some experiments have described increases in latencies as OR became CR and others have even described a third response called the anticipatory response, AR, which occurs just before the US. These varieties of responses are probably influenced by the duration of the CS-US interval, latencies of the response variable, etc. Since our primary purpose was to describe the differences between two criterion groups rather than detail the intricacies of classical conditioning, we can pursue this problem no further. It is sufficient to note (see Figures 17 to 24, next page) that the healthy control group had larger OR at the beginning of the habituation session but that at the end of the habituation session their mean OR was no larger than that for the schizophrenic group. Thus the conditional response differences between groups cannot be accounted for simply in terms of larger responses to the CS prior to conditioning nor by the OR since the correlations between OR and mean CR are small, averaging .27 for the control group and .21 for the schizophrenic group (Table 15).

ADAPTATION OF ORIENTING RESPONSES

	SC			FP			SP_i			SP_d		
	C	S	*p*	C	S	*p*	C	S	*p*	C	S	*p*
1st OR - last 3 hab.	.373	.022	-	12.73	8.02	-	.029	.039	-	.281	.020	-
2nd Or - last 3 hab.	.244	.070	-	14.30	-5.01	-	.253	.004	-	.166	.007	-
Comb. OR - last 3 hab.	.299	.034	<.01	13.09	-2.11	.01	.122	.018	.05	.249	.014	.01

1st OR is the response to the first 3 tones of habituation.

2nd OR is the response to the first tone (T_1) of first conditioning.

Combined OR is (1st OR + 2nd OR)/2.

Last 3 hab. is the mean of the responses to the last 3 tones of habituation $(T_1 + T_2 + T_0)/3$.

Table 15

CORRELATIONS OF OR HABITUATION vs CONDITIONING

	SC	FP	SP_i	SP_d
Control (N=18)	.363	.096	.691	.539
Prob	NS	NS	.01	.05
Schiz (N=28)	.413*	.137	.440	.018
Prob	.02	NS	.02	NS

Orienting Response Habituation is computed by

(Σ3 First trials/$_3$ - 3 last trials/3 for habituation + (First trial, T_1, 1st cond. - Σ last 3 trials/3 for habituation).

The conditioning score is the mean amplitude of CR for first plus second conditioning.

* One subject caused extreme distortion of the distribution requiring a non-parametric Rank Difference correlation. Product moment r = .789.

Table 16

The OR habituation (Table 16) correlates with conditioning on the average considerably better

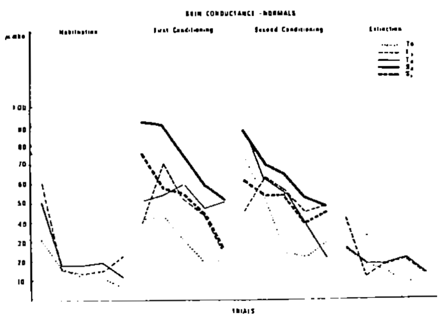


Figure 17

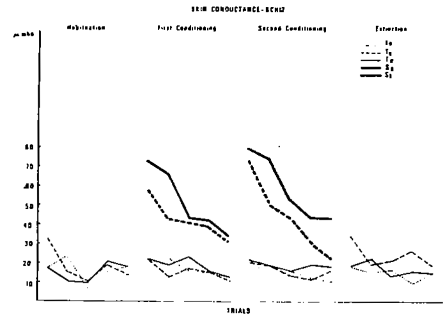


Figure 18

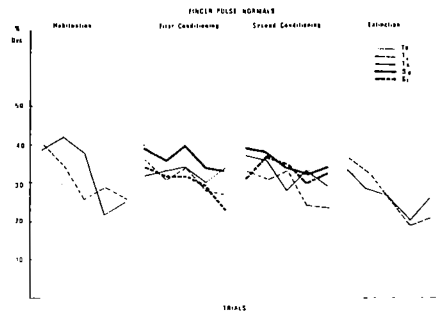


Figure 19

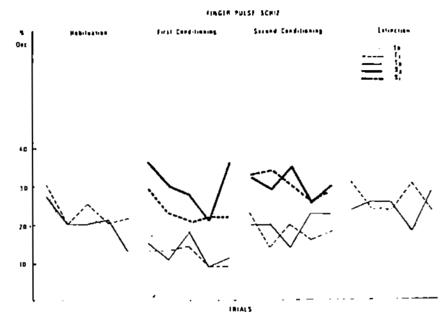


Figure 20

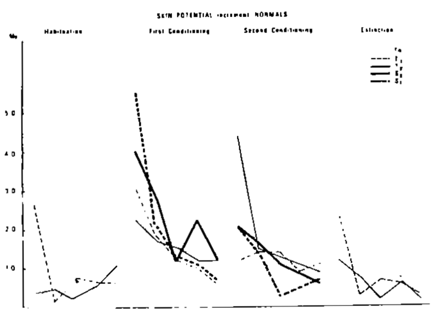


Figure 21

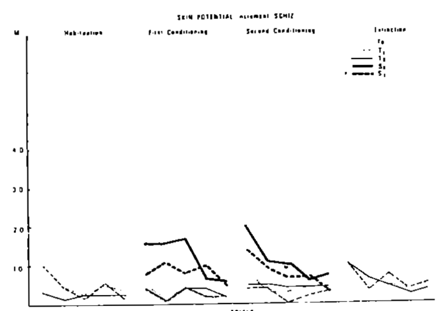


Figure 22

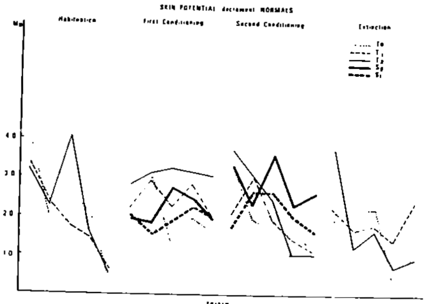


Figure 23

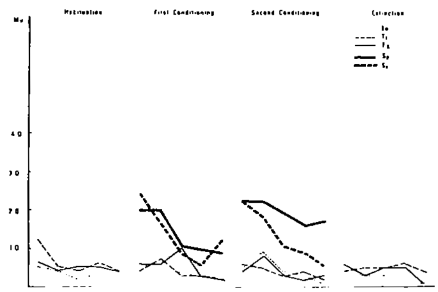


Figure 24

for controls (.419) than for schizophrenics (.252).

It could be that two factors are involved here. The higher initial OR for the healthy group may represent a greater sensitivity to their environment and their rapid habituation could be considered as conditioning. Conditioning in the general sense is modification of a response with experience and may include decreases as well as increases. The role of the OR ("sensitivity to stimuli not yet classified as to relevance") in conditioning is not well understood, although it could be argued that for a stimulus to become a successful conditional stimulus, it must be taken cognizance of (responded to) in some manner by the organism. It is unknown to what extent an organism will develop a sensitivity to a previously totally ignored stimulus by associative conditioning.

c. Unconditional Responses.

A second important consideration for conditioning is for the unconditional stimulus (US) to elicit an adequate unconditional response (UR). Reference to Figures 17-24 and Tables 17

RESPONSE AMPLITUDES

	SC			FP			SP_i			SP_d		
CR	C	S	p*	C	S	p*	C	S	p*	C	S	p*
Habituation	.21	.17	NS	28.44	27.55	NS	.68	.50	NS	2.11	.55	.01
1st Conditioning	.49	.16	.01	31.98	11.47	.01	1.58	.34	NS	2.79	.53	.01
2nd Conditioning	.54	.16	.01	31.12	18.90	.01	1.58	.41	.05	2.11	.48	.01
1st & 2nd Condit.	.52	.16	.01	31.89	15.06	.01	1.67	.38	.05	2.47	.51	.01
Extinction	.20	.18	NS	29.99	40.71	NS	.79	.50	NS	1.72	.42	.01
UR												
1st Conditioning	.63	.47	.05	32.59	24.60	NS	2.24	1.10	.05	2.06	1.44	NS
2nd Conditioning	.58	.51	NS	33.82	31.34	NS	1.12	1.01	NS	2.51	1.69	.05
1st & 2nd Condit.	.61	.48	.05	32.56	28.63	NS	1.68	1.07	NS	2.21	1.58	NS

Amplitudes for the habituation and extinction sessions are means of responses to all tones. Amplitudes for the conditioning sessions are means of the responses to the reinforced tones (T_1 and T_2), and means of the responses to the unconditioned stimuli (S_1 and S_2).

*Kruskal-Wallis one way analysis of variance.

Table 17

and 18 shows that both the amplitude and frequency of UR appear adequate for the two groups. No subject failed to provide UR. The correlations between parameters of CR and UR are very low (.01 to .21) which suggests that if some minimal UR is present, it suffices for conditioning.

PERCENT RESPONSE FREQUENCY

	SC			FP			SP_i			SP_d		
CR	C	S	p*	C	S	p*	C	S	p*	C	S	p*
Habituation	72.7	59.6	NS	70.0	65.9	NS	20.3	28.3	NS	67.1	39.3	.0013
1st Conditioning	93.7	59.1	.00003	93.1	43.1	.00003	18.1	17.1	NS	81.2	39.9	.0004
2nd Conditioning	91.7	61.2	.00016	89.4	63.3	.0011	24.2	18.5	NS	70.1	42.9	.0008
1st & 2nd Condit.	93.2	59.8	.00003	91.1	53.2	.00003	21.0	18.0	NS	74.3	41.3	.00004
Extinction	66.0	61.1	NS	71.1	69.8	NS	20.5	28.0	NS	57.1	35.6	.0228
UR												
1st Conditioning	96.5	90.2	NS	94.6	78.6	.0217	35.0	23.7	NS	63.8	65.2	NS
2nd Conditioning	90.9	84.5	NS	92.8	86.9	NS	24.4	27.3	NS	70.5	59.0	NS
1st & 2nd Condit.	93.7	87.6	NS	93.6	83.0	.0113	29.2	25.2	NS	67.8	62.2	NS

SKIN POTENTIAL SUBTYPES

	Positive Uniphasic		Positive Diphasic		Negative Uniphasic		Negative Diphasic	
CR	C	S	C	S	C	S	C	S
Habituation	18.7	28.3	1.6	0	52.6	33.3	14.5	6.0
1st Conditioning	18.1	17.1	0	0	61.9	33.2	19.4	6.7
2nd Conditioning	21.4	15.3	2.8	3.2	46.0	32.5	24.1	10.4
1st & 2nd Condit.	19.5	16.3	1.4	1.6	53.7	33.0	20.6	8.3
Extinction	17.4	27.5	3.1	.5	47.6	30.0	9.5	5.6
UR								
1st Conditioning	33.8	23.7	1.2	0	39.4	46.2	24.4	19.0
2nd Conditioning	20.6	22.1	3.9	5.2	39.4	44.4	31.1	14.6
1st & 2nd Condit.	26.4	22.6	2.8	2.6	40.6	45.8	27.2	16.4

Percent response frequency is the percent of possible responses made to all three tones for the habituation and extinction sessions. For the conditioning sessions the percent frequencies are those for the reinforced tones (T_1 and T_2), and for the unconditioned stimuli (S_1 and S_2).

*Mann-Whitney U test.

Table 18

d. Conditional Responses.

The most remarkable finding is the greatly reduced mean conditional responses for the schizophrenic group as shown in Tables 17 and 18. Appropriate probability tests of these group mean differences indicate it is highly improbable ($p < .01$) that these differences could be due to chance. The percent of cases correctly classifiable by these scores indicate several individual scores to be highly diagnostic, thus indicating the autonomic conditional approach may have considerable power as a diagnostic test.

e. Tone Discrimination by CR.

