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THE EFFECT OF CERTAIN CONDITIONS OF MUSCULAR CONTRACTION AND RELAXATION ON THE NON-VOLUNTARY REACTION TO AN ELECTRIC SHOCK.

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226.

I wish to express my indebtedness to the many persons who have assisted with this experiment. Dr. Edmund Jacobson is responsible for suggesting the problem, for the long course of training given the subjects, and for help and advice throughout the experiment. Professor Harvey B. Lemon and Mr. Barton Hoag of the Physics Department very kindly assisted with the apparatus. Thanks are due to the fellow students who served as subjects, not only for the time which they gave so generously, but for many helpful suggestions. Finally, I am deeply indebted to Professor Harvey A. Carr for his unfailing interest and kindness and his invaluable criticism.

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THE EFFECT OF CERTAIN CONDITIONS OF MUSCULAR CONTRACTION AND RELAXATION ON THE NON-VOLUNTARY REACTION TO AN ELECTRIC SHOCK

INTRODUCTION

The general problem of this experiment was to determine the effect of different conditions of muscular relaxation and contraction on the non-voluntary reaction to an electric shock. The stimulus was applied for a fraction of a second to two fingers of the right hand, and the response measured was the quick upward jerk of the arm which followed. The stimulus was given without warning, and the subject was instructed not to attempt any voluntary control of his reaction. Graphic records of the reaction permitted the calculation of both the extent of the movement and the length of the reaction time.

The problem was suggested by Dr. Edmund Jacobson, and the persons who served as subjects received preliminary training from him in inducing relaxation. At the end of this training they were able to assume and maintain a state of general muscular relaxation which differed radically, in the judgment of subjects and experimenter, from the ordinary muscular condition.

Apparatus

The apparatus was designed 1) to give a stimulus which could be kept constant for each subject in intensity, duration, and rate of interruption of the current, 2) to record the beginning of the stimulus on a revolving drum and 3) to obtain upon the drum a parallel record of the reaction.

The part of the apparatus designed for giving and recording the stimulus had as its essential features

1. <u>The primary circuit</u>, passing through the primary coil (F) of an inductorium and including

   a storage battery (A), the source of the current
   a revolving commutator (D), to interrupt the current
   a milliammeter (C) to measure its strength
   a rheostat (B) to control its strength

2. <u>The secondary circuit</u>, passing through the secondary coil (G) of the inductorium and including

   the stimulating electrodes (H)
   a revolving contact (r) to close the circuit
   a galvanometer (L) to measure the strength of the current

