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THE EFFECT OF HIGH INTENSITY
INTERMITTENT STIMULI ON HUMAN
BEHAVIOR AND PHYSIOLOGY

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Abstract

Psychophysical studies of high intensity intermittent sound showed that intermittent tones are judged as unpleasant or painful at lower intensity levels than steady tones and that pain thresholds seemed to be related primarily to power per pulse rather than total energy in a series of pulses. Repetition rates of three pulses or beats per second had lower pain thresholds than other pulse rates tested. Compensatory tracking performance was not affected by high intensity intermittent sound but error variability was increased on a mirror-tracing task. Several methodological studies were performed in relation to physiological indices. One found that skin impedance characteristics varied widely with electrode location and that females had significantly higher skin impedance than males. Another showed that the impedance of the human skin decreased from 130 to 30 kohm as the frequency of the a-c input increased from 1 to 1000 cps. Phase angle also decreased over this frequency range. A further study showed that high intensity intermittent sound had no effect on mean heart rate, blood pressure or skin temperature, but did produce a decrease in skin impedance which was linearly related to the intensity of stimulation. The problem of auditory "driving" was then considered. Using the EEG frequency analyzer, it was found that only one subject out of ten showed a direct driving effect. However, in all subjects it was found that 10 cps pulse rate inputs at auditory pain threshold produced an inhibition of the alpha rhythm. In many instances, after the sound was turned off, the 10 per second alpha frequency increased greatly in amplitude. Evoked potentials in man were then studied using a CAT computer. It was found that maximum evoked responses to auditory clicks were obtained with monopolar leads over the motor area and the parietal area and that evoked responses to flashes of light were quite different from those to auditory pulses. Stimulus intensity and repetition rate affected some characteristics of the evoked response and the simultaneous presentation of clicks and flashes of light changed the pattern of the response. The method developed seems to be a promising approach to the study of sensory interaction. The last major study was concerned with the effect of photic stimulation, audio stimulation, hyperventilation, electric shock and conditioning and extinction trials on various physiological indices. These measures included: filtered alpha EEG, integrated alpha, GSR, respiration and heart rate. Results showed that photic stimulation produced the maximum decrease in percent time alpha, but the effect was mainly an on-off effect. Heart

rate decreases occurred during photic stimulation and during the weak auditory CS, findings which seem consistent with Lacey's concept of "environmental intake". However, neither heart rate nor respiration rate seemed to be a sensitive indicator of the effects of stimulation. The most sensitive index of conditioning seemed to be the latency of the GSR. During the course of the researches described, several techniques for psychometrically measuring affects were developed.

Contents

	<u>Page</u>
I. Auditory Psychophysics	1
II. Motor Performance Studies	3
III. Psychophysiological Studies	4
IV. Personality and Emotion Variables	7
V. Polygraphic Recording of Reactions to Various Stimuli	9
VI. Studies of Evoked Potential in Man	14
VII. Publications and Reports	18

**The Effect of High Intensity Intermittent
Stimuli on Human Behavior and Physiology**

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Summary of Research

An increasing amount of research has begun to reveal the interaction that takes place between periodic external stimulation and the biological rhythms of human physiology, particularly brain rhythms (Plutchik, 1959). For example, intermittent sounds have interesting effects, especially in the range of the alpha rhythm of the brain; to illustrate: (a) Weber's ratio for flutter rates shows a minimum in the region of 10 per second (Pollack, 1952); (b) the ability to count auditory pulses shows a limit at about 8 to 11 pulses per second; (c) a series of pulses is judged to be louder than a steady tone of the same intensity level, with this effect being relatively greatest at rates below 10 pulses per second.

In a similar way, intermittent sounds have been reported to depress blood oxygen-saturation levels and to modify EEG rhythms.

Because of the theoretical and practical significance of such observations a program of research was instituted in an effort to isolate more fully the effects of high intensity intermittent stimulation.

I. Auditory Psychophysics

An apparatus was constructed which could deliver square-wave pulses of any repetition rate and duration to a pair of calibrated earphones up to intensities of 130 decibels. Five repetition rates, ranging from 1 to 15 pulses per second, were chosen for an initial pilot study using four subjects. Pulse duration was kept constant at 40 milliseconds.

Each subject was given an audiogram and an ear examination by a medical specialist to insure normalcy before being allowed to participate in the experiment. This procedure was followed through all phases of the experiment.

The sounds were presented to the subjects in a series of ascending steps, using the method of limits, until two thresholds were obtained: "just noticeably unpleasant" and then "just noticeably painful". Several different pure tone frequencies were also used, ranging from 1000 to 4000 cps. The two most important findings of this study were that pain thresholds were reached more quickly at 3 pulses per second than at other pulse rates and that a frequency of 1000 cps was painful at a lower intensity than was 4000 cps (Plutchik, 1957).