The response discrimination between the reinforced tones (T_1, T_2) and the unreinforced tone (T_0) shows essentially no discrimination for the schizophrenic group and only moderate discrimination by the normal group (Figure 25, Table 19).

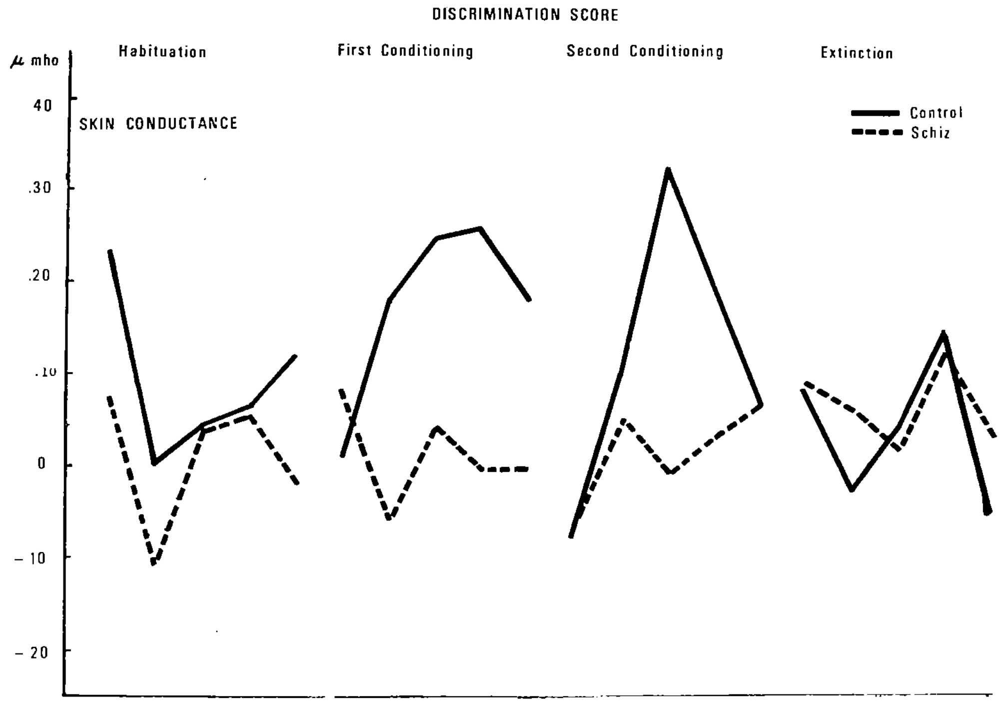


Figure 25

DISCRIMINATION SCORES

	SC			FP			SP_i			SP_d		
	C	S		C	S		C	S		C	S	
Habituation	.08	.01	.05	9.31	.17	.05	.22	-.03	.05	.10	.21	NS
First Cond.	.17	.02	.01	-5.79	-6.07	NS	.08	.00	NS	.58	.06	.05
Second Cond.	.11	.02	NS	-7.68	-6.37	NS	.11	-.07	NS	.18	-.03	NS
First and Second Cond.	.14	.02	.01	-6.52	-5.47	NS	.13	-.02	NS	.38	.02	.01
Extinction	.03	.05	NS	1.23	1.88	NS	-.01	.17	NS	.25	.21	NS

Discrimination Score = $(T_1 + T_2)/2 - T_0$

Table 19

The curves do not suggest any improvement in discrimination with increasing trials after the middle of the first conditioning session. Any discrimination that had developed during the reinforced period promptly disappeared when reinforcement was omitted in the extinction session.

The significantly greater discrimination demonstrated by the control group shows that at least a part of the conditioning superiority of the control is due to discriminative learning and not mere sensitization as could be claimed for the greater frequency and amplitude of the CR since there was no control for pseudo-conditioning.

f. Variance in Latencies.

Still another measure of response to the CS is the variance in latency. If the responses of a subject have a significantly smaller variance than would be expected by chance to randomly selected periods where no experimental stimuli were given, it is demonstrated that at least some of his responses measured during the stimulus are elicited by the stimulus.

Since the latencies to an imaginary random stimulus would have a uniform random distribution the theoretical variance would be:

$$\sigma^2 = (\alpha - \beta)^2/12$$

where α is the lower boundary and β the upper boundary of the range. Since our conditional stimulus period was 5.8 seconds the theoretical variance is 2.83. It was found for GSR latencies of CR for 8 trials selected for best discrimination between groups by GSR CR amplitude that the 18 normal subjects had significantly smaller than chance variance in latency whereas only 13 of 23 of the schizophrenic patients had such small latencies (variances were not computed for five subjects who had less than three responses).

This finding suggests that about half of the patients were not responding to the tones significantly more than chance. One can confidently conclude that at least these subjects and those with too few responses did not condition probably because their responsiveness to the CR was too small or inconsistent to enable conditioning. On the other hand those who had significantly smaller than chance variance in latency do not by that fact alone demonstrate conditioning. Their responses to the tones could mean only that they were continuing to make orienting responses to the CS with neither normal adaptation of the OR nor with any enhancement due to conditioning. Without additional control groups for pseudo-conditioning for which the CS and US are given but not paired, it is impossible to distinguish between "true conditioning" and sensitization or failure to habituate the OR.

g. Combined Scores.

By combining several of the conditioning measures (Table 20,

SUMMATED SCORES

	Σ React.	Σ Cond.	Σ Disc.	Σ CP	Σ Tot
Cont.	.459	.939	.505	.715	.656
Schiz.	-.295	-.602	-.352	-.470	-.431
Diff.	.753	1.541	.857	1.185	1.087
Prob.	< .02	< .01	< .01	< .01	< .01

Reactivity = (1) Mean FP_{dec} and SC_{inc} to 4 pain stimuli at end of extinction +
(2) Total FP and SC response to T_1, S_1 and T_2, S_2 for 1st and 2nd conditioning +
(3) FP decrement plus SC increment during CP session.

conditioning = SC + FP + SP_{dec} CR amplitude + FP_d % frequency for 1st and 2nd conditioning.

Σ Disc = $(T_1 + T_2)/_2 - T_0$ for 1st and 2nd conditioning for SC and SP_d.

Σ CP = $(HR_i + SC_i + BC_i) - (DBP_i + MT_i + \# \text{ GSR})$ for Cold Pressor.

Table 20

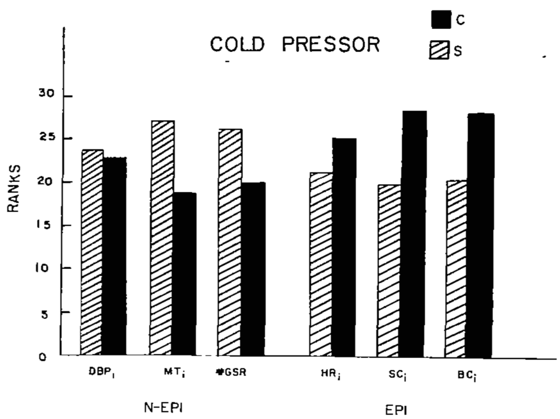


Figure 26

which best distinguish between the two groups it is possible to classify 87% of the total group correctly with only 3 normals and 3 patients misclassified. This is the same percent correct classification as for the single best conditioning score which implies that the autonomic conditioning is similarly reflected in all 3 variables. Probably much of the variance not common to these conditioning variables is due to error.

However if we add to the conditioning scores an index obtained from the physiological response scores to the cold pressor test (Table 21,

COLD PRESSOR SCORES

	REST			INC			DEC		
	C	S	*p*	C	S	*p*	C	S	*p*
HR	63.4	70.0		30.0	26.8		8.0	6.1	N.S.
SBP	116.4	113.2		17.6	21.3	N.S.	-	-	
DBP	73.3	73.0		14.3	14.8	N.S.	-	-	
BCG	.79	.75		26.2%	16.9%	.05	23.2%	21.4%	
FP	.43	.40		8.8%	41.4		76.3%	63.1%	.01
SC	2.63	3.60	N.S.	4.06	2.65	.01	-	-	
# GSR	.59	1.18	N.S.	2.15	1.02	.01	-	-	
RR	15.9	15.1		5.3	5.4	N.S.	3.6	2.0	

Table 21

Figure 26) done on the fifth day of testing we find the number of misclassified subjects reduced to one control and one patient. A review of these two misclassified subjects confirms the patient to be clearly a chronic schizophrenic with no signs of improvement. The case history of the control subject does reveal some difficulties in gaining emotional maturity with one severe psychiatric breakdown but currently he is functioning well. Obviously our measures contain enough error to readily permit this much failure in classification even if our basic variables were primary to schizophrenia which as yet is quite unconfirmed. It is to be expected that upon replication these combined best discrimination scores would inevitably regress somewhat in their diagnostic power.

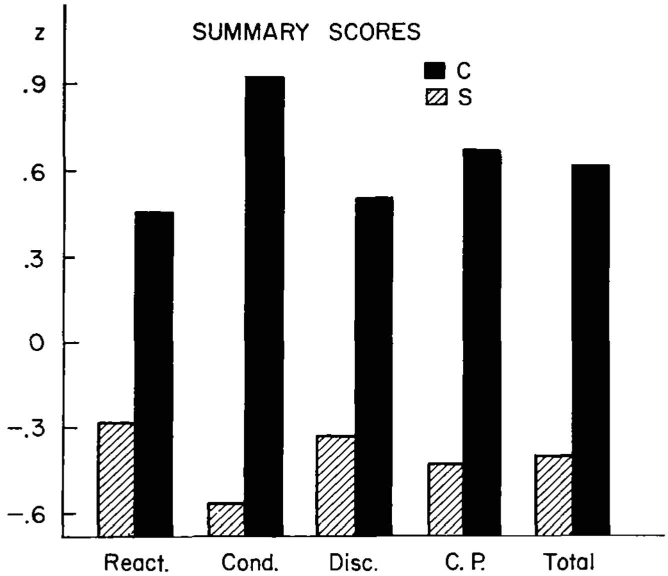


Figure 27

As yet we have not had an opportunity to utilize the response amplitudes to standard pain stimuli as possible correction modulators for the conditional responses, but they are included in Table 22 as a basic part of the findings.

BASE LEVELS AND RESPONSES TO 4 PAIN STIMULI FOLLOWING THE EXTINCTION SESSION

Stimulus Intensity	Skin Conductance				Finger Pulse			
	Control N=11		Schizophrenics N=21		Control N=13		Schizophrenics N=21	
ma	Base (umho)	Response (umho)	Base (umho)	Response (umho)	Base (mv)	Response (% Change)	Base (mv)	Response (% Change)
2.5	2.85	.53	4.25	.93	15.2	32.5	19.1	42.4
3.5	2.71	74	4.41	1.02	16.5	34.3	21.8	49.1
4.0	2.59	1.18	4.42	1.27	15.8	39.1	21.8	51.6
4.5	2.62	1.37	4.44	1.35	17.2	36.8	19.8	52.3

Table 22

Other aspects of a battery for best discrimination between two groups should include: (1) an increase in the range of difficulty of the items so as to optimally test each subject regardless of his aptitude; (2) to optimize the test item combinations by the discriminant function; (3) to replicate on new and larger groups; and (4) to purify or subdivide the groups into more homogeneous categories. This last notion of subdivision is very important. There are usually several mechanisms by which an individual copes with his problems. Some of these mechanisms such as "passivity" and "aggressiveness" which might serve fairly well by themselves, in combination may elicit maximum retaliatory reaction from the environment and cause great distress. Such incompatible or conflictual mechanisms may exist at the psychological (behavioral), physiological, and biochemical levels. Our test profiles must take into consideration these various styles of adjustment.