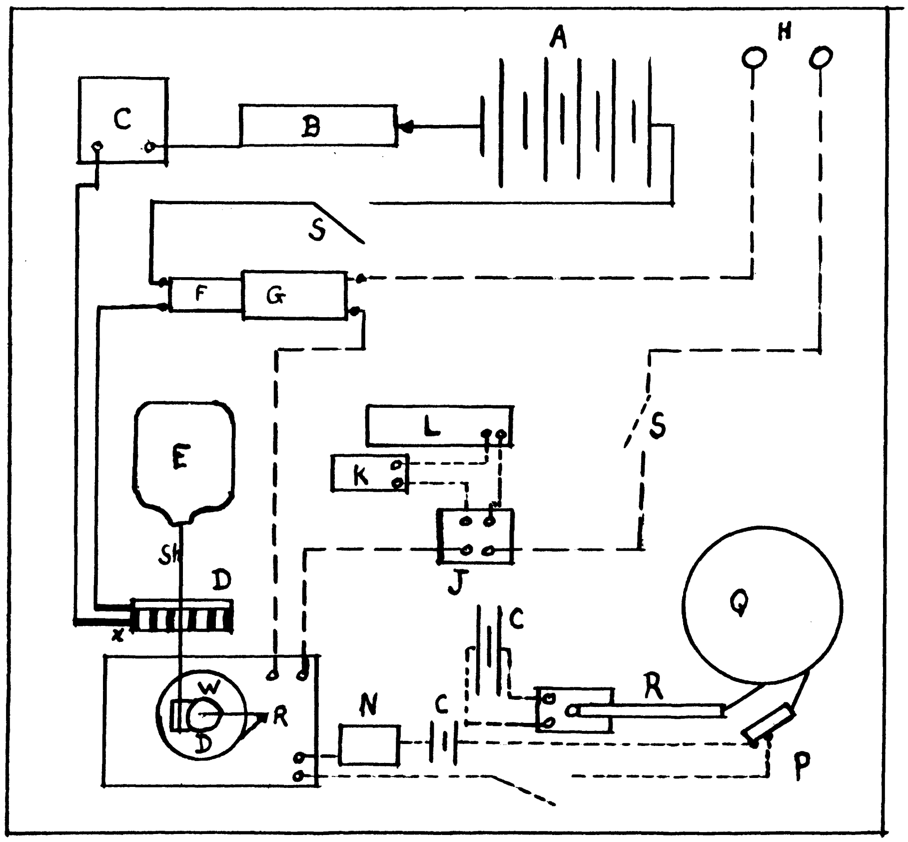
3. <u>The marker circuit</u>, including

   an electromagnetic signal marker (P), which marked the time of stimulation on the drum
   a contact which closed the circuit simultaneously with the beginning of the stimulus (inserted in d)
   a dry cell (c) actuating the magnet

4. <u>A tuning fork</u> (R), electrically driven, tracing a time line on the drum

   a dry cell (c) to actuate the fork

5. <u>The kymograph drum</u> (Q)



——— Primary circuit
— — — Secondary "
- - - - - - Other circuits

A Storage battery
B Rheostat
C Milliammeter
D Commutator
E Motor
F Primary coil
G Secondary coil
H Electrodes
J Thermo-couples
K Resistance box
L Galvanometer
M Stand holding worm and gear, fixed disc, and revolving contact

N Reverser
P Time marker
Q Kymograph drum
R Tuning fork

c dry cell
s knife switch
sh shaft of motor
x carbon contacts
w worm and gear
r revolving contact
d fixed disc
y switch key

Fig. 1 shows diagrammatically the arrangement of the apparatus; its detailed description follows.

Primary circuit

The source of the primary current was a six volt Edison storage battery with a capacity of 37 ampere hours. The current was led through the primary coil of a small inductorium of a type standardised at the Harvard laboratory, with coils 2 5/8 inches long. The commutator which interrupted the current was driven by a Leeds and Northrup D. C. motor with a constant speed of 1860 revolutions per minute. The commutator had fifty segments, of brass and a non-conducting material alternately, so that the current was made or broken 1550 times a second. The current was led through the commutator by means of two carbon contacts. A small condenser (not shown in the diagram) was placed across the gap to prevent sparking. The current was led through a D. C. milliammeter reading to 2 amperes and through a slide rheostat capable of giving any resistance up to 11 ohms. The circuit also contained a hand-operated knife switch.

Secondary circuit

The current generated in the secondary coil of the inductorium was led through two brass cups, 1 in. deep and 1 1/4 in. in diameter, filled to a constant height with a normal saline solution. In these the subject placed two fingers of one hand, the finger tips barely touching the bottom. The cups were not electrically connected except by way of the subject's fingers.

The circuit was closed by means of an automatic contact driven by the motor which drove the commutator. Attached to the shaft of the motor through a worm and gear which reduced its speed fifty times, was a revolving arm carrying a copper strip. In revolving, this strip made contact with the edge of a fixed disc of non-conducting material containing, when the apparatus was first set up, two segments of brass. By means of a switch key either one of these segments could be thrown into the circuit, so that the circuit was closed while the copper strip was passing the segment. The segments were of different lengths, permitting the circuit to be closed for a period of either 50 or 95 sigma, approximately. Later, a segment was added which permitted the closing of the circuit for 400 sigma. The circuit also contained a hand switch.

Since it was thought that the secondary current might vary even though the primary remained constant, a galvonometer was connected with this circuit by means of two vacuum thermo-couples introduced into the circuit in series. The secondary current was led through the heaters of the thermo-couples, and a d'Arsanoval galvanometer and a resistance box were placed in the other thermo-couple circuit. Thus while the galvanometer did not measure the current in amperes, its readings were always proportional to the current strength.