In order to follow up these observations more fully, repetition rates of 3, 6 and 15 pulses per second and frequencies of 1000 and 2500 cps were chosen and used with ten new subjects. In addition, as a control on the effects of the transients which are produced by the square-wave pulse, it was decided to use "beats" as well. For this purpose, two audio oscillators were set to produce beats at either 3, 6 or 15 pulses per second while this was monitored by one of the pens of a Grass EEG. Two steady tones at 1000 and 2500 cps were also used. Each tone stimulus, whether intermittent, "beat", or steady was heard for a duration of four seconds. Counterbalancing was used to avoid practice effects.

The major findings were as follows:

1. Individual pain thresholds varied from about 100 db to over 130db.
2. The 2500 cps tone, irrespective of whether it was presented as a series of pulses, a series of beats, or as a steady tone, is reacted to as "unpleasant" or as "painful" at a slightly but consistently lower intensity level than the corresponding 1000 cps tone.
3. At each frequency used, intermittent tones are judged as "unpleasant" or "painful" at lower intensity levels than steady tones.
4. Repetition rates of 3 pulses or beats per second have lower or unpleasantness and pain thresholds than either 6 or 15 pulses per second.

In general, pain thresholds seemed to be related primarily to power per pulse, rather than total energy in a series of pulses (Plutchik, 1958, 1963).

One further study was performed on the threshold characteristics of intermittent sound; pain thresholds were determined for intermittent "white" noise (Plutchik, 1960) A Grason-Stadler random noise generator was introduced into the system used earlier in order to produce "white" noise. To calibrate the generator, four subjects were asked to match the loudness of a "white" noise against pure tones of 1000, 2500 and 4000 cps, which were set at various known intensity levels ranging from 90 to 120 db. Matching within this range was linear and varied only slightly as a function of frequency. The subjects were quite consistent in their matching behavior and individual differences were small.

The "white" noise was then presented at pulse rates of 3, 6, 10 and 15 per second and, as a basis for comparison, a pure tone of 1000 cps was also included in the series. All five conditions were presented in counter-

balanced order.

The results were interesting in several respects: (1) the pain thresholds for all four subjects and all pulse rates seemed to be above 130 db for "white" noise, whereas pain thresholds ranged from 106 to 121 db for the pure tone; (2) the unpleasantness thresholds for "white" noise were all 10 to 15 db higher than for the pure tone.

II. Motor Performance Studies

At this point, a study was instituted, concerned with the effect of intermittent sound on tracking behavior. Six male subjects were required to work at two tasks, mirror-tracing a star pattern and compensatory tracking of an "horizon line" moving up and down on the screen of an oscilloscope, driven by a sinusoidal input at 24 cycles per minute. The subjects could compensate for the movements of the target by manipulating a "joy" stick forward and back. The resulting path taken by the target was presented graphically by one pen of an EEG unit. Each subject's performance would be somewhere between the sine-wave path of the target and the horizontal straight line which represented perfect compensation. This performance could be represented as a ratio of lengths, i.e. length of the actual path taken by the subject's performance to the length of the theoretically best performance. These lengths, in turn, could be simply measured in centimeters by a planimeter rolled over the line representing the subject's performance. This method of scoring was determined to have very high intra and inter-individual reliability. The mirror-tracing apparatus was constructed in such a way as to allow both the total time to complete the task and the total error-time to be recorded.

At certain times during the performance on these tasks, a high intensity intermittent tone at the subject's pain threshold and at 3 pulses per second, was introduced. Each duration of stimulation was in most cases about half a minute in length.

It was found that the sound had no effect on compensatory tracking performance or upon total time taken to complete the mirror-tracing task. There was however, a significant increase in the variability of error time during the mirror-tracing. The interpretation which is suggested for these data is as follows: (a) tasks which require greater information for successful performance are more likely to be affected by high intensity intermittent sound than simpler, less redundant tasks, (this is based partly on a review of the literature); (b) tasks in which successful performance produces termination of the high intensity sound will elicit greater individual differences and thus greater variability of performance than tasks in which the onset and offset of sound is independent of the performance, (as was the case with compensatory tracking) (Plutchik, 1961). In a brief earlier study (Plutchik, 1957) it had been found that there was no effect of high intensity intermittent sound on pursuit rotor performance, a task in which

the target moves at constant speed in a circle of uniform diameter, and one in which the trial lengths are preset and independent of performance.

III. Psychophysiological Studies

It was at this point that the research started to include the recording of physiological variables. Initially, four measures were chosen: (1) skin temperature as recorded by a thermister taped to the fingers; (2) heart rate as recorded on a standard electrocardiograph; (3) GSR as measured with a constant current generator, and (4) systolic blood pressure as recorded with a continuous systolic monitor using a cuff placed on a finger. Various calibration checks were run on the equipment and then several methodological studies were begun.

