Mem. Shiraume Gakuen Coll. No. 15 (1979) 51—57

STUDIES ON PAIN SENSATIONS AND REACTIONS [1][1]

Apparatus and measurement of skin potential response

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A number of methods have been devised to evoke a threshold sensation of pain and to ascertain the intensity of the stimulus required. These methods include mechanical, chemical, electrical and thermal procedures. For measuring the threshold sensation of pain by whatever methods, the stimulus must meet some requirements. According to Hardy *et al* (1953), these requirements are i) controllability and measurability of the stimulus ii) minimum of the tissue damage at pain threshold iii) the measurability of the stimulus aspect associated with changes causing pain iv) reproduceability of quantitative pain threshold, and so on.

Oppel and Hardy (1936), who demonstrated that the radiation technique could be applied quantitatively to the study of temperature sense, adapted it to measuring the intensity of the thermal stimulus required to evoke a painful sensation in the skin. Subsequently, the thermal method of evoking pain has been gradually developed and nearly fulfilled criteria mentioned above.

In recent years, Nakahama (1975) improved Hardy, Wolff and Goodell dolorimeter and made it possible to heat the aperture to the optional temperature. Sato *et al* (1977) evaluated statistically the new dolorimeter which had been modified by Nakahama, and found that it is of valuable application not only in physiological pain research but also in clinical or practical evaluation of analgesic treatments and progress follow-ups of patients.

Yamanaka and Watanabe (1977) performed a series of researches which were with the object of psychological pain reduction. They also used Hardy, Wolff and Goodell dolorimeter, which had been imported, to give the pain stimulus in the skin. They proposed that pain responses could be analyzed by signal detection theory and that biofeedback of EEG would be very efficient in therapy of pain.

In this article, the authors measure skin potential responses (SPRs) in the three degrees of thermal stimulus using modified Hardy type algesimeter, and report the construction of the apparatus and the data obtained.

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1. This study was supported in part by a Grant in Aid of Scientific Researches, Ministry of Education.

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Dolorimeter

The apparatus for measuring pain threshold by means of thermal radiation was constructed of Exposure Unit and Control Unit (Fig. 1, 2.)

Exposure Unit: The light from a 150 watt lamp was focused through a fixed aperture onto the skin of the subject. The aperture, circular in shape with a diameter of 1cm, could be heated to the optional temperature. In back of the aperture, between the lamp and aperture, was interposed a shutter which could be opened and closed quickly by an electric device.

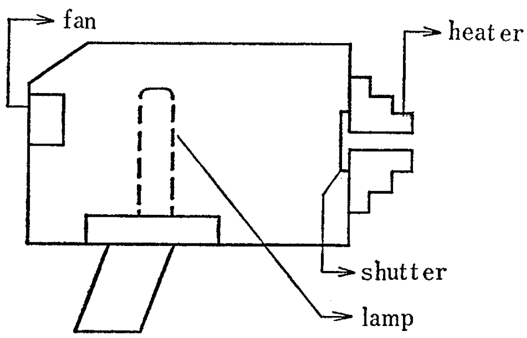

Fig. 1 Dolorimeter used in the experiment
(manufactured by Tosoku Kogyo Co., Ltd)

Control Unit: Control unit was constructed of three circuits, which were heater control, lamp control and timer, and shutter. The block diagrams of these were shown in Fig 2.

Calibration: The essential accessories to the instrument are a thermopile (Kipp and Zonen) and a voltmeter for measuring the intensity of radiant flux per unit area passing through the aperture per unit of time. The procedure for the calibration is:
1) Fit the aperture of the thermal stimulator in the aperture of the thermopile, and connect the thermopile output with the digital voltmeter. Set the diaphram of the thermopile at 4.

2) Put timer indicator on "continuous" and open the shutter. By adjusting the volume in back of the control unit, set intensity at 200 mc./sec./cm^2. (=31.2 mV in the case of this thermopile)

3) Set digital counter in front of the control unit at number 50, 100, 150, 200, 250, 300, 350, 400, 450, 500, and read millivolts on digital voltmeter five times at each level.