Marker circuit

The time marker was an ordinary electric electric signal magnet with a brass writing point which traced a line on the drum; it was actuated by the current from a dry cell. Its circuit was closed as follows. As described above, the copper contacts that closed the secondary circuit revolved around a fixed disc containing segments of brass. These segments were double; that is, they each had two layers of brass, an upper and a lower, separated from each other by insulating material. When the upper layer of any segment was thrown by means of the switch key into the secondary circuit, the lower layer was thrown into the marker circuit. Thus each segment represented a device for closing simultaneously the secondary and the marker circuits, and so recording the stimulus at the instant of its beginning.

The circuit also included a hand switch, and a reverser for changing the direction of the current through the magnet.

The time line was traced by a tuning fork of 250 d.v.; attached to one of its prongs was a light parchment point which wrote directly on the drum. The fork was kept vibrating by the current from a dry cell.

The drum was an ordinary kymograph drum; it was found more convenient to turn it by hand than to use the kymograph motor.

The motor and the tuning fork were kept running continuously during each sitting, but the primary circuit was left open except when the stimulus was given. To give a stimulus, the experimenter closed the primary circuit by means of the hand switch, adjusted the rheostat if necessary until the milliammeter gave the desired reading, and then threw in the hand switches in the secondary and the marker circuits during one rotation of the revolving contact. These two switches were really two parts of a double knife switch, so that their operation left one hand free to turn the drum. Any sound arising from the closing of the switches was completely masked by the noise of the motor.

It was stated at the beginning that this apparatus was designed to secure constancy of the stimulus in strength, duration, and rate of interruption, and simultaneity between the beginning of the stimulus and its registration on the drum. We may now review the means of testing for these conditions, and state the degree to which they were attained.

Constancy of stimulus intensity. Both the milliammeter and the galvanometer were introduced for the purpose of detecting variations in intensity of the stimulating current; the galvanometer did this directly, the milliammeter indirectly by measuring the strength of the primary current. The milliammeter could be read before each stimulus and the rheostat adjusted accordingly; but the galvanometer could not be read except at the beginning and end of a sitting, for in making this reading it was necessary to have the secondary circuit closed for several successive revolutions of the copper contact, to allow for the initial heating up of the thermo-couples. Accordingly the procedure was to set the secondary coil at an arbitrary point (not necessarily the one used for the subject) and, with the experimenter's fingers in the electodes, to find the strength of primary current which would bring the galvanometer to a certain fixed point. This was at the beginning of the sitting. Throughout the sitting the primary current was kept at the strength thus determined by means of the milliameter and the rheostat. At the end of the sitting another galvanometer reading was taken, and if this varied from the first by more than 5% the series was discarded. It was not unusual for the reading to be from 2 to 3% lower at the end of the hour than at the beginning.

As a matter of fact the galvanometer was not used until the experiment was about half over. At first it was assumed that the resistance in the secondary circuit was constant for a given subject and, this being the case, that the strength of the secondary current would vary only with that of the primary. When the galvanometer was introduced, however, it was found that there were considerable variations in the secondary current from day to day or from hour to hour even though the primary remained constant. The chief source of these seemed to be the accumulation of carbon on the commutator; such an accumulation also affected the primary current, but even after this effect had been compensated for by adjustment of the rheostat, there remained an independent effect on the secondary. From this time on the commutator was sandpapered after each stimulus, although previously this had been done only once a day.

Constancy of duration. The duration of the stimulus depended on the length of time the revolving copper strip and the brass segment in the secondary circuit were in effective contact, and this in turn depended partly on the speed of the motor and partly on the wear of the contacts and other variable factors.

The speed of the motor could be measured by counting, with the aid of a stop watch, the revolutions per minute of the contact, which was geared to the shaft of the motor. This varied less than 2% during the whole course of the experiment, and was extremely constant over short periods of time--three or four weeks, for example.

The length of contact between the copper strip and the brass segment could be directly measured by placing the strip and segment in circuit with a second time marker and taking a record on the drum; the point of the marker was held down by the magnet as long as the circuit was closed. Thus measured, the duration varied considerably in the course of the experiment, but was not found to vary by more than two sigma in any one day. A series of readings was taken every day. For the shortest segment the range was from 46 to 54 sigma, for the second, 90 to 97, and for the longest, 396 to 416; in the last case the variation was immaterial, for the duration exceeded the subjects' longest reaction time. In the first part of the experiment the second segment was used for one subject, the shortest for the others; later, the longest segment was used for all subjects.