Simple linear combinations suitable for only monotonic variables such as the linear discriminant function cannot do this. The general finding that samples of schizophrenic patients nearly always have a wider range than normal on nearly all tests strongly suggests that two or more mechanisms are involved in their disability. The first step usually made in the attempt to recognize this heterogeneity is to classify schizophrenics into two groups on the basis of some variable. The presence or absence of a blood serum factor (Frohman, et al., 1961) or nor-epinephrine-like response to stress (Funkenstein, et al., 1957; Ax, 1953) are examples. Since such variables can operate in combination with still quite unknown results, they need to be simultaneously recorded and utilized together. This multiple variable team approach is being attempted at The Lafayette Clinic. Although we had in common a substantial group of schizophrenic patients on whom we can intercorrelate our variables, our control groups were not in common and thus our comparisons are incomplete.

h. Non-Schizophrenic Low Motivation Subjects.

In order to test our hypothesis that low aptitude for autonomic conditioning should have profound relationships to social maladjustment other than schizophrenia we attempted to test a sample of skid row habitues who have a life history of low social motivation. Only four of these were successfully recruited, demonstrated to be free from physical and psychotic pathology and who would come into the hospital for two weeks for the diagnostic workup and psychophysiological testing. The scores analyzed on these show very similar results to those found for the schizophrenic group. The conditioning scores were as low or lower than for schizophrenia and the unconditional response to the pain stimulus was lower for skin conductance but essentially normal for finger pulse. Base level for skin conductance was low, BP was high. There were many circumstances such as age, alcoholism, chronically poor diet, etc. that make these subjects unsatisfactory. These were the main reasons why more were not tested.

Instead we undertook a research program (with Department of Labor assistance) to study students in the vocational retraining schools most of whom were school dropouts and adults who have had a long history of low achievement. These subjects will be classified as to evidence of motivation and also compared to other groups comparable with regard to race, education, socio-economic origin, I.Q., personality variables, age, etc., but who differ markedly with regard to achievement and social motivation.

B. Physiological Concomitants of Psychological Differentiation.

The results of the conditioning experiment indicated there was relatively little autonomic discrimination between the three tones. The question was raised as to what subject characteristics might relate to the discrimination variable. Mr. Courter and Dr. Watttenmaker were graduate students in psychology at Wayne State University and also were research assistants in our laboratory. They designed this experiment (Courter, Wattenmaker and Ax, 1965) to relate the cognitive style of "field independency" with autonomic differentiation. Field independency was measured by a "closure flexibility test" a form of imbedded figures test, and a "verbal concept attainment test". Forty normal college students served as subjects and were grouped into relatively higher and lower field independency. The group having the greater field independency very significantly ($p < .01$) better discriminated the tones by their GSR responses. "This study demonstrates that the stimulus generalization gradient involves an interaction between the cognitive style of the organism and the impinging stimuli, not merely the quantitative physical characteristics of the stimuli". These findings further suggest that the field dependent person may have a functionally less well-differentiated autonomic nervous system.

More research will be required to describe the functional relationships between perceptual discrimination and autonomic differentiation and the role learning plays in both, and their interactions.

IV. Conclusions.

The desirability of utilizing the digital computer for processing psychophysiological data is more obvious than ever. This study has clarified somewhat the problems in doing so and the specifications required for a practicable system. The difficulties which we experienced were due to an underestimation of the magnitude of the task and an over-estimation of our engineering resources. The best approach now (1967) would appear to be the use of an on-line type of computer with integral A/D and D/A converters and sampling under computer program control. Both analog and digital tape storage should be provided as backup when the computer is not available during data acquisition or when more computing is required than can be done in real time or when much less computing is required than real time requires so as to enable the computer to use its full speed potential by tape speedup.

Signal conditioning, including automatic editing by pattern recognition and less exotic methods, should be done both by analog and digital methods at various stages of the signals' progress through the system. An optimum compromise between early on-line analog signal conditioning and later digital manipulation must be worked out so as to maximize signal/noise ratio under the constraints of engineering and apparatus costs, signal distortion (such as lags due to analog filtering), digital computer speed, computing costs and time available. The nature of the variable, the parameters desired from it, and the local situation with regard to engineering sophistication, apparatus, and funds available all enter the compromise equation.

Sampling rates and resolutions should be kept to a minimum required to provide the information desired since the cost of digital computing is roughly proportional to the number of bits to be processed. Flexible sampling rates under computer program control can often save a great deal of computing time.

The system must be easily calibrated by the regular operator of the acquisition system on a daily basis or more frequently if necessary. Ideally where small drifts cannot be avoided a calibration signal for the variable which it calibrates should be periodically updated (manually or automatically) and carried along with the signal and made available to the computer program which should be able to normalize the computed values to the standard calibration. Time code event mark and ID mark must be provided for both polygram and magnetic tape and a tape search system provided so as to locate any record, event, or time on the analog record. Ideally, these codes should be automatically converted to appropriate digital values so as to avoid human work and error. It might appear that the above recommendations are merely obvious good engineering practice. In the practical laboratory situation, however, numerous compromises must be made. We have found the above considerations to be essential minimal requirements that cannot be ignored.

Our computing programs have not been used enough to provide the experience necessary for any conclusions or recommendations beyond the rationale for their design. The response approach and correlations among parameters of responses matched for minimal variance in lag appear to be a useful and theoretically valid approach.

The findings that the parameters of autonomic conditioning and the epi-norepi-like physiologic response patterns have great diagnostic power indicates the method is well worthy of further study and application to other groups of interest. While there is still much to be learned by the classical conditioning method of autonomic processes in humans, the instrumental method may prove even more fruitful. Classical conditioning with laboratory stimuli may fail to involve the basic motives sufficiently to tap the significant aspects of human life. Instrumental conditioning which makes the reinforcement contingent on the physiologic response, on the other hand, is more potent in getting involvement. It also appears to be a better fit with natural real-life learning. Accordingly, a next logical step in the development of physiological indices of stress tolerance, motivational aptitude and emotional development should involve instrumental conditioning of autonomic processes.

Finally an area of motivation as much in need of clarification as the aptitude for motivational learning is that of <u>current motivation</u>. All performance tasks including intelligence, personality and aptitude tests, as well as our own tests of motivational aptitude, are influenced by the <u>current motivation</u> as they are by the aptitude under test. It would be of great value to have an index of current motivation independent of the performance and of antecedent conditions such as instructions, deprivations, or promises. We have made this investigation our highest priority for our next study. During a standard tracking task which serves as the criterion of motivation the physiological parameters of arousal will be monitored during several intensities of positive (money and visual feedback) and negative (pain) reinforcement. Conflictual motives and anxiety will also be investigated to determine whether they have characteristic physiological patterns which can be identified and removed from the physiological indices of the arousal related to the criterion performance. The characteristic physiological patterns of pleasant and unpleasant reinforcement will be a very interesting byproduct of this study.

These studies can be of value to NASA and the theory of human motivation by demonstrating and describing some of the relationships between physiological response and the motivation aspect of performance efficiency. To the extent that positive results are obtained, the prediction equations can indicate how indices of physiological response can be used to monitor the motivation being brought to bear on performance and learning.