The data obtained were shown in Fig 3. The vertical and horizontal axes were changed into logarithm, and the method of least squares was applied. The equation which was changed to antilogarithm was as follows:

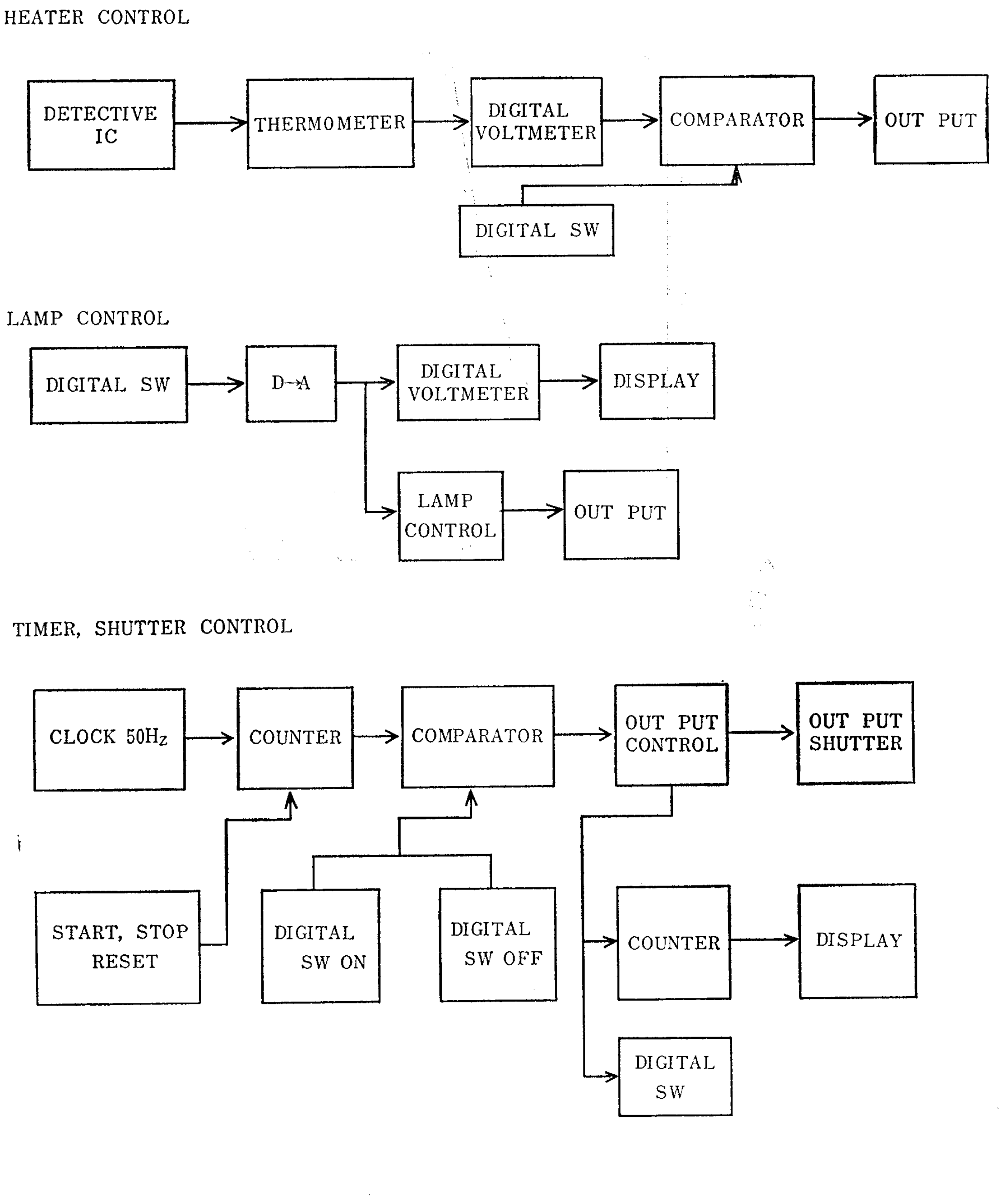

Fig. 2 Block diagrams of Control Unit

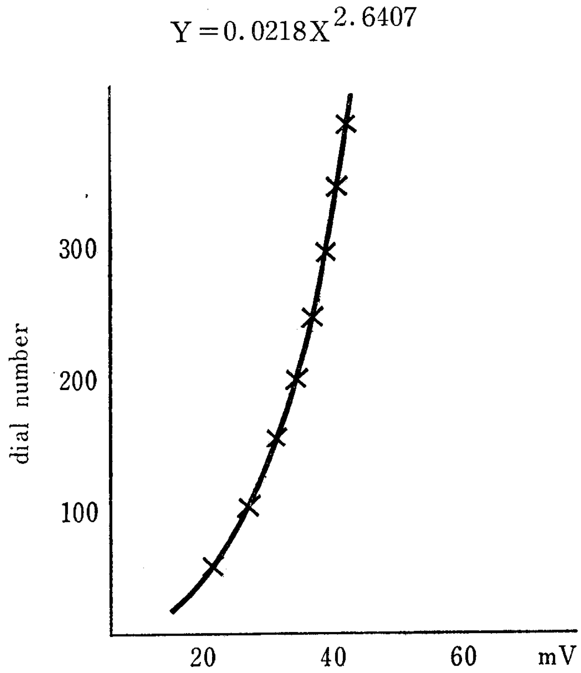

Fig. 3 Data for calibrating the dolorimeter

METHOD

Subjects: Twenty male students of Waseda University served as subjects (Ss). The average age was 20, ranging from 18 to 24. None of them had any prior experience with experiment of this kind.