One of the problems that has received attention only relatively recently is the problem of individual differences in psychophysiological responsiveness (Plutchik, 1958), and as an aspect of this, the extent of spontaneous variability. In order to study this problem, continuous recordings were made of four physiological measures -- heart rate, skin temperature, GSR and systolic blood pressure -- over two hour periods in normal, resting subjects. Random samples of the records were taken amounting to a total of 20-minutes of observation, during which time data was obtained at the end of each 15-second interval.

The results showed wide individual differences both in the degree of variability for any given subject and the mean level. For example, the range of systolic blood pressures is from 95 to 164 millimeters of mercury. The distribution for each individual subject tends to be normal but with a smaller range. Other measures tend similarly to have wide distributions which are not always normal (Bender, 1961).

One of the implications that stems from these observations concerns the problem of initial level. There have been many reports using drugs, stressors, and other stimuli which show that an 'individual's' response depends to a greater or lesser degree on his level of functioning at the time the stimulus is applied (Plutchik, 1958). If under resting conditions, a subject's blood pressure may spontaneously vary as much as 30 mm of mercury, then his blood pressure reaction to a standard stimulus is also likely to vary, and the results obtained will depend on some interaction between initial level variations and changes in the stimulus. Although no generalizations can be made at the present time about the influence of initial level, it highlights the need to consider this factor in any analysis of data.

This may be illustrated by reference to the findings of a study concerned with basal skin impedance as a function of electrode placement (Plutchik, 1964).

Ten male and ten female college students were used as subjects. Silver disc EEG electrodes $3/8$ inch in diameter without electrode paste were attached to five skin locations: the ventral surface of the first and third finger, the palm and dorsal surface of the right hand, and the ventral surface of the right forearm. A square-wave alternating current at 60 cycles per second produced by a constant current stimulator was used. Skin impedance under these conditions is directly proportional to the voltage needed to keep the current at the electrodes constant at the pre-selected value of 100 microamperes.

Seven combinations of electrode placement were selected as follows: finger-finger, finger-palm, finger-dorsum, finger-forearm, palm-dorsum, palm-forearm, and dorsum-forearm. The subjects rested for half an hour while recordings were taken from successive pairs of electrodes every 15 seconds in a counterbalanced sequence. There were 15 observations per electrode-pair per subject.

Analysis of variance of the data showed that females had significantly higher skin impedance than males and that electrode position was a significant variable.

It was also noted that there was a certain amount of drift of impedance during the half hour resting period. For example, all subjects showed a decrease in basal impedance during this period, as measured by the dorsum-forearm electrode pair. However, 12 of the 20 subjects, (and 8 of the 10 females) showed an increase in basal impedance during this same period, as measured by the finger-palm electrode placement.

Exploring this further it was then found that the number of male subjects who showed a decrease in skin impedance at a given electrode placement was almost linearly related to the mean impedance at the electrodes. This clearly seems to be an initial level phenomenon, although the relationship is not so evident with the female subjects.

These observations suggest that GSR studies should choose electrode placements partly in terms of the purposes of the experiment and should examine the data for initial level variations.

Another methodological study was then performed which was concerned with the study of a-c-frequency and current effects of skin impedance and phase angle of human skin (Plutchik and Hirsch, 1963). It was found that the impedance of the human skin decreased from approximately 130 to 30 Kohm as the frequency of a-c input increased from 1 to 1000 cycles per second. Over this same range of frequencies, the phase angles changed from -2 to -58 degrees. Changing the peak-to-peak current through the subject from 14 to 62 microamperes had no effect on either the impedance of the skin or the phase angle. These findings suggested that

the use of low frequency a-c sine wave inputs avoids some of the artifacts often associated with research on galvanic skin response, and possibly provides unequivocal measures of certain electrical characteristics of the skin.

At this point a study was begun on the effect of high intensity intermittent sound on four physiological measures, using the techniques described earlier. Auditory pain thresholds were obtained for each of 16 college students using the methods previously described. Three intensities of stimulation were then chosen on the basis of these data averaging 120 db for the "high" intensity stimulus, 110 db for the "medium" intensity stimulus and 100 for the "low" intensity stimulus. The sound was set at 2500 cps and had a repetition rate of 3 pulses per second. It was presented for 15 seconds at a time, for nine exposures. Pre and Post-stimulation levels were recorded as well as the response during stimulation.

The major findings can be reported very briefly. There was no average effect of high intensity intermittent sound on heart rate, blood pressure, or skin temperature. There was, however, a drop of skin impedance which was linearly related to the intensity of stimulation. No evidence of an initial level effect was found.

The study most recently completed was concerned with the problem of auditory driving. Photic driving is a well established and easily obtainable phenomena. Auditory driving in humans has been reported only twice as far as I know. In 1952, Goldman reported that interrupted pure tones produced auditory driving in temporal areas in two out of eight subjects. No other data was given. More recently, Neher (1961) reported that the use of sound produced by beating on a drum produced auditory driving. Here again, not enough data were presented to unequivocally evaluate the experiment.