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Table 2

IDBLK IS 047520206010

TIME	VARIABLE NO.																			
515	2006	2076	2073	2072	2073	2069	2068	2069	2073	2069	2106	2149	2149	2149	2145	2141	2143	2145	2146	210
517	2065	2057	2058	2056	2057	2053	2053	2054	2057	2042	2073	2070	2071	2071	2067	2064	2067	2069	2031	205
519	2065	2062	2061	2060	2061	2057	2057	1965	1984	1978	1978	1978	1978	1980	1976	1974	1949	1975	1972	196
521	1974	1973	1970	1972	1972	1970	2093	2103	2110	2105	2110	2103	2107	2107	2105	2042	2076	2076	2076	207
523	2081	2074	2076	2073	1974	1977	1977	1978	1980	1974	1976	1976	1978	1986	2056	2046	2055	2055	2053	204
525	2057	2055	2042	2040	2041	2038	2036	2037	2041	2037	2040	2010	1970	1969	1966	1961	1964	1966	1965	196
527	1964	2006	2006	2008	2008	2004	2004	2006	2010	2005	2014	2128	2129	2131	2127	2121	2125	2129	2128	211
529	2046	2046	2046	2044	2045	2042	2041	2042	2032	1977	1974	1976	1976	1976	1972	1969	1974	1971	2000	200
531	2008	2008	2005	2004	2004	2002	1902	1907	1906	1902	1902	1902	1902	1905	1900	1920	1977	1978	1974	197
533	1974	1976	1977	1973	1955	1970	1970	1970	1973	1969	1968	1970	1972	1956	1978	1974	1976	1978	1976	197
535	1978	1920	1894	1888	1892	1886	1886	1888	1892	1886	1874	1886	1889	1888	1884	1880	1885	1888	1842	186
537	1870	1870	1866	1865	1868	1864	1862	1914	1956	1952	1950	1952	1954	1954	1952	1862	1867	1866	1866	1861
539	1864	1866	1862	1876	1834	1828	1828	1830	1832	1828	1829	1746	1766	1764	1760	1757	1760	1760	1761	1764
541	1848	1846	1844	1843	1844	1841	1840	1818	1824	1818	1818	1818	1820	1820	1814	1810	1842	1854	1853	1849
543	1852	1853	1850	1849	1855	1942	1941	1942	1946	1941	1942	1942	1944	1928	1970	1962	1966	1970	1966	1962
545	1966	1966	1893	1899	1900	1896	1896	1896	1900	1896	1862	1894	1894	1896	1891	1886	1891	1893	1892	1890
547	2069	2078	2079	2075	2078	2073	2072	2073	2077	2026	2055	2051	2055	2055	2051	2044	2048	2053	1989	2003
549	2006	2006	2002	2004	2004	2002	2002	2002	2074	2069	2075	2069	2073	2071	2071	2065	2069	2071	2205	2219
551	2233	2225	2224	2221	2224	2221	2219	2221	2205	2236	2244	2234	2236	2237	2234	2227	2232	2233	2121	2117
553	2129	2123	2121	2117	2121	2117	2115	2113	2149	2147	2158	2149	2151	2151	2149	2144	2148	2085	2098	2089
555	2101	2096	2096	2093	2096	2093	2000	2002	2001	1998	1998	1997	1998	2001	1998	1993	2073	2084	2084	2077
557	2088	2083	2083	2080	2083	2051	2084	2083	2086	2081	2087	2081	2084	2084	2052	2046	2046	2055	2048	2041
559	2053	2046	2046	2044	2061	2075	2075	2076	2079	2074	2081	2075	2077	2078	2141	2187	2189	2193	2192	2185
561	2199	2193	2189	2160	2093	2088	2089	2087	2091	2088	2094	2088	2089	2068	2103	2095	2099	2101	2099	2096
563	2105	2101	2099	2107	2260	2263	2261	2261	2265	2261	2269	2261	2264	2133	2116	2107	2111	2111	2111	2106
565	2117	2111	2024	2018	2016	2014	2014	2014	2016	2013	2014	2014	2079	2090	2089	2083	2087	2089	2089	2083
567	2095	2071	2103	2099	2103	2097	2096	2097	2101	2099	2059	2020	2017	2020	2015	2010	2014	2017	2014	2009
569	2051	2055	2055	2052	2053	2046	2046	2046	2053	2042	2101	2091	2096	2096	2091	2085	2089	2094	2093	2088
571	2130	2125	2122	2120	2121	2118	2117	2119	2029	2034	2036	2033	2034	2034	2030	2026	2030	2027	2069	2063
573	2073	2069	2068	2065	2067	2064	2064	2069	2138	2131	2140	2131	2133	2134	2133	2126	2129	2117	2160	2153
575	2167	2160	2156	2154	2157	2153	2116	2053	2051	2045	2051	2044	2048	2051	2044	2040	2059	2154	2152	2147
577	2160	2151	2150	2149	2152	2147	2077	2083	2085	2081	2087	2081	2085	2085	2083	2006	2034	2034	2033	2027
579	2034	2034	2034	2032	2034	2123	2163	2164	2167	2163	2171	2162	2165	2165	2111	2089	2089	2093	2093	2085
581	2097	2053	2093	2089	2079	2101	2099	2100	2105	2099	2107	2099	2101	2103	2137	2160	2161	2164	2165	2157
583	2172	2165	2164	2157	2137	2140	2140	2139	2144	2140	2148	2139	2141	2143	2180	2193	2197	2199	2198	2193
585	2205	2200	2197	2189	2145	2145	2145	2144	2148	2143	2153	2145	2148	2145	2175	2175	2181	2185	2185	2175
587	2191	2184	2183	2065	2077	2073	2072	2073	2076	2075	2079	2073	1973	1986	1982	1974	1980	1982	1981	1976
589	1982	1988	2044	2040	2042	2040	2038	2038	2042	2040	2042	2078	2113	2115	2113	2105	2109	2111	2111	2105
591	2017	2026	2024	2021	2024	2022	2020	2021	2024	2018	2075	2069	2071	2073	2069	2064	2068	2071	2071	2064
593	2215	2227	2225	2222	2225	2221	2221	2221	2225	2219	2184	2175	2181	2181	2179	2173	2175	2179	2175	2014
595	2026	2026	2024	2022	2022	2021	2022	2022	2026	2130	2141	2132	2136	2137	2134	2127	2129	2134	2107	2133
597	2140	2137	2135	2132	2134	2131	2131	2051	2006	2000	2002	1998	1998	2002	1998	1994	1993	2036	2036	2032
599	2038	2038	2035	2033	2034	2033	2033	2149	2277	2271	2281	2269	2272	2273	2272	2264	2269	2264	2258	2253
601	2267	2259	2257	2255	2257	2253	2253	2189	2147	2139	2148	2139	2139	2139	2139	2133	2136	2125	2167	2157
603	2169	2165	2162	2160	2161	2160	2160	2093	2117	2111	2119	2111	2111	2115	2111	2107	2012	2026	2022	2017
605	2022	2022	2022	2020	2022	2018	2085	2087	2091	2087	2093	2086	2091	2091	2089	2081	2146	2147	2148	2140
607	2151	2145	2145	2143	2135	2042	2042	2040	2043	2040	2044	2040	2042	2043	2046	2125	2129	2133	2131	2125
609	2137	2131	2131	2125	2065	2064	2064	2064	2067	2066	2071	2064	2067	2026	2055	2044	2051	2055	2053	2044
611	2055	2055	2042	2081	2083	2081	2081	2079	2082	2079	2087	2079	2060	2081	2079	2073	2077	2079	2079	2073
613	2083	1968	1978	1976	1976	1974	1976	1974	1976	1974	1978	1998	1998	2001	1997	1990	1996	1999	1998	1984
615	2032	2030	2028	2026	2026	2024	2024	2022	1986	2022	2020	2018	2018	2021	2018	2014	2018	1957	1979	1970
617	1976	1978	1974	1974	1974	1973	1974	2089	2101	2101	2107	2099	2097	2101	2099	2092	2024	2033	2033	2026
619	2032	2034	2032	2028	2076	1970	1978	1978	1980	1978	1978	1976	1978	1981	2006	2085	2085	2088	2089	2081
621	2091	2088	2087	2077	2075	2076	2076	2075	2077	2076	2081	2075	2040	1987	1976	1972	1974	1978	1976	1971
623	1976	1977	2030	2037	2038	2037	2035	2034	2038	2037	2038	2036	2156	2168	2167	2159	2160	2165	2165	2159
625	2169	2141	2143	2139	2143	2139	2135	2137	2141	2137	2029	1987	1980	1982	1978	1973	1977	1980	1978	1965
627	2016	2016	2014	2012	2012	2010	2012	2011	2014	2064	2093	2085	2087	2089	2088	2081	2085	2059	1958	1948
629	1954	1956	1952	1950	1952	1950	1949	2011	2026	2025	2026	2022	2024	2026	2022	2008	1984	1987	1989	1980
631	1986	1988	1984	1982	1984	2013	2031	2031	2034	2032	2034	2030	2034	2034	2016	2048	2053	2056	2055	2046
633	2057	2056	2055	2048	2109	2124	2124	2123	2128	2123	2133	2123	2125	2087	2089	2079	2083	2085	2085	2079
635	2089	2087	2030	2010	2006	2006	2006	2005	2006	2003	2006	1962	1982	1982	1980	1973	1976	1980	1978	1974
637	1922	1946	1942	1939	1939	1938	1939	1937	1924	1908	1906	1906	1905	1907	1905	1899	1902	1872	1904	1897
639	1900	1902	1900	1898	1900	1898	1930	1937	1941	1938	1940	1938	1939	1942	1908	1926	1928	1931	1930	1924

Table 2, Contd.

VARIABLE NO. 3

TIME																				
515	2216	2237	2239	2229	2264	2291	2301	2288	2285	2299	2305	2293	2289	2309	2298	2273	2270	2291	2298	2275
517	2273	2293	2300	2254	2227	2233	2241	2231	2230	2241	2249	2239	2251	2289	2301	2281	2282	2305	2309	2291
519	2291	2311	2309	2289	2284	2296	2305	2292	2289	2300	2309	2277	2263	2281	2287	2271	2268	2288	2297	2288
521	2297	2315	2323	2310	2307	2318	2324	2311	2309	2341	2363	2355	2354	2371	2375	2354	2352	2372	2373	2291
523	2271	2285	2289	2275	2267	2281	2291	2273	2243	2247	2255	2241	2237	2254	2261	2240	2241	2288	2307	2289
525	2289	2309	2311	2297	2293	2308	2305	2275	2269	2281	2293	2277	2273	2291	2301	2281	2275	2293	2301	2280
527	2277	2296	2305	2291	2290	2301	2309	2297	2293	2309	2320	2305	2297	2316	2341	2331	2327	2341	2363	2333
529	2333	2350	2361	2309	2245	2244	2252	2237	2231	2243	2256	2242	2239	2255	2262	2243	2240	2257	2268	2249
531	2246	2293	2325	2315	2310	2323	2334	2323	2317	2339	2405	2411	2411	2426	2434	2416	2416	2435	2467	2507
533	2521	2544	2556	2542	2532	2540	2553	2551	2559	2575	2588	2577	2571	2586	2597	2581	2517	2344	2299	2269
535	2265	2279	2289	2277	2265	2183	2150	2128	2117	2128	2141	2127	2122	2069	1980	1938	1939	1949	1956	1938
537	1936	1937	1828	1773	1757	1768	1782	1779	1763	1777	1762	1666	1631	1641	1659	1629	1624	1642	1652	1559
539	1510	1518	1530	1516	1510	1524	1537	1477	1441	1446	1460	1442	1434	1459	1460	1405	1384	1398	1409	1388
541	1386	1406	1414	1406	1398	1410	1425	1408	1402	1415	1434	1426	1419	1435	1445	1425	1419	1434	1449	1446
543	1462	1481	1492	1479	1468	1479	1494	1486	1502	1523	1542	1526	1518	1539	1543	1526	1523	1561	1584	1568
545	1562	1580	1590	1577	1567	1582	1600	1599	1581	1594	1606	1594	1582	1601	1611	1590	1585	1602	1619	1598
547	1594	1613	1624	1652	1683	1703	1724	1711	1701	1713	1730	1717	1704	1705	1712	1693	1685	1703	1715	1709
549	1694	1714	1742	1731	1725	1735	1749	1734	1729	1740	1769	1786	1798	1817	1839	1813	1804	1818	1831	1814
551	1810	1826	1841	1830	1822	1831	1847	1839	1829	1838	1858	1845	1832	1844	1854	1838	1834	1852	1866	1849
553	1845	1859	1867	1852	1842	1854	1870	1857	1846	1857	1876	1876	1875	1893	1906	1890	1883	1898	1913	1895
555	1886	1886	1892	1874	1864	1877	1892	1882	1874	1886	1938	1937	1926	1941	1954	1934	1926	1945	1961	1962
557	1972	1993	2006	1994	1986	1993	2010	2002	1994	2009	2029	2016	2006	2021	2032	2016	2010	2026	2014	1977
559	1965	1977	1990	1977	1966	1973	1990	1998	2021	2042	2064	2047	2034	2048	2061	2043	2037	2060	2084	2069
561	2064	2079	2092	2076	2066	2077	2096	2065	2034	2040	2061	2044	2034	2046	2063	2051	2045	2083	2101	2085
563	2079	2093	2106	2089	2080	2089	2104	2121	2131	2147	2165	2151	2139	2151	2165	2151	2142	2116	2111	2091
565	2087	2100	2109	2098	2089	2103	2117	2099	2091	2191	2122	2107	2096	2109	2123	2121	2128	2149	2168	2153
567	2147	2160	2173	2161	2151	2133	2131	2113	2104	2115	2129	2115	2107	2125	2101	2057	2040	2059	2075	2055
569	2050	2065	2079	2087	2097	2114	2133	2124	2113	2121	2139	2127	2121	2172	2195	2193	2175	2195	2211	2192
571	2184	2159	2207	2187	2175	2188	2205	2195	2181	2191	2211	2203	2183	2193	2205	2190	2183	2197	2211	2197
573	2192	2225	2247	2233	2221	2236	2253	2238	2227	2239	2261	2258	2247	2260	2274	2257	2252	2271	2285	2268
575	2260	2233	2229	2213	2199	2210	2226	2215	2207	2217	2193	2145	2125	2138	2153	2137	2128	2146	2163	2143
577	2042	2003	2006	1992	1978	1990	2004	1994	1988	1933	1775	1710	1686	1698	1710	1692	1682	1699	1690	1562
579	1522	1529	1545	1533	1518	1530	1550	1541	1510	1448	1446	1433	1422	1437	1451	1436	1425	1441	1386	1313
581	1294	1308	1326	1310	1294	1306	1326	1314	1302	1319	1332	1320	1308	1318	1333	1318	1313	1321	1297	1262
583	1253	1269	1285	1274	1269	1269	1289	1254	1194	1190	1206	1194	1181	1192	1210	1193	1186	1190	1148	1110
585	1099	1114	1130	1117	1105	1115	1134	1118	1102	1111	1133	1118	1106	1118	1134	1118	1110	1114	1114	1090
587	1084	1098	1116	1100	1086	1100	1118	1090	1070	1078	1096	1085	1068	1084	1101	1078	1038	1045	1058	1041
589	1032	1046	1066	1054	1042	1046	1062	1051	1040	1048	1069	1054	1044	1062	1074	1041	1028	1046	1066	1046
591	1034	1049	1066	1056	1058	1076	1097	1084	1073	1081	1103	1093	1085	1084	1089	1070	1054	1074	1094	1077
593	1066	1081	1097	1091	1109	1116	1137	1124	1114	1123	1143	1130	1122	1129	1138	1119	1110	1126	1146	1129
595	1122	1136	1180	1215	1216	1230	1259	1239	1224	1234	1257	1246	1218	1218	1230	1214	1202	1216	1234	1221
597	1212	1227	1258	1257	1246	1258	1278	1265	1254	1266	1287	1265	1246	1257	1275	1257	1242	1259	1278	1265
599	1262	1286	1305	1292	1289	1290	1310	1297	1291	1298	1318	1307	1297	1314	1332	1313	1304	1317	1334	1321
601	1314	1320	1322	1305	1286	1298	1329	1305	1293	1302	1325	1322	1317	1334	1350	1334	1323	1339	1361	1345
603	1336	1357	1378	1365	1349	1358	1378	1366	1354	1365	1384	1348	1325	1336	1354	1338	1325	1339	1358	1339
605	1293	1254	1310	1294	1279	1287	1312	1301	1289	1286	1298	1286	1270	1282	1299	1281	1271	1285	1305	1260
607	1222	1231	1249	1235	1217	1226	1249	1238	1240	1270	1298	1289	1275	1291	1307	1289	1278	1294	1293	1261
609	1245	1259	1282	1270	1254	1262	1283	1278	1278	1293	1313	1302	1285	1297	1318	1306	1294	1316	1340	1322
611	1311	1325	1342	1330	1315	1326	1351	1346	1334	1345	1368	1357	1340	1354	1373	1355	1333	1342	1362	1345
613	1334.	1348	1366	1355	1338	1333	1348	1334	1320	1332	1352	1339	1326	1339	1368	1354	1346	1361	1382	1369
615	1359	1370	1388	1398	1390	1402	1422	1408	1393	1403	1427	1415	1400	1412	1430	1415	1405	1418	1441	1429
617	1414	1429	1449	1438	1422	1433	1452	1442	1430	1440	1461	1450	1435	1450	1470	1453	1439	1452	1473	1458
619	1438	1449	1468	1457	1440	1450	1474	1462	1445	1452	1476	1462	1447	1462	1480	1466	1454	1470	1522	1516
621	1506	1522	1542	1526	1510	1519	1546	1537	1519	1528	1548	1537	1519	1532	1549	1534	1527	1548	1572	1555
623	1544	1557	1577	1564	1549	1553	1563	1549	1537	1546	1566	1552	1537	1549	1569	1559	1554	1571	1594	1579
625	1565	1578	1596	1582	1570	1564	1571	1557	1542	1553	1569	1558	1542	1557	1590	1542	1574	1592	1614	1597
627	1586	1600	1618	1630	1629	1642	1665	1654	1641	1651	1674	1663	1651	1664	1681	1663	1649	1662	1685	1672
629	1662	1667	1678	1662	1644	1653	1672	1661	1648	1660	1690	1690	1677	1693	1716	1695	1682	1698	1719	1694
631	1674	1686	1702	1691	1675	1685	1706	1694	1676	1681	1701	1690	1681	1699	1706	1690	1678	1695	1721	1710
633	1702	1714	1732	1718	1702	1713	1734	1722	1704	1713	1730	1716	1701	1713	1734	1718	1708	1698	1699	1681
635	1670	1686	1702	1689	1677	1689	1694	1669	1654	1662	1685	1670	1657	1670	1688	1650	1628	1643	1662	1646
637	1632	1646	1666	1649	1621	1623	1642	1639	1613	1625	1649	1641	1596	1578	1590	1574	1560	1578	1597	1581
639	1561	1542	1550	1534	1518	1526	1547	1537	1523	1513	1502	1482	1464	1477	1493	1478	1468	1485	1490	1463