Apparatus: The SPRs were recorded with equipment having stable DC amplifiers. Ag-AgCl chamber electrodes were attached by means of adhesive tape, one electrode to the middle finger of the left hand and the other on the anterior surface of the left forearm. ECG was taken by biophysiograph, a cardiotachograph. Electrodes for measuring ECG were attached to the left hand and both legs. In addition to the physiological measures, time between onset and termination of thermal stimulus was measured by a electric timer in 1/100 second. In the present study, length of time required to perceive pain and SPR measures were analyzed.

Instructions: The instructions for the subjects were as follows: It is not a test of his ability to endure pain but rather of his capacity to percieve the pain sensation. After three seconds from the signal "ready", thermal stimulus is presented on an adjacent spot. When he perceives pain sensation, he can turn off the switch by his right index finger. Turning off the switch, thermal stimulus is shut off. Be sure to turn off the switch after perceiving pain sensation.

Procedure: Subject sat down on a chair in the electrically-shielded room and the recording electrodes were attached. Furthermore, in order to insure a high degree of absorption of the radiation, the volar surface of the right forearm (3×12 cm^2) was blackened with India ink. Instructions were given, demonstration of turning off the switch was run, and questions were answered by reexplaining some parts of the instructions. Then, the experiment was begun after a few minutes delay for stabilization of the recording.

Stimulus: The stimulus intensities which were used in the experiment were 100 mc./sec./cm^2., 200 mc./sec./cm^2. and 300 mc./sec./cm^2. The stimulus presentations consisted of 15 trials and intertrial interval was approximately 40 sec. The order of presentation was rondomized, but was not counter-balanced to each subject.

RESULT AND DISCUSSION

The curves indicated in Fig. 4 show the changes of mean time to pain sensation in each stimulus intensity. Remarkable differences of mean time to pain sensation were observed in Fig. 4. According to anlysis of variance, the differences in the mean time to pain sensation among three stimulus intensities were highly significant at less than the 0.1% level ($F=132.41$ $df=2/38$). Then 1 multiple comparison was applied among three stimulus intensities. At the 1% level of significance, there were following orders in mean time to pain sensation, 100 mc./sec./cm^2.>200 mc./sec./cm^2>300 mc./sec./cm^2.

Hardy, wolff and Goodell (1940) published a series of studies of pain threshold measurements made on the forehead of three traind subjects. The average value of the pain threshold was 232 mc./sec./cm^2. with a standard deviation of $\pm$ 9 mc./sec./cm^2. Hazouri and Mueller (1950) reported that the average of pain threshold was 230 mc./sec./cm. with 100 paraplegic patients. Sato *et al* (1977) reported that using radiant heat energy of 250 mc./sec./cm^2., average time to perceiving pain was 3.0 $\pm$

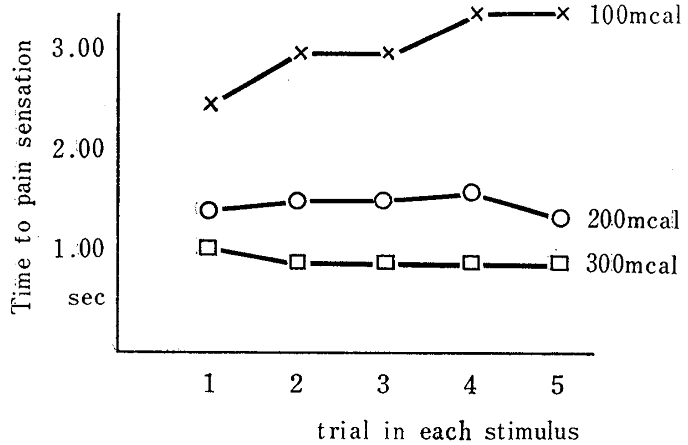

Fig. 4 Time to pain sensation

0.07 seconds. In contrast with these previous data, the result of this experiment seems to show lower threshold. This can be partially accounted for by the procedure of the present experiment in which naive (not trained) subjects were used and time mode was selected as a measure of pain threshold. The use of the forearm as test area may also have contributed to lowering the threshold.