In the present study, ten subjects were used (Plutchik, 1966). Auditory pain thresholds were determined in the usual fashion. Three intensities were selected with the maximum at pain threshold and the others either 10 or 20 db below it. Repetition ranging from rates of 3 to 15 pulses per second were used with a tone at 2500 cps.

EEG's were taken in a standard way on an eight channel electroencephalograph using bipolar recording but with a vertex lead as a common reference point. One of the channels was used to provide an EEG frequency spectrum readout using the frequency analyzer available at Hillside Hospital and made available by Dr. Max Fink. This device uses tuned filters to select out 24 frequency bands on the EEG, ranging from 3.0 to 33.0 cycles per second, and provides an index of the relative magnitude of each frequency component. The frequency analyzer was used with the occipital-vertex lead with the other five subjects. Pulse rates were presented in

counterbalanced orders and at the end of each session, photic driving was produced in all ten subjects.

A typical frequency spectrum for a subject obtained under resting conditions shows a maximum in the alpha range. Frequency spectrums for the anterior-temporal leads show more subject variability. The alpha maximum is generally not nearly so evident.

When the pulsed sounds, lasting in most cases for 10 to 20 seconds, are introduced at high intensity, no obvious changes took place in the frequency readout except for one subject during some stimulations. If an evoked effect exists, it can only be shown by statistical analysis of the data.

One approach to such an analysis is simply to record the number of frequencies in the spectrum which increase and the number which decrease when the sound stimuli are presented. Under low intensity stimulation, the percent of frequencies which increase ranges around 40-50 percent, which is not very different from spontaneous resting changes. However, at high sound intensities there are fewer increases and more decreases; this is especially noted at pulse rates of 10 per second. This seems to imply an inhibitory effect but only at very high intensities of sound and mainly in the alpha range. These findings suggest a limited interaction between the visual and auditory modalities.

Auditory driving was clearly obtained in only one subject, using an anterior-temporal EEG lead. The distribution of his frequency spectrum under resting conditions showed an elevation at 9, 10 and 11 cycles per second with the peak at 10. During stimulation at 125 db and 3 pulses per second, he showed an elevation in the frequency readout at 9 cycles per second. Stimulation at 4 pulses per second produced elevations at 4, 8 and 12 cps. He also showed driving at 5, 6, 8, 12 and 15 pulses per second. These reactions did not occur consistently even in this one subject. In many instances, just after the sound was turned on, the 10 per second alpha frequency increased greatly in amplitude.

IV. Personality and Emotion Variables

While the studies described above were being carried out, I gradually developed some views about the role of individual differences in psychophysiological research. I pointed out in a paper (1966) that there are several attitudes one may have with respect to the fact of individual differences. One approach is to take them for granted and to

measure their extent. Thus, Williams (1956) and others have described the extent of the large individual differences in physique, metabolism, brain structure, nutritional requirements and reactions to drugs, to name a few. Psychophysiological research based upon this point of view is concerned with correlating variables to the distributions of differences.

A second approach to individual differences is to assume that the differences measured are partly real and partly artifactual. The research strategy this implies is to try to distinguish between the "real" and the "artifactual" sources of variation and then to eliminate or minimize the artifacts.

A third attitude one may take toward individual differences is to assume that they reflect the phenotypic expressions of an underlying genotypic uniformity. This attitude assumes that the basic units of analysis are constant and unvarying, like the basic elements of chemistry, the fundamental particles of physics, or the genes of genetics. Individual differences are assumed to reflect mixtures or combinations of the unchanging basic elements.

This last described idea was given a formal expression in my book entitled The Emotions: Facts, Theories and a New Model, published in 1962. In this book an attempt was made to develop a model which assumed that there are eight basic emotions or adaptive patterns of reaction which can combine to produce the limitless mixed emotions and personality traits which are a part of daily experience. A large variety of studies supporting these ideas are included in the book.

In addition, an attempt was made to develop measures of the eight basic emotions that could be used in animal and human studies. While spending a summer at the Jackson Laboratories, a technique was developed for measuring individual and breed differences in timidity and approach in dogs (Plutchik and Stelzner, 1966). Independently, a different technique was developed for measuring the relative strength of the eight primary emotions in human adults (Kellerman, 1964). This approach utilizes a forced-choice format. The subject is asked to choose one word out of a series of pairs which is more descriptive of him. Each choice has been precoded as implying one or more of the emotion primaries assumed by the theory. The test is brief, objective and reliable and relatively free of the social desirability response set. It takes less than ten minutes to administer and provides a score for each of the eight primary emotions. It is now being used in a number of research settings.