Table 2, Contd.

VARIABLE NO. 12

TIME																				
515	1396	1392	1396	1393	1397	1393	1394	1392	1394	1394	1396	1390	1394	1390	1396	1393	1394	1390	1394	1394
519	1394	1390	1393	1390	1394	1390	1390	1388	1392	1390	1392	1386	1390	1386	1390	1386	1388	1386	1388	1387
523	1388	1382	1388	1384	1390	1387	1388	1386	1388	1387	1389	1384	1388	1387	1392	1390	1393	1391	1394	1392
527	1394	1392	1396	1393	1398	1396	1399	1397	1402	1398	1403	1400	1404	1400	1406	1404	1404	1402	1405	1406
531	1410	1404	1410	1409	1414	1413	1414	1414	1418	1420	1424	1420	1425	1422	1428	1426	1427	1426	1430	1432
535	1438	1436	1443	1442	1451	1452	1461	1462	1468	1469	1474	1470	1478	1476	1485	1484	1486	1486	1490	1490
539	1493	1488	1494	1492	1498	1496	1497	1496	1498	1499	1502	1497	1502	1498	1504	1501	1502	1500	1502	1499
543	1502	1496	1501	1496	1502	1499	1499	1496	1499	1498	1500	1492	1498	1493	1498	1493	1492	1490	1490	1488
547	1491	1484	1488	1482	1486	1484	1484	1482	1483	1482	1484	1477	1480	1474	1480	1475	1474	1472	1474	1470
551	1474	1465	1470	1464	1470	1465	1464	1462	1464	1461	1466	1458	1462	1457	1462	1460	1458	1456	1458	1455
555	1460	1452	1454	1450	1454	1452	1451	1448	1451	1450	1454	1445	1450	1446	1452	1450	1448	1446	1450	1446
559	1451	1447	1448	1442	1446	1443	1442	1439	1442	1440	1444	1434	1442	1436	1441	1437	1436	1434	1438	1435
563	1438	1430	1438	1434	1442	1438	1440	1438	1442	1442	1446	1438	1446	1442	1445	1442	1442	1441	1444	1441
567	1448	1438	1446	1438	1446	1442	1442	1440	1444	1441	1448	1438	1446	1442	1446	1444	1445	1442	1446	1442
571	1450	1442	1446	1440	1446	1442	1442	1439	1442	1438	1444	1436	1442	1436	1441	1440	1442	1443	1454	1458
575	1473	1470	1482	1479	1486	1484	1486	1483	1486	1481	1488	1480	1486	1484	1492	1491	1494	1493	1502	1502
579	1512	1504	1514	1510	1522	1523	1528	1528	1537	1534	1538	1521	1517	1500	1494	1480	1474	1470	1468	1462
583	1466	1458	1462	1458	1462	1462	1463	1462	1470	1471	1481	1475	1486	1483	1490	1488	1490	1490	1496	1493
587	1502	1498	1506	1505	1514	1515	1522	1524	1534	1537	1547	1544	1555	1556	1566	1570	1578	1580	1588	1587
591	1599	1594	1602	1602	1608	1608	1611	1610	1618	1614	1622	1614	1622	1618	1622	1620	1624	1621	1624	1622
595	1628	1620	1627	1621	1626	1624	1626	1618	1624	1620	1626	1618	1622	1618	1622	1618	1618	1614	1620	1614
599	1620	1612	1618	1614	1618	1615	1616	1610	1613	1608	1614	1606	1610	1606	1610	1606	1606	1602	1606	1602
603	1608	1602	1606	1602	1606	1604	1604	1598	1602	1596	1600	1590	1596	1590	1594	1590	1594	1589	1594	1590
607	1596	1590	1594	1590	1594	1590	1592	1585	1590	1586	1590	1582	1587	1582	1585	1582	1585	1579	1586	1581
611	1588	1582	1586	1582	1584	1580	1582	1576	1580	1574	1579	1574	1574	1570	1574	1572	1574	1566	1572	1565
615	1570	1564	1566	1562	1566	1560	1564	1558	1564	1557	1563	1557	1560	1556	1560	1556	1558	1550	1558	1550
619	1556	1548	1550	1548	1548	1546	1549	1542	1548	1542	1548	1541	1544	1540	1542	1538	1542	1534	1540	1534
623	1539	1533	1534	1530	1532	1528	1531	1524	1528	1522	1528	1522	1525	1521	1522	1518	1525	1517	1523	1516
627	1522	1516	1518	1518	1521	1518	1521	1514	1521	1514	1520	1514	1515	1512	1513	1510	1513	1506	1510	1504
631	1510	1504	1506	1505	1508	1506	1510	1504	1510	1502	1510	1504	1506	1502	1505	1502	1506	1500	1506	1501
635	1508	1507	1514	1516	1522	1520	1528	1522	1530	1524	1530	1527	1530	1526	1530	1526	1532	1524	1533	1526
639	1534	1529	1532	1530	1536	1534	1542	1534	1544	1538										

VARIABLE NO. 23

TIME												
515	918	905	910	920	910	908	926	915	913	892	913	901
527	902	896	915	898	1478	1170	1352	956	1556	1221	910	1590
539	902	908	910	902	908	910	913	930	918	908	911	913
551	930	910	926	901	913	902	914	910	915	904	910	899
563	907	914	906	910	921	941	908	918	942	902	905	896
575	902	899	906	4061	910	913	915	924	934	974	2514	914
587	921	912	908	924	905	908	900	917	912	924	924	907
599	920	916	914	928	918	926	934	904	912	916	918	928
611	901	913	918	906	907	921	908	908	914	934	963	1061
623	948	944	945	954	1018	1000	914	921	930	913	905	914
635	918	910	915	913	934	907						

VARIABLE NO. 27

TIME												
515	1804	180	1807	1806	1808	1807	1804	1808	1800	1797	1798	1798
527	1798	1800	1802	1798	1795	1804	1798	1794	1794	1794	1798	1805
539	1810	1809	1810	1819	1810	1809	1808	1802	1805	1806	1812	1810
551	1810	1814	1812	1812	1810	1812	1812	1812	1812	1812	1810	1810
563	1809	1809	1809	1809	1808	1805	1806	1807	1809	1810	1806	1802
575	1801	1802	1812	1822	1834	1841	1848	1862	1862	1866	1872	1878
587	1842	1886	1887	1884	1876	1874	1872	1870	1868	1869	1866	1864
599	1864	1866	1864	1864	1864	1864	1860	1860	1862	1862	1862	1858
611	1857	1854	1848	1846	1849	1846	1843	1840	1842	1836	1834	1836
623	1833	1828	1826	1824	1826	1826	1827	1826	1826	1828	1826	1822
635	1824	1826	1830	1830	1834	1832						