It is worthwhile to note in Fig. 4, that time to pain sensation for 100 mc./sec./cm^2. increased with trial in contrast with other stimulus intensities. As to pain sensation for 100 mc/sec/cm^2, a significant difference was found between the first and last two trials ($t=2.245$, $df=19$, $p<.05$). No significant changes with trial were observed in other stimulus intensities. Why time to pain sensation only for 100 mc./sec./sec./cm^2. increased with trials? Now, two suggestions will be here. The first is that repeated effect may have occured only in the weaker stimulus (100 mc./sec./cm^2). The second is that interaction with stronger stimuli may have occured in the weaker stimulus.

Amplitude of each SPRs to signal "ready" and onset and/or termination of thermal stimulus was analyzed respectively. The changes of SPRs to signal "ready" with trials are shown in Fig. 5. Mean amplitude of SPRs to signal "ready" was found to decrease with trial. Remarkable trend of decrease of mean amplitude, as has been called "negative adaptation" or "habituation", was also observed in this experiment.

In fig. 6 which indicates the mean amplitude of SPRs to onset and/or termination of thermal stimulus, response to 300 mc/sec./cm^2 was largest. But no noticeable relationship was observed among two weaker stimulus intensities. This relationship was not statistically examined because of partial lack of data.

Presently, we are exploring elapsed time to pain sensation and SPRs to the stimuli varied in intensity to make clear statistically.

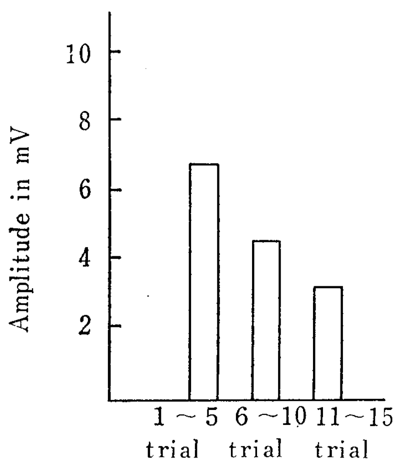

Fig. 5 Changes of amplitude of skin potential responses to signal "ready" with trial

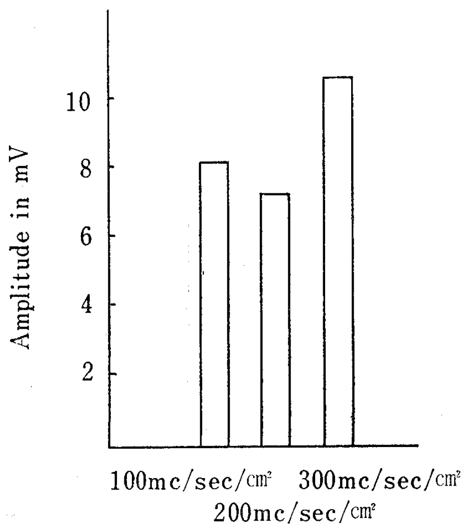

Fig. 6 Mean amplitude of skin potential responses to three stimuli varied in intensity

SUMMARY

Hardy type dolorimeter was modified and calibrated. With three stimuli varied in intensity (100mc./sec./cm., 200mc./sec./cm., and 300mc./sec./cm.), elapsed time from onset of thermal stimulus to perceiving pain sensation and skin potential responses (SPRs) were measured. The results show that elapsed time from onset of thermal stimulus to perceiving pain sensation is shorter than that of the previous data, mean amplitude of SPRs to signal "ready" decrease as a function of repetition of trial, and mean amplitude of SPRs is not correspondent with stimulus intensity.

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Hardy タイプの催痛刺激装置を改良し，キャリブレーションを行った。装置の概要，キャリブレーションの手続を概説し，実施した予備的実験結果を報告した。

男子大学生20名を対象に，100mc/sec/cm^2，200mc/sec/cm^2，300mc/sec/cm^2 の3刺激を用い，各刺激で5回，それぞれ“用意”の合図のあと 3 sec 後に墨を塗布した右前腕部に照射した。

痛知覚所要時間は，100mc/sec/cm^2 で 2.95sec，200mc/sec/cm^2 で 1.45sec，300mc/sec/cm^2 で 0.93sec であった。同時に測定した SPR では，試行が重ねられるにしたがって，“用意”に対する反射は小さくなる habituation が観察された。又，刺激強度との対応では300mc/sec/cm^{2}に対する反射が最大であったが，残り2刺激に対しては明確な結果が得られなかった。

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