<u>Rate of interruption</u>. The rate of interruption of the stimulus varied only with the speed of the motor, and this, as has already been shown, was highly constant.

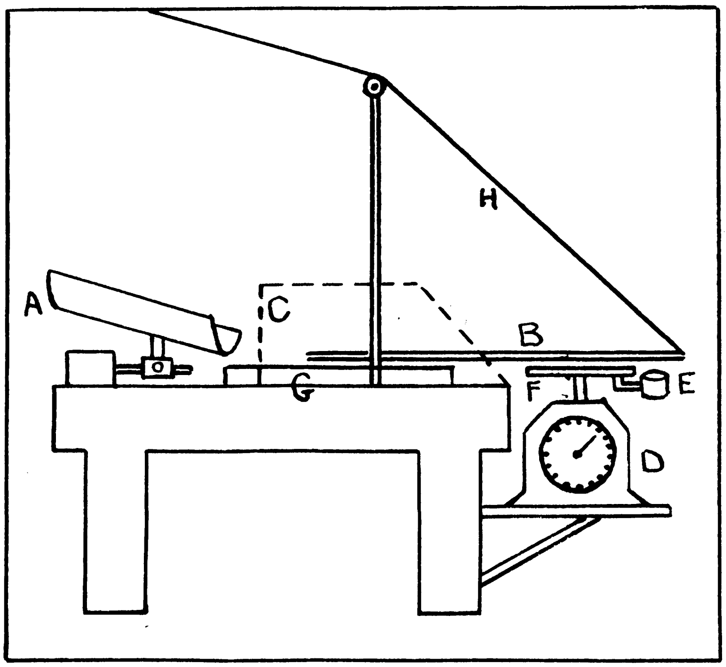
<u>Simultaneity between stimulus and marker</u>. To determine whether the closing of the marker circuit was simultaneous with that of the secondary circuit, the contacts of the latter were connected with a second time marker, and a record of both markers taken on the drum. There was always a difference of a few sigma in the time of closing of the two circuits, and this difference varied in the course of the experiment; but it was not found to vary more than one or at most two sigma in the course of any one day. Readings were taken at the beginning and end of each day's

work, and the reaction times which were read from that day's records were corrected for that day's error. That the signal marker itself was not the source of any variable error was shown by the fact that the readings from the two circuits remained the same if the markers were made to exchange places.

Such variations in the intensity and duration of the stimulus as have been described were not great enough to affect the validity of the results obtained under the conditions of the present experiment. The variability of the stimulus was independent of the experimental conditions which were under investigation; and the differences in the results obtained under these different conditions were too great to be obscured by the variability of the reactions for any one condition.

The upward jerk of the arm which followed stimulation of the fingers was recorded, along with the stimulus, on the revolving drum. The subject lay on a couch, with his head toward the table which held the apparatus for giving the stimulus. The electrodes were fastened, in a way to be described later, at one end of a low stand beside the couch. When the subject's fingers were in the electrodes, his arm was supported on this stand in such a way that the only movement possible was an upward movement of the forearm. Fig. 2 shows the stand with its attachments. The upper arm was strapped into an adjustable support attached to the stand, and the forearm and hand were strapped to a light movable frame which prevented movement at the wrist. This frame consisted of a thin bottom piece of hard rubber, 16 in. long and 5 wide, with side pieces of sheet aluminum. The third and fifth fingers projected a little beyond the end of the rubber piece; the second and fourth

Fig. 2



A Support for upper arm

B Bottom of frame attached to forearm (sides not shown)

C Guides for frame

D Spring scales

E Electrodes (fingers extend to E through holes in B)

F Pan of scales

G Felt pad for elbow

H Thread to lever writing on drum

were extended down, through two holes in the rubber, into the electrodes. Small straps over the fingers prevented their being drawn out of the electrodes except by a movement from the elbow. At each side of the frame, in a plane parallel with its side piece and almost touching it, was an upright sheet of very thick brass, firmly braced and attached to the stand. These brass guides kept the frame from moving sideways, but allowed it to move upward freely with the subject's arm. If there was friction between the side pieces of the frame and the brass guides, it was very slight, and was imperceptible to the subject; the frame was made as light as possible, and the subject did not feel that it hampered his upward movement.