LISTING FOR ID 047520206010 VAR 1 HEART PERIOD IN SECONDS

TIME	TYPE	AMPL	CURV	TIME	TYPE	AMPL	CURV
421.0	EE	0.90	0.	1110.0	EE	1.03	0.
~~422.0~~	BEP	0.93	0.	~~1110.1~~	~~HI~~	~~1.06~~	~~0.50~~
422.4	HI	0.96	0.35	1111.2	BEP	1.05	0.
424.1	LO	0.92	-0.16	1111.9	EF	1.00	-0.14
426.2	HI	0.98	0.55	1115.6	BF	1.00	0.
426.9	LO	0.92	-0.26	1115.9	LO	0.97	-0.77
427.8	EEP	0.98	0.	1117.0	EEP	1.06	0.
429.0	BE	1.00	0.	1117.0	BEP	~~1.06~~	~~0.~~
571.0	EE	1.04	0.	1118.0	HI	1.19	0.32
572.0	BEP	0.99	0.	1121.5	LO	0.94	-0.51
572.5	LO	0.99	-0.51	1122.8	EEP	0.99	0.
5[illegible].0	HI	1.06	0.51	1124.0	BE	1.01	0.
5[illegible].5	LO	1.00	-0.59	1230.0	EE	0.99	0.
5[illegible]7.0	HI	1.05	0.69	1231.4	BEP	0.97	0.
577.8	EEP	1.02	0.	1231.9	LO	0.95	-0.31
577.8	BEP	1.02	0.	1233.0	HI	1.01	0.56
578.5	LO	0.98	-0.36	1234.6	LO	0.97	-0.29
580.0	HI	1.07	0.43	1237.0	HI	1.05	0.55
580.4	FF	1.03	-0.21	1237.2	EEP	1.03	0.
582.4	BR	1.05	0.	1239.0	BE	0.99	0.
583.6	EEP	1.05	0.	1364.0	EE	0.97	0.
585.0	BE	1.09	0.	1365.4	BEP	0.91	0.
705.0	EE	0.98	0.	1366.2	LO	0.90	-0.54
706.6	BEP	1.04	0.	1367.2	HI	0.97	0.39
707.0	HI	1.05	0.66	1369.5	LO	0.92	-0.41
709.3	LO	0.98	-0.35	1371.2	EEP	1.01	0.
710.3	FR	1.04	0.11	1371.2	BEP	1.01	0.
712.4	EEP	1.03	0.	1373.0	HI	1.07	0.55
712.4	BEP	1.03	0.	1375.5	LO	0.98	-0.48
715.9	BF	1.04	0.	1377.0	HI	1.04	0.55
716.5	LO	1.00	-0.80	1377.0	EEP	1.04	0.
718.0	HI	1.06	0.28	1378.0	BE	1.00	0.
718.0	FEP	1.06	0.	1484.0	EE	0.97	0.
719.0	BE	1.00	0.	1485.5	LO	0.93	-0.47
855.0	EF	0.97	0.	1485.8	BEP	0.97	0.
856.4	BFP	1.03	0.	1487.0	HI	1.00	0.59
857.0	HI	1.03	0.57	1488.6	LO	0.92	-0.40
857.6	LO	0.98	-0.15	1491.6	EEP	1.01	0.
859.0	HI	1.05	0.43	1493.0	BE	1.04	0.
859.5	LO	0.98	-0.16	1635.0	EE	0.94	0.
862.2	FEP	1.05	0.	1635.3	HI	0.98	0.19
862.2	BFP	1.05	0.	1636.0	BEP	0.98	0.
864.0	HI	1.22	0.31	1636.1	EF	0.95	-0.16
865.6	EF	1.06	-0.32	1640.5	BR	0.94	0.
867.6	BP	1.06	0.	1641.8	FEP	1.09	0.
868.0	HI	1.09	0.76	1641.8	BEP	1.09	0.
868.0	FEP	1.09	0.	1642.0	HI	1.09	0.51
869.0	BE	1.05	0.	1643.5	LO	1.02	-0.63
977.0	EF	0.93	0.	1645.0	HI	1.08	0.69
978.4	BEP	0.95	0.	1645.6	LO	1.06	-0.29
979.2	HI	0.99	0.42	1647.0	HI	1.09	0.40
981.4	LC	0.94	-0.05	1647.8	EEP	1.07	0.
984.2	FEP	1.00	0.	1649.0	BE	1.04	0.
986.0	BE	1.12	0.	1769.0	EE	0.98	0.

Table 3. Heart Period in Seconds.

POINTS OF INTEREST SUMMARY

SESSION NO 04752C2C0010 NAME (CONTROL) ID 0317 TESTED MARCH 5, 1964 SECOND CONDITIONING

VARIABLE 1 HEART PERIOD IN SECONDS SUMMARY NO 1 6 POINTS OF INTEREST

EPOCH 2 112

BEG EPOCH	572.0	END EPOCH	577.8	DURATION	5.8
BEG AMP	0.99	AT TIME	572.0		
END AMP	1.02	AT TIME	577.8		
MAX AMP	1.06	AT TIME	575.0		
MIN AMP	0.99	AT TIME	572.5		
MEAN AMP	1.02	STAN DEV	0.03		

100.0 PER CENT GOOD DATA 0. PER CENT LONG EDIT 0. PER CENT SHORT EDIT

	INIT AMP	INCREMENT	DURATION	SLOPE	CURV	LATENCY	PREC DRIFT
FIRST INTERVAL	0.99	-0.01	0.5	-0.01		0.	
RESPONSE 1	0.99	0.08	2.5	0.03	0.51	0.5	0.
RESPONSE 2	1.06	-0.07	1.5	-0.05	-0.59	3.0	0.
RESPONSE 3	1.00	0.07	0.5	0.13	0.69	4.5	0.
LAST INTERVAL	1.06	-0.04	0.8	-0.05		5.0	

POINTS OF INTEREST SUMMARY

SESSION NO 04752C2C0010 N. MUTTLEY (CONTROL) ID 0317 TESTED MARCH 5, 1964 SECOND CONDITIONING

VARIABLE 1 HEART PERIOD IN SECONDS SUMMARY NO 1 5 POINTS OF INTEREST

EPOCH 3 152

BEG EPOCH	577.8	END EPOCH	583.6	DURATION	5.8
BEG AMP	1.02	AT TIME	577.8		
END AMP	1.05	AT TIME	583.6		
MAX AMP	1.07	AT TIME	580.0		
MIN AMP	0.98	AT TIME	578.5		
MEAN AMP	1.04	STAN DEV	0.03		

100.0 PER CENT GOOD DATA 0. PER CENT LONG EDIT 0. PER CENT SHORT EDIT

	INIT AMP	INCREMENT	DURATION	SLOPE	CURV	LATENCY	PREC DRIFT
FIRST INTERVAL	1.02	-0.04	0.7	-0.06		0.	
RESPONSE 1	0.98	0.09	1.5	0.06	0.43	0.7	0.
RESPONSE 2	1.07	-0.03	0.4	-0.08	-0.21	2.2	0.
LAST INTERVAL	1.05	0.00	1.2	0.00		4.6	

Table 4. Heart Period in Seconds - 6 Points of Interest.

PI LISTING FOR ID 047520206010 VAR 3 FINGER PULSE IN PERCENT FULL RANGE PAGE 4

TIME	TYPE	AMPL	CURV	TIME	TYPE	AMPL	CURV	TIME	TYPE	AMPL	CURV
421.0	EE	6.45	0.	1122.8	EEP	3.49	0.	1775.8	BEP	9.05	0.
422.0	BEP	6.70	0.	1124.0	BE	3.33	0.	1781.6	EEP	4.22	0.
423.1	HI	6.82	0.48	1230.0	EE	5.60	0.	1783.0	BE	3.57	0.
427.8	EEP	5.47	0.	1231.2	LO	5.32	-0.05	1918.0	EE	8.63	0.
429.0	BE	4.58	0.	1231.4	BEP	5.47	0.	1919.0	BEP	7.92	0.
571.0	EE	8.60	0.	1233.0	ER	5.93	0.36	1919.7	LO	7.62	-0.41
572.0	BEP	8.73	0.	1237.2	EEP	5.72	0.	1920.7	HI	8.09	0.26
574.8	HI	9.09	0.35	1237.4	BE	5.88	0.	1920.9	BSE	7.95	0.
577.8	EEP	7.65	0.	1239.0	BE	5.36	0.	1923.0	ESE	7.80	0.
577.8	BEP	7.65	0.	1364.0	EE	7.71	0.	1924.8	EEP	6.52	0.
583.6	EEP	4.24	0.	1365.4	BEP	7.05	0.	1924.8	BEP	6.52	0.
585.0	BE	3.32	0.	1366.0	LO	6.57	-0.48	1930.6	EEP	3.95	0.
705.0	EE	5.91	0.	1368.2	HI	6.90	0.52	1932.0	BE	3.31	0.
706.4	HI	6.40	0.45	1371.2	EEP	5.40	0.	2068.0	EE	6.81	0.
706.6	BEP	6.25	0.	1371.2	BEP	5.40	0.	2069.0	BEP	6.66	0.
712.4	EEP	5.14	0.	1377.0	EEP	4.07	0.	2071.2	HI	7.40	0.26
712.4	BEP	5.14	0.	1378.0	BE	3.59	0.	2074.8	EEP	6.55	0.
718.0	EEP	3.67	0.	1484.0	EE	10.51	0.	2074.8	BEP	6.55	0.
719.0	BE	3.43	0.	1485.2	LO	9.59	-0.54	2081.0	EEP	3.62	0.
855.0	EE	6.45	0.	1485.8	BEP	9.76	0.	2082.0	BE	3.75	0.
856.4	BEP	6.87	0.	1487.4	HI	10.11	0.52	2188.0	EE	10.89	0.
859.7	HI	7.37	0.47	1491.6	EEP	8.56	0.	2188.8	HI	11.23	0.58
862.2	EEP	6.35	0.	1493.0	BE	8.19	0.	2189.6	BEP	10.79	0.
862.2	BEP	6.35	0.	1635.0	EE	10.55	0.	2190.2	LO	10.09	-0.50
868.0	EEP	3.54	0.	1636.0	BEP	10.98	0.	2192.4	HI	10.69	0.48
869.0	BE	3.24	0.	1636.3	HI	11.09	0.45	2193.8	LO	10.02	-0.55
977.0	EE	7.11	0.	1637.7	LO	10.53	-0.59	2195.2	HI	11.07	0.49
977.5	LO	6.80	-0.22	1639.1	HI	11.21	0.57	2195.4	EEP	10.20	0.
978.4	BEP	7.05	0.	1641.8	EEP	9.56	0.	2197.0	BE	7.14	0.
979.7	HI	7.36	0.50	1641.8	BEP	9.56	0.	2322.0	EE	10.49	0.
981.1	LO	6.58	-0.62	1647.8	EEP	3.78	0.	2323.8	BEP	9.96	0.
982.5	HI	7.27	0.49	1649.0	BE	3.28	0.	2323.9	LO	9.91	-0.34
984.2	EEP	6.44	0.	1769.0	EE	9.95	0.	2326.1	HI	11.27	0.61
986.0	BE	5.20	0.	1769.7	LO	9.64	-0.21	2329.6	EEP	10.18	0.
1110.0	EE	9.00	0.	1770.0	BEP	9.75	0.	2329.6	BEP	10.18	0.
1111.2	BEP	9.05	0.	1771.1	HI	10.01	0.47	2335.6	EEP	4.92	0.
1117.0	EEP	6.32	0.	1775.8	EEP	9.05	0.	2337.0	BE	4.46	0.
1117.0	BEP	[illegible]	0.								