Another approach was also tried for assessing mood in humans. This involved the use of single affect words such as angry, frightened, joyful, etc., with an intensity scale for each. In one study with college students, it was found that seven of the eight affect scales significantly differentiated moods associated with an examination and its return, from

a control period (Plutchik, 1966).

V. Polygraphic Recording of Reactions to Various Stimuli

Since it was decided to eventually identify some personality and emotion variables affecting psychophysiological responses, a large scale study of physiological responses to various stimulus conditions was undertaken.

A six-channel Offner Dynograph was used. Channel 1 recorded from an occipital EEG placement and gave some indication of alpha activity. Channel 2 represented the amount of alpha rhythm. The EEG signal was passed through a narrow bandpass filter with a center frequency of 10 cps so that 10 cps EEG signals would produce maximum pen deflection. Channel 3 recorded skin resistance or GSR. Channel 5 provided a measure of the subjects breathing rate and Channel 6 recorded the EKG as a pulse rate.

In all cases, the room temperature, barometric pressure and the subjects blood pressure during rest and after hyperventilation were recorded. Each session began with a 20-30 minute period of rest for each subject, while the equipment was attached and calibrated, and instructions were given. Then two one-minute rest periods were recorded with "eyes-closed" followed by a one-minute rest with "eyes open".

A photic stimulator (Strobolum) was then used to produce high intensity flashes at 10 cps. In each case a 15-second prestimulus period was followed by a 10-second stimulation period and a 15-second post-stimulation period. This whole photic stimulation sequence was repeated three times with one-to-two minute rest intervals between each repetition.

The next stimulus was a 100 decibel tone at 1000 cps delivered for 6 seconds at a time through binaural earphones. This stimulus was also repeated three times.

The third stimulus condition is forced breathing to a metronome, but at normal depth and volume. The metronome was set beating at one per second and the subject was to breath in for two seconds and out for two seconds. A pre and post stimulus period was obtained along with a 20 second period of forced rate breathing. Measures were taken on the first and last six seconds of this rhythmic breathing period, and the whole sequence was repeated three times.

The fourth stimulus condition was a repetition of the previous one except that the depth of respiration was increased so that we had a hyper-

ventilation condition.

The fifth stimulus was a six second shock delivered at an intensity judged by the subject to be "just noticeably painful". This was repeated three times with pre and post-stimulus sample records taken.

The remaining trials were concerned with a brief classical conditioning sequence. The subject was given five trials of conditioning consisting of a soft 30 decibel tone followed by a "just noticeably painful" electric shock to the fingers of one hand. Preaudio, preshock and post shock records were also sampled. Following these five conditioning trials, three trials of extinction were given. This consisted simply of the 30 decibel tone presented alone. Randomly selected intervals of from one to three minutes were used between each of the conditioning and extinction trials.

Twenty college students were used in the study, and each individual mean, with a few exceptions, is based on an N of 17 to 20.

Measures Used

Seven measures were obtained from the polygraph records:

1. The filtered alpha record was measured by the number of peaks exceeding a certain level and converted to peaks per second. This gave, in essence, a percent time alpha measure. During the rest period with eyes closed, the mean percent time alpha was approximately 50 percent while during rest with eyes open it averaged 22 percent.

2. The filtered alpha EEG was integrated. Each time the voltage built to a maximum preset value, it automatically reset to zero and began again to cumulate. The mean number of cumulations per second was the measure used. During rest with eyes closed the mean energy was 1.66 cumulations per second, while resting with eyes open led to .97 cps. In general, there is a correlation between the first and second measure but it is not perfect, mainly because the integrated EEG includes all the smaller cycles rejected by the percent time alpha measure.

3. The GSR channel provided three measures: (a) the actual change in skin resistance, in ohms, associated with each stimulus condition; (b) the latency of the GSR in seconds; (c) the time in seconds it takes for the pen to reach a maximum response once the response begins. This last was determined during the first five seconds after stimulation. This fact plus the mechanical limits of the pen excursion make the specific figures obtained suspect, so that this will be treated mainly as a quantitative measure.

4. The respiration rate was measured by the mean number of maximums reached per second.

5. The heart rate was measured by the mean number of pulses per second and was converted into the mean number of beats per minute.

Major Results of Polygraphic Study

The findings for each of the stimulus conditions will first be presented separately and then a comparison of the conditions will be made.

Photic Stimulation: As the photic stimulus comes on, the percent time alpha dropped from a mean of 45 percent to around 32 percent in the first five seconds of stimulation. This was followed by an increase to 40 percent during the last five seconds of stimulation and another drop to 34 percent when the flickering light was turned off. The integrated alpha values showed the same trend. The pattern suggest a brief EEG desynchronization associated with both the onset and offset of the flickering light.