Table 5. Finger Pulse in Percent Full Range - Var. 3

POINTS OF INTEREST SUMMARY

SESSION NO 04752C2C6010 NAME (CONTROL) ID 0317 TESTED MARCH 5, 1964 SECOND CONDITIONING

VARIABLE 3 FINGER PULSE IN PERCENT FULL RANGE SUMMARY NO 1 3 POINTS OF INTEREST

EPOCH 2 1T2

BEG EPOCH	572.0	END EPOCH	577.8	DURATION	5.8
BEG AMP	8.73	AT TIME	572.0		
END AMP	7.65	AT TIME	577.8		
MAX AMP	9.09	AT TIME	574.3		
MIN AMP	7.65	AT TIME	577.8		
MEAN AMP	8.49	STAN DEV	0.75		

100.0 PER CENT GOOD DATA 0. PER CENT LONG EDIT 0. PER CENT SHORT EDIT

	INIT AMP	INCREMENT	DURATION	SLOPE	CURV	LATENCY	PREC DRIFT
FIRST INTERVAL	8.73	0.36	2.8	0.13		0.	
LAST INTERVAL	9.09	-1.45	3.0	-0.48		2.8	

POINTS OF INTEREST SUMMARY

SESSION NO 04752C2C6010 NAME (CONTROL) ID 0317 TESTED MARCH 5, 1964 SECOND CONDITIONING

VARIABLE 3 FINGER PULSE IN PERCENT FULL RANGE SUMMARY NO 1 1 POINTS OF INTEREST

EPOCH 3 1S2

BEG EPOCH	577.8	END EPOCH	583.6	DURATION	5.8
BEG AMP	7.65	AT TIME	577.8		
END AMP	4.24	AT TIME	583.6		
MAX AMP	7.65	AT TIME	577.8		
MIN AMP	4.24	AT TIME	583.6		
MEAN AMP	4.24	STAN DEV	0.		

100.0 PER CENT GOOD DATA 0. PER CENT LONG EDIT 0. PER CENT SHORT EDIT

	INIT AMP	INCREMENT	DURATION	SLOPE	CURV	LATENCY	PREC DRIFT
FIRST INTERVAL	7.65	-3.40	5.8	-0.59		0.	
LAST INTERVAL	4.24	0.	0.	0.		5.8	

Table 6. Finger Pulse in Percent Full Range - 3 Points of Interest.

TIME	TYPE	AMPL	CURV
421.0	EE	-8.16	0.
422.0	BEP	-7.97	0.
424.4	BR	-8.53	0.
427.8	EEP	-10.99	0.
429.0	BE	-11.18	0.
571.0	EE	-8.16	0.
572.0	BEP	-7.78	0.
572.4	EF	-7.64	-0.62
574.4	BR	-7.63	0.
575.8	ER	-9.85	0.60
577.8	EEP	-10.14	0.
577.8	BEP	-10.14	0.
578.4	BR	-10.19	0.
581.0	HI	-12.33	0.55
582.6	EF	-9.00	-0.62
583.6	EEP	-8.53	0.
585.0	BE	-9.62	0.
705.0	EE	-7.88	0.
706.2	ER	-8.44	0.32
706.6	BEP	-8.49	0.
708.8	BR	-8.72	0.
712.4	EEP	-12.14	0.
712.4	BEP	-12.14	0.
715.4	HI	-14.21	0.59
716.0	EF	-13.10	-0.49
718.0	BR	-13.29	0.
718.0	EEP	-13.29	0.
719.0	BE	-14.16	0.
855.0	EE	-6.80	0.
856.4	BEP	-6.52	0.
859.0	BR	-6.85	0.
862.2	EEP	-9.38	0.
862.2	BEP	-9.38	0.
864.6	HI	-11.33	0.53
866.0	LO	-10.33	-0.45
868.0	EEP	-11.14	0.
869.0	BE	-11.57	0.
977.0	EE	-8.20	0.
978.4	BEP	-7.97	0.
980.0	BR	-7.78	0.
982.0	ER	-9.85	0.30
984.2	EEP	-9.95	0.
986.0	BE	-10.80	0.
1110.0	EE	-2.50	0.
1111.2	BEP	-2.50	0.
1113.4	BR	-2.60	0.
1117.0	EEP	-6.01	0.
1117.0	BEP	-6.01	0.
1120.0	ER	-8.91	0.52
1122.0	BR	-9.38	0.
1122.8	EEP	-10.42	0.
1124.0	BE	-11.09	0.
1230.0	EE	-3.15	0.
1231.4	BEP	-2.96	0.
1237.0	BR	-4.06	0.
1237.2	EEP	-4.25	0.
1239.0	BE	-5.26	0.
1364.0	EE	-1.23	0.
1365.4	BEP	-1.55	0.
1365.6	ER	-1.87	0.29
1368.2	BR	-2.14	0.
1370.6	ER	-4.43	0.55
1371.2	EEP	-4.43	0.
1371.2	BEP	-4.43	0.
1373.0	BR	-4.76	0.
1377.0	EEP	-9.10	0.
1378.0	BE	-9.76	0.
1484.0	EE	-1.32	0.
1485.8	BEP	-1.00	0.
1488.6	BR	-1.77	0.
1491.6	EEP	-3.33	0.
1493.0	BE	-3.79	0.
1635.0	EE	-0.78	0.
1636.0	BEP	-0.87	0.
1638.8	BR	-1.14	0.
1641.8	EEP	-3.15	0.
1641.8	BEP	-3.15	0.
1647.8	EEP	-9.10	0.
1649.0	BE	-10.99	0.
1769.0	EE	-1.41	0.
1770.0	BEP	-1.32	0.
1773.2	BR	-1.87	0.
1775.8	EEP	-3.33	0.
1775.8	BEP	-3.33	0.
1781.6	EEP	-8.34	0.
1783.0	BE	-9.71	0.
1918.0	EE	-2.64	0.
1919.0	BEP	-2.60	0.
1920.8	BSE	-2.41	0.
1921.8	BR	-3.10	0.
1922.6	ER	-3.65	0.50
1923.0	ESE	-4.06	0.
1924.8	EEP	-3.93	0.
1924.8	BEP	-3.93	0.
1925.4	BR	-4.11	0.
1930.6	EEP	-7.41	0.
1932.0	BE	-8.20	0.
2068.0	EE	-1.68	0.
2069.0	BEP	-1.96	0.
2072.4	BR	-2.05	0.
2074.8	EEP	-3.05	0.
2074.8	BEP	-3.05	0.
2081.0	EEP	-7.97	0.
2082.0	BE	-8.72	0.
2188.0	EE	-3.05	0.
2189.6	BEP	-2.87	0.
2192.4	BR	-3.51	0.
2193.8	ER	-4.06	0.43
2195.4	EEP	-4.11	0.
2197.0	BE	-4.16	0.
2322.0	EE	0.31	0.
2323.8	BEP	0.35	0.
2326.4	BR	-0.01	0.
2329.6	EEP	-1.87	0.
2329.6	BEP	-1.87	0.
2335.6	EEP	-7.22	0.
2337.0	BE	-7.59	0.

Table 7. Skin Potential in Millivolts - Var. 12.

POINTS OF INTEREST SUMMARY

SESSION NO 0475202C6010 **NAME** (CONTROL) ID 0317 TESTED MARCH 5, 1964 SECOND CONDITIONING

VARIABLE 12 SKIN POTENTIAL IN MILLIVOLTS SUMMARY NO 1 5 POINTS OF INTEREST

EPOCH 2 1T2

BEG EPOCH	572.0	END EPOCH	577.8	DURATION	5.8
BEG AMP	-7.78	AT TIME	572.0		
END AMP	-10.14	AT TIME	577.8		
MAX AMP	-7.64	AT TIME	572.4		
MIN AMP	-10.14	AT TIME	577.8		
MEAN AMP	-8.65	STAN DEV	1.24		

100.0 PER CENT GOOD DATA 0. PER CENT LONG EDIT 0. PER CENT SHORT EDIT

	INIT AMP	INCREMENT	DURATION	SLOPE	CURV	LATENCY	PREC DRIFT
FIRST INTERVAL	-7.78	0.14	0.4	0.35		0.	
RESPONSE 1	-7.83	-2.03	1.4	-1.45	0.60	2.4	2.0
LAST INTERVAL	-9.85	-0.28	2.0	-0.14		3.8	

POINTS OF INTEREST SUMMARY

SESSION NO 0475202C6010 **NAME** (CONTROL) ID 0317 TESTED MARCH 5, 1964 SECOND CONDITIONING

VARIABLE 12 SKIN POTENTIAL IN MILLIVOLTS SUMMARY NO 1 4 POINTS OF INTEREST

EPOCH 3 1S2

BEG EPOCH	577.8	END EPOCH	583.6	DURATION	5.8
BEG AMP	-10.14	AT TIME	577.8		
END AMP	-8.53	AT TIME	583.6		
MAX AMP	-8.53	AT TIME	583.6		
MIN AMP	-12.33	AT TIME	581.0		
MEAN AMP	-10.01	STAN DEV	1.69		

100.0 PER CENT GOOD DATA 0. PER CENT LONG EDIT 0. PER CENT SHORT EDIT

	INIT AMP	INCREMENT	DURATION	SLOPE	CURV	LATENCY	PREC DRIFT
FIRST INTERVAL	-10.14	-0.05	0.6	-0.08		0.	
RESPONSE 1	-10.19	-2.14	2.6	-0.82	0.55	0.6	0.
RESPONSE 2	-12.33	3.33	1.6	2.08	-0.62	3.2	0.
LAST INTERVAL	-9.00	0.47	1.0	0.47		4.8	

Table 8. Skin Potential in Millivolts - 3 Points of Interest.

PI LISTING FOR ID 04752020C6010 VAR 23 MUSCLE TENSION IN MICROVOLTS PAGE 6

TIME	TYPE	AMPL	CURV	TIME	TYPE	AMPL	CURV	TIME	TYPE	AMPL	CURV
421.0	EE	24.98	0.	864.0	EE	25.63	-0.50	1491.6	EEP	23.88	0.
422.0	BEP	24.98	0.	868.0	BR	24.61	0.	1493.0	BE	23.44	0.
427.8	EEP	24.98	0.	868.0	EEP	24.61	0.	1635.0	EE	24.91	0.
429.0	BE	24.03	0.	869.0	BE	93.96	0.	1636.0	BEP	22.70	0.
571.0	EE	26.92	0.	977.0	EE	24.91	0.	1641.0	BSE	23.37	0.
572.0	BEP	24.03	0.	978.4	BEP	24.76	0.	1641.8	EEP	23.37	0.
577.0	BSE	24.32	0.	984.2	EEP	24.03	0.	1641.8	BEP	23.37	0.
577.8	EEP	24.40	0.	986.0	BE	23.88	0.	1643.0	ESE	23.59	0.
577.8	BEP	24.40	0.	1110.0	EE	22.48	0.	1647.8	EEP	24.61	0.
579.0	ESE	24.51	0.	1111.2	BEP	23.[illegible]	0.	1648.0	BR	24.83	0.
583.6	EEP	28.[illegible]	0.	1116.0	BSE	24.25	0.	1649.0	BE	51.49	0.
584.0	BR	29.13	0.	1117.0	EEP	23.88	0.	1769.0	EE	23.14	0.
585.0	BE	95.32	0.	1117.0	BEP	23.88	0.	1770.0	BEP	23.44	0.
705.0	EE	23.74	0.	1118.0	ESE	23.44	0.	1775.0	BE	24.18	0.
706.6	BEP	25.34	0.	1122.8	EEP	24.25	0.	1775.8	EEP	24.18	0.
711.0	BR	26.13	0.	1123.0	BR	24.18	0.	1775.8	BEP	24.18	0.
711.0	BSE	26.13	0.	1124.0	BE	79.63	0.	2068.0	EE	25.05	0.
712.4	EEP	59.76	0.	1230.0	EE	24.32	0.	2069.0	BEP	25.34	0.
712.4	BEP	59.76	0.	1231.4	BEP	24.18	0.	2074.0	BSE	25.49	0.
713.0	ESE	70.44	0.	1237.2	EEP	23.83	0.	2074.8	EEP	26.21	0.
713.0	HI	70.44	0.50	1238.0	BR	25.56	0.	2074.8	BEP	26.21	0.
715.0	EE	27.21	-0.69	1239.0	BE	30.84	0.	2076.0	ESE	27.35	0.
718.0	BR	25.77	0.	1364.0	EE	24.83	0.	2081.0	BR	27.49	0.
718.0	EEP	25.77	0.	1365.4	BEP	24.61	0.	2081.0	EEP	27.49	0.
719.0	BE	75.46	0.	1370.0	BSE	24.91	0.	2082.0	BE	90.94	0.
855.0	EE	24.83	0.	1371.2	EEP	23.96	0.	2188.0	EE	23.74	0.
856.4	BEP	23.96	0.	1371.2	BEP	23.96	0.	2189.6	BEP	24.91	0.
861.0	BR	24.40	0.	1372.0	ESE	23.29	0.	2195.4	EEP	25.34	0.
861.0	BSE	24.40	0.	1377.0	BR	23.29	0.	2197.0	BE	25.34	0.
862.2	EEP	29.60	0.	1377.0	EEP	23.29	0.	2322.0	EE	23.14	0.
862.2	BEP	29.60	0.	1378.0	BE	75.09	0.	2323.8	BEP	23.51	0.
863.0	ESE	32.94	0.	1484.0	EE	25.05	0.	2328.0	BE	23.14	0.
863.0	HI	32.94	0.50	1485.8	BEP	23.37	0.				