During stimulation the GSR went steadily down with a change in the first five seconds of 3777 ohms. The GSR response began after a mean latency of 1.16 seconds and reached a maximum change after approximately three seconds. There seems to be a GSR adaptation effect since the GSR drop got smaller on each of the three successive trials.

In each of the three trials, the heart rate decreased slightly but consistently during photic stimulation. In six out of six cases the heart rate during the first and second five-second periods was lower than the pre or post-stimulus heart rate. The maximum change was from a mean of 74 beats per minute to 69 beats per minute.

Audio Stimulation: In all three trials, the percent time alpha and the integrated alpha decreased when the 100 decibel tone was given. The mean percent decrease in percent alpha was 9 percent.

The mean latency for the GSR was 1.72 seconds and the mean drop (which occurred in all three trials) was 5900 ohms in the first five seconds. The mean time to reach a maximum was 2.16 seconds. A GSR adaptation effect occurred with the drop getting smaller on each successive trial.

There was no systematic change in either respiration rate or heart rate.

Forced Breathing (Normal Depth): In all three trials, the percent time alpha decreased by an average of 6.7% in the first five seconds after the forced breathing was begun. The integrated alpha showed the same trend.

GSR latency was 1.32 seconds with a mean drop of 4609 ohms in the first five seconds. An adaptation effect was again apparent with smaller GSR's on each successive trial. The mean time to reach a maximum value was about 2 seconds.

There seemed to be no effect on heart rate.

Forced Breathing (Deep): No clearcut trends are evident in either the percent time alpha or the integrated alpha.

Latency of the GSR was 1.03 seconds with a mean drop in the first five seconds of 6064 ohms. The time required for the GSR to reach a maximum was approximately 2.3 seconds.

The mean heart rate increased by 2.10 beats per minute during the first six seconds of hyperventilation and then dropped back to the pre-stimulus value as hyperventilation continued.

Electric Shock: The effect of a "just noticeably painful" electric shock on percent time alpha is very slight, if at all present. There is a mean decrease of about 2 percent which occurred over each of the three trials. The integrated alpha did not show any trend.

The latency of the GSR is 1.69 seconds and the mean decrease in resistance is 7000 ohms. A definite trend was observed however. The drop on the first trial was 11,000 ohms and on the third was 5,000 ohms. Mean time to reach a maximum is 2.6 seconds.

In two of the three trials there was a slight decrease in the respiratory rate.

There were no consistent changes in heart rate.

Conditioning: In this condition each subject was exposed to a weak audio tone at 30 decibels followed by a five second rest. He was then given a "just noticeably painful" electric shock to the fingers of one hand.

During all five trials, there was a consistent decrease in percent time alpha during the weak audio signal. The mean decrease was 3.4 percent. The effect of the shock itself on percent time alpha was inconsistent; on two of the trials it increased it, on two it decreased it and on one there was no change. There was no trend over the five trials on the magnitude of change during the CS or during the CS-US interval. This may be related to the fact that the shock, i.e. the unconditioned stimulus, did not produce a consistent unconditioned response. What is especially interesting here is that there was a larger and more consistent EEG response to the weak audio signal than to the strong electric shock. The ambiguity of reaction was noted with regard to the integrated alpha.

The GSR latency to shock remained about 1.7 seconds for all five trials. However, the GSR latency to the weak audio signal was around 0.80 seconds for the first three trials and 0.36 seconds for the last two trials. This suggests that a conditioned response has been established. The GSR decrease to shock was consistent over all five trials at around 6600 ohms. By this measure, the shock is acting as an unconditioned stimulus. When the audio tone first was presented, the GSR drop was about 1000 ohms. The GSR's to tone on the 3rd, 4th and 5th trials are larger but inconsistent and in one case goes in the wrong direction. There

is thus no clearcut sign that a conditioned response to the tone has been established as measured by magnitude of GSR change.

The time for the GSR to shock to reach a maximum is a little over 2 seconds, but the time for the GSR to reach a maximum during the weak tone is only about three-quarters of a second. The data on this measure suggests that the rate of change of the GSR during the weak audio signal is faster than during the electric shock. There is also a definite trend showing that the rise time to a maximum gets faster and faster as the trials continue. It begins at 1.01 seconds and drops consistently to .27 seconds. This does imply the possibility of a conditioned response.

No systematic changes in respiration rate occurred.

In 4 out of 5 trials, the heart rate decreased slightly (a maximum of 2 beats per minute) during shock. During the weak audio signal the heart rate decreased in 5 out of 5 trials relative to the pre-stimulus period by as much as 4 beats per minute. Here again, the response of a physiological system to a mild stimulus seems to be greater than to a strong stimulus. Also important to notice is that the response is a decrease in heart rate and not an increase. This finding is consistent with Lacey's concept of heart rate decreases under condition of "environmental intake".

There were no trends in heart rate or heart rate change over the five trials raising the possibility that no conditioning occurred on the basis of this measure.

Extinction: During the three extinction trials in which only the 30 db tone is presented, there are no clearcut reactions or trends as measured by percent time alpha or integrated alpha.

On the first extinction trial, the GSR decreased over 4000 ohms during the tone; on the second and third trials there was almost no mean change. This could be interpreted as indicating that extinction had occurred in one trial and that no further responses were occurring. However, GSR latency to the tone continued to decrease from .55 seconds on the first trial to .28 seconds on the second to .16 seconds on the third. This trend looks like conditioning rather than extinction.

There were no consistent trends in heart rate response, but respiration rate during the tone became consistently slower on each trial, as if the subject was holding his breath more and more (in anticipation of shock). This spontaneous and uncontrolled change could account for the apparent conditioning that seemed to occur as measured by GSR latency.

Some Overall Conclusions:

1. The maximum decrease in percent time alpha occurred during the photic stimulation and was apparently a result of a transient desynchronization associated with both the onset and offset of the stimulus.

This is consistent with the fact that photic stimulation affects the alpha rhythm (an occipital rhythm) more than other kinds of stimulation do. The GSR change to photic stimulation was less than that to any of the other stimuli. The rank-order of effect of the different stimuli on percent time alpha are: photic stimulation, auditory stimulation (100 db), forced breathing at normal depth, auditory stimulation (30 db), electric shock.

2. The percent time alpha shows more clearcut trends and effects than the integrated alpha and is recommended for future use.

3. The maximum GSR decrease in resistance is to the electric shock, but forced breathing and high intensity sound also produce large GSR's.

4. The latency of the GSR to each of the unconditioned stimuli varied from 1.03 to 1.72 seconds. The latency of the GSR to the weak audio tone used as a conditioned stimulus, however, was closer to a half-a-second. This observation is difficult to relate to previous findings.

5. The time for the GSR to reach a maximum value varied from 2 to 3 seconds in most cases.

6. Changes in respiration rate were not a sensitive indicator of any of the effects of stimulation.

7. Heart rate decreased during photic stimulation, and during the weak auditory CS. The magnitude of the mean change was never greater than 4 beats per minute. Heart rate increased slightly during hyperventilation. The heart rate decreases are consistent with Lacey's concept of "environmental intake". Heart rate, however, is not a sensitive measure of the effects of sensory stimulation. One possible reason for this is that heart rate changes may be phasic (as was found during hyperventilation) so that averages taken over a period of time do not show much of a change. More sophisticated measures of heart rate change are needed than simple averages over long periods.

8. The results of the conditioning and extinction phase of the study are quite complex. Some of the measures show no evidence of conditioning and some suggest that conditioning is taking place. The most sensitive measure seems to be the latency of the GSR and it is recommended that this measure be explored more systematically.

VI. Studies of Evoked Potentials in Man

Previous studies have suggested that intermittent stimuli have certain unusual effects that might not be predicted on the basis of knowledge of steady stimuli of the same intensity (Plutchik, 1959).

This led to an interest in studying sensory interaction using intermittent stimuli. Examination of this literature showed that although there has been a good deal of research dealing with sensory interaction, the findings have tended to be unreliable and difficult to reproduce. This appears to be due to several factors: (1) the effects obtained are usually not large; (2) the conditions of measurement are sometimes crude; and (3) many parameters influencing interaction have not been thoroughly explored.

In addition to these points, it is worth noting that most research on sensory interaction has been based upon the measurement of threshold changes as determined by the usual psychophysical methods. In contrast to this behavioral approach to interaction, a number of physiologists have used measures based directly upon the recording of electrical changes in neural tissue in animal subjects.

The relatively recent development of methods for averaging electrical signals in the presence of noise now makes it possible to study interaction effects in man at a physiological as well as behavioral level. However, in order to evaluate interactions due to simultaneous stimulation of more than one sense modality, some basic parametric data are necessary. The purpose of the research described here was to provide some basic information on the effects of stimulus intensity and stimulus rate on the evoked potential, and to determine what happens when some of these parameters are varied simultaneously. Auditory pulses and light flashes were the types of stimuli used. The subjects were four undergraduate college students who were paid for the times they participated in the experiment.

Method: The evoked potentials were measured by a Computer of Average Transients (CAT) using the EEG signals recorded by a standard Grass electroencephalograph. A Tektronix oscilloscope was used to monitor the EEG channels which provided the potentials which were averaged. The output of the CAT computer was recorded on tape and later plotted on an X-Y plotter. All measurements were made on the records provided by the X-Y plotter. In each case the evoked potential record was based upon at least 100 stimulations.

The visual stimuli were provided by a Grass photic stimulator. A special chamber was built to house the stimulator. There was a fixed distance from the eye of the subject to the light source so that a field of approximately 24 degrees was exposed. The photic stimulator was set at maximum brightness and the light intensity was reduced by means of wratten neutral tint filters over a range of three log units. Monocular viewing was used and the light entered the eye through a 2 millimeter artificial pupil. Timing pulses were produced by a Grass Stimulator which also triggered the CAT computer.