Table 9. Muscle Tension in Microvolts.

POINTS OF INTEREST SUMMARY

SESSION NO 047520200010 NAME (CONTROL) ID C317 TESTED MARCH 5, 1964 SECOND CONDITIONING

VARIABLE 25 MUSCLE TENSION IN MICROVOLTS SUMMARY NO 1 3 POINTS OF INTEREST

EPOCH 2 112

BEG EPOCH	572.0	END EPOCH	577.8	DURATION	5.8
BEG AMP	24.03	AT TIME	572.0		
END AMP	24.40	AT TIME	577.8		
MAX AMP	24.40	AT TIME	577.8		
MIN AMP	24.03	AT TIME	572.0		
MEAN AMP	24.25	STAN DEV	0.19		

86.2 PER CENT GOOD DATA 0. PER CENT LONG EDIT 13.8 PER CENT SHORT EDIT

	INIT AMP	INCREMENT	DURATION	SLOPE	CURV	LATENCY	PREC DRIFT
FIRST INTERVAL	24.03	0.37	5.8	0.06		0.	
LAST INTERVAL	24.40	0.	0.	0.		5.8	

POINTS OF INTEREST SUMMARY

SESSION NO 047520200010 NAME (CONTROL) ID C317 TESTED MARCH 5, 1964 SECOND CONDITIONING

VARIABLE 25 MUSCLE TENSION IN MICROVOLTS SUMMARY NO 1 2 POINTS OF INTEREST

EPOCH 3 152

BEG EPOCH	577.8	END EPOCH	583.6	DURATION	5.8
BEG AMP	24.40	AT TIME	577.8		
END AMP	28.06	AT TIME	583.6		
MAX AMP	28.06	AT TIME	583.6		
MIN AMP	24.40	AT TIME	577.8		
MEAN AMP	26.34	STAN DEV	2.43		

79.3 PER CENT GOOD DATA 0. PER CENT LONG EDIT 20.7 PER CENT SHORT EDIT

	INIT AMP	INCREMENT	DURATION	SLOPE	CURV	LATENCY	PREC DRIFT
FIRST INTERVAL	24.40	3.66	5.8	0.63		0.	
LAST INTERVAL	28.06	0.	0.	0.		5.8	

Table 10. Muscle Tension in Microvolts - 3 Points of Interest.

PI LISTING FOR ID 047520206010 VAR 27 SKIN CONDUCTANCE IN MICROMHOS PAGE 7

TIME	TYPE	AMPL	CURV	TIME	TYPE	AMPL	CURV	TIME	TYPE	AMPL	CURV
421.0	EE	3.64	0.	1112.0	BSE	3.40	0.	1775.8	BEP	3.06	0.
422.0	BEP	3.63	0.	1114.0	ESE	3.34	0.	1777.0	BR	3.08	0.
426.0	BR	3.68	0.	1114.0	LO	3.34	-0.48	1781.6	EEP	3.25	0.
427.8	EEP	3.73	0.	1117.0	EEP	3.41	0.	1783.0	BE	3.29	0.
429.0	BE	3.75	0.	1117.0	BEP	3.41	0.	1918.0	EE	3.07	0.
571.0	EE	3.60	0.	1122.0	BSE	3.61	0.	1919.0	BEP	3.07	0.
572.0	BEP	3.61	0.	1122.8	EEP	3.61	0.	1920.0	BSE	3.07	0.
577.0	BR	3.62	0.	1124.0	ESE	3.60	0.	1923.0	ESE	3.07	0.
577.8	EEP	3.66	0.	1124.0	BE	3.60	0.	1924.8	EEP	3.11	0.
577.8	BEP	3.66	0.	1230.0	EE	3.25	0.	1924.8	BEP	3.11	0.
583.6	EEP	3.71	0.	1231.4	BEP	3.26	0.	1927.0	BR	3.11	0.
585.0	BE	[illegible]	0.	1237.2	EEP	3.29	0.	1930.6	EEP	3.21	0.
705.0	EE	3.57	0.	1239.0	BE	3.30	0.	1932.0	BE	3.26	0.
706.6	BEP	3.56	0.	1364.0	EE	3.16	0.	2068.0	EE	2.88	0.
711.0	BR	3.60	0.	1365.4	BEP	3.16	0.	2069.0	BEP	2.89	0.
712.4	EEP	3.67	0.	1369.0	BR	3.20	0.	2074.8	EEP	2.91	0.
712.4	BEP	3.67	0.	1371.2	EEP	3.26	0.	2074.8	BEP	2.91	0.
718.0	EEP	3.83	0.	1371.2	BEP	3.26	0.	2076.0	BR	2.92	0.
719.0	BE	3.83	0.	1377.0	EEP	3.42	0.	2081.0	EEP	3.13	0.
855.0	EE	3.48	0.	1378.0	BE	3.43	0.	2082.0	BE	3.21	0.
856.4	BEP	3.48	0.	1484.0	EE	3.07	0.	2188.0	EE	2.91	0.
860.0	BR	3.51	0.	1485.8	BEP	3.09	0.	2189.6	BEP	2.90	0.
862.2	EEP	3.59	0.	1491.6	EEP	3.14	0.	2192.0	HI	2.98	0.03
862.2	BEP	3.59	0.	1493.0	BE	3.16	0.	2192.0	BSE	2.98	0.
868.0	EEP	3.60	0.	1635.0	EE	3.03	0.	2194.0	ESE	2.90	0.
869.0	BE	3.60	0.	1636.0	BEP	3.02	0.	2195.4	EEP	2.89	0.
977.0	EE	3.42	0.	1641.8	EEP	3.02	0.	2197.0	BE	2.91	0.
978.4	BEP	3.45	0.	1641.8	BEP	3.02	0.	2322.0	EE	2.82	0.
982.0	BSE	3.60	0.	1644.0	BR	3.08	0.	2323.8	BEP	2.78	0.
984.0	ESE	3.56	0.	1647.6	EEP	3.28	0.	2329.6	EEP	2.82	0.
984.2	EEP	3.56	0.	1649.0	BE	3.34	0.	2329.6	BEP	2.82	0.
986.0	BE	3.57	0.	1769.0	EE	3.03	0.	2331.0	BR	2.86	0.
1110.0	EE	3.34	0.	1770.0	BEP	3.04	0.	2335.6	EEP	3.07	0.
1111.2	BEP	3.35	0.	1775.8	EEP	3.06	0.	2337.0	BE	3.09	0.
1112.0	HI	3.40	0.25								

Table 11. Skin Conductance in Micromhos.

POINTS OF INTEREST SUMMARY

SESSION NO 0475202C010 NAME (CONTROL) ID C317 TESTED MARCH 5, 1964 SECOND CONDITIONING

VARIABLE 27 SKIN CONDUCTANCE IN MICROMHOS SUMMARY NO 1 3 POINTS OF INTEREST

EPOCH 2 112

BEG EPOCH	572.C	END EPOCH	577.8	DURATION	5.8
BEG AMP	3.61	AT TIME	572.0		
END AMP	3.66	AT TIME	577.8		
MAX AMP	3.66	AT TIME	577.8		
MIN AMP	3.61	AT TIME	572.0		
MEAN AMP	3.63	STAN DEV	0.03		

100.0 PER CENT GOOD DATA 0. PER CENT LONG EDIT 0. PER CENT SHORT EDIT

	INIT AMP	INCREMENT	DURATION	SLOPE	CURV	LATENCY	PREC DRIFT
FIRST INTERVAL	3.61	C.01	5.0	0.00		0.	
LAST INTERVAL	3.62	C.05	0.8	0.C6		5.0	

POINTS OF INTEREST SUMMARY

SESSION NO 04752020C10 NAME (CONTROL) ID 0317 TESTED MARCH 5, 1964 SECOND CONDITIONING

VARIABLE 27 SKIN CONDUCTANCE IN MICROMHOS SUMMARY NO 1 1 POINTS OF INTEREST

EPOCH 3 132

BEG EPOCH	577.8	END EPOCH	583.6	DURATION	5.8
BEG AMP	3.66	AT TIME	577.8		
END AMP	3.91	AT TIME	583.6		
MAX AMP	3.91	AT TIME	583.6		
MIN AMP	3.66	AT TIME	577.8		
MEAN AMP	3.91	STAN DEV	0.		

100.0 PER CENT GOOD DATA 0. PER CENT LONG EDIT 0. PER CENT SHORT EDIT

	INIT AMP	INCREMENT	DURATION	SLOPE	CURV	LATENCY	PREC DRIFT
FIRST INTERVAL	3.66	C.25	5.8	0.04		0.	
LAST INTERVAL	3.91	C.	0.	0.		5.8	

Table 12. Skin Conductance in Micromhos - 3 Points of Interest.

NASA-Langley, 1968 — 5 CR-1122

Conversion of Data Logger Units to Physiological Values

The following formula is used to convert data logger units to physiological units: $Y = A + BX + CX^2 + DX^3$

where X = Data Logger Units (range 0 to 4095 for ± 10 volts)

and Y = Physiological Units.

The conversion values for each variable are as follows:

		A	B	C	D
Heart Period (seconds)	=	-.11063	+.000542299		
Finger Pulse Amplitude (% total range)	=	-2.03070	+.004868120		
Finger Skin Potential (MV)	=	48.5797	-.031005	-.0000057979	+.00000000013476
Integrated Muscle Potential (μV)	=	-66.842	+.132097	-.000039165	+.0000000048841
Smoothed GSR (μmhos)	=	-5.17890	+.004039820	+.000000449881	

Conversion of Voltage Changes as Recorded on the Polygraph to Changes in Physiological Units

By means of the following relationships it is possible to determine the amount of change in physiological variables from the fluctuations in voltage recorded on the polygraph.

Heart Period Change (10 mil. sec.). = .039 inch.

Finger Pulse Amplitude Change (.01% total range) = .00294 inch.

Finger Potential Change (.01 MV) = .00067 inch.

Integrated Muscle Potential Change (.01 μV) = .0002 inch.

Smoothed GSR (.01 μmhos) = .00488 inch.

Table 13