The pulses produced by the Grass Stimulator were amplified and then sent to a set of PDR-8 headphones calibrated with a 6-cc coupler. Monaural hearing was used, and the voltage input was monitored with the oscilloscope. The intensity levels used varied from close to the subject's absolute threshold to close to his pain threshold. A constant voltage transformer was used to regulate the line voltage.

The design method employed was as follows: Using all the standard EEG leads, evoked responses were obtained to a one pulse per second (1 pps) auditory click set at an intensity which the subject judged to be "just noticeably unpleasant" (JNU). This value has been found to be approximately 90-100 decibels for all subjects.

The two electrode placements which showed the maximum evoked response under these conditions were used for all subsequent conditions. It turned out that these locations were the same in all four subjects; namely, parietal area vs earlobe and motor area vs earlobe.

Pulse rates were then varied from 1 to 20 pps at a fixed intensity (JNU). Each pulse rate was repeated four times in random order.

At a later time the subjects were exposed to a 1 pps click set at four different intensity values ranging from absolute threshold to pain threshold. Only an ascending order of intensities was used with two minute rests between periods of stimulation.

One subject was tested several times with all combinations of intensity for both auditory and visual stimulation. This was done to determine whether interaction occurs and to identify some of the main factors influencing it.

Results: 1. In all subjects tested maximum evoked responses to auditory clicks were obtained with monopolar leads over the motor area and the parietal area.

2. The shape of the evoked response varied somewhat from one subject to another.

3. The evoked responses to flashes of light were quite different from those to auditory pulses.

4. The evoked response pattern was not distinguishable at pulse rates of 6 pps or greater.

5. The auditory pulse duration over the range of 1-40 milliseconds had little effect on the pattern of the evoked response.

6. As intensity of stimulation increased, the amplitude of the evoked response tended to increase, and the pattern itself also changed somewhat.

7. Repetition of stimulus conditions with a given subject sometimes produced a markedly different response.

8. During the interaction phase of the experiment the motor area response was quite different from the parietal response. Com-

bining light and sound changed the evoked response pattern but no generalization is yet possible.

Implications and Conclusions: The evoked responses to flashes of light and auditory pulses showed considerable individual variation. Even the same subject showed variation in his response from time to time, and the magnitude of the variation also depends upon the individual. Both intensity of stimulation and stimulus pulse rate have been found to affect the magnitude and pattern of the evoked response. Presenting auditory pulses in phase with flashes of light changes the evoked response, but the baseline data is too variable to unequivocally evaluate the changes.

The method that has been used does seem to be a promising approach to an evaluation of sensory interaction. Follow-up research should be designed to compare different sensory modalities and should include behavioral measures as well as physiological ones.

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Resulting from this Project

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13. ABSTRACT Intermittent tones are judged as unpleasant or painful at lower intensity levels than steady tones and pain thresholds are related primarily to power per pulse rather than total energy in a series of pulses. Skin impedance characteristics varied widely with electrode location and females had significantly higher skin impedance than males. The impedance of the human skin decreased from 130 to 30 kohm as the frequency of the a-c input increased from 1 to 1000 cps. Phase angle also decreased over this frequency range. High intensity intermittent sound had no effect on mean heart rate, blood pressure or skin temperature, but did produce a decrease in skin impedance which was linearly related to the intensity of stimulation. Using an EEG frequency analyzer, it was found in all subjects that 10 cps pulse rate inputs at auditory pain threshold produced a partial inhibition of the alpha rhythm. Maximum evoked responses to auditory clicks were obtained with monopolar leads over the motor area and the parietal area and evoked responses to flashes of light were quite different from those to auditory pulses. Stimulus intensity and repetition rate affected some characteristics of the evoked response and the simultaneous presentation of clicks and flashes of light changed the pattern of the response. Comparing photic stimulation, audio stimulation, hyperventilation, electric shock and condition, results showed that photic stimulation produced the maximum decrease in percent time alpha, but the effect was mainly an on-off one. Heart rate decreases occurred during photic stimulation and during the weak auditory CS, findings which seem consistent with Lacey's concept of "environmental intake." The most sensitive index of conditioning seemed to be the latency of the GSR. During the course of the researches described, several techniques for psychometrically measuring affects were developed.			

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Auditory Pain Thresholds						
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Individual Differences						
Skin Impedance						
Galvanic Skin Responses						
Phase Angle of Human Skin						
EEG Frequency Analysis						
Auditory Driving						
Emotions						
Photic Stimulation						
Hyperventilation'						
Percent Time Alpha						
Integrated Alpha						
Heart Rate						
GSR Latency						
Evoked Potentials						
Sensory Interaction						