The movement of the frame, and hence of the subject's arm, was recorded on the drum by means of a lever. This was attached to the end of the frame by a silk thread passing over two small brass pulleys, one above the stand, the other above the table holding the drum. The lever itself was a fine steel rod, with a thin writing point of flexible brass. The long arm was 12 1/2 inches long, the short arm, 6 1/4. The thread was attached to the long arm and the writing point to the short, so that the movement appeared on the drum reduced by one half. When the subject's arm rested on the stand the thread was pulled taut and the long arm of the lever was drawn up toward the pulley; as the subject's arm was raised the long arm was allowed to fall. A small weight attached near the fulcrum helped to bring it down.

In one series of the experiment the subject was directed either to press down with the forearm or to lift it slightly, in the period preceding the stimulus. In order that he might do this without having the position of his hand altered in relation to the electrodes, and also that he might have a means of seeing for himself whether he was following directions, the frame attached to his forearm was arranged with the end near the elbow resting on the stand, and the farther end on the pan of a spring scale (See Fig. 2). It was to the pan of the scales that the electrodes were attached. When the subject merely rested his arm on the scales, the pan was depressed somewhat by the weight of the arm. If he pressed down, the pan was depressed farther; if he lifted up, but not enough to counterbalance the weight of the arm, the pan followed his arm up. In either case the position of the electrodes relative to his arm was unchanged.

The arrangement for making the movement of the scales visible to the subject is not shown in the figure. On the wall facing the couch was pinned a sheet of cardboard, on which was drawn a circle marked off into scale divisions. A pointer fastened at the center of this circle moved around it like the hand of a clock. This pointer was attached, by a thread passing around a pulley, to the pointer of the scales. To obtain a constant downward pressure or upward lift, the subject had only to bring the pointer to a fixed point on the scale and keep it there. This device was not intended for accurate measurement of the amount of pressure, but was merely to let the subject see in a general way what he was doing, and in particular to keep him from lifting above the point to which the scale pan would rise.

In series where no pressure or lifting was called for, a clamp could be attached to the scale pan in such a way as to make it immovable.

Records.

The records obtained by means of this apparatus showed three parallel lines, 1) the time line, 2) the line indicating the beginning of the stimulus, and 3) the line representing the reaction.

The extent of movement was determined by measuring the distance between the highest point of the reaction line and its base line. This measure was subject to a certain inaccuracy, especially in the case of the more extended movements, due to the use of a lever as the recording instrument. Since the point of a lever moves in the arc of a circle rather than in a vertical line, the vertical distance which it covers is less than its total displacement; and the farther it gets from the horizontal position, the more is this the case. The vertical distance which the lever covered on the drum was therefore not exactly proportional to the extent of the subject's movement; but as the error did not exaggerate any differences found, but rather tended to represent them at less than their true value, it was disregarded.

To determine the reaction time, the distance was measured from the beginning of the stimulus line to the point indicating the stimulus, and from the beginning of the reaction line to the point where it began to leave the base line. These two distances were then laid off from the beginning of the time line, and the number of vibrations counted between the two points thus determined. Multiplied by four, this gave the reaction time in sigma.

The extent of movement could be read in every case except with one subject, who sometimes sent the lever beyond the edge of the drum. It was not always possible, however, to determine accurately the corresponding reaction time. Sometimes the reaction line rose so gradually that it was impossible to say exactly where the rise began; sometimes the fork failed to register, or the experimenter let the drum revolve too far, and blurred the time line. Hence, there is sometimes a greater number of cases in the tables showing the extent of movement than in the corresponding tables for reaction time.

In order to determine how consistently the readings were being made, a second reading was made of 20% of the records. The differences between this and the first reading were too small to affect the final averages and not large enough even for the group averages (averages of five reactions) to be of any significance.

Procedure.

Before the apparatus was set up in its final form a preliminary series, varying in length from 10 to 80 reactions, was given to ten subjects who did not serve in the later experiment. The purpose of this series was merely to determine whether there was a characteristic reaction to the particular stimulus used. The reaction was found with all these subjects to take the form of an upward jerk of the arm, usually accompanied by slighter movements in other parts of the body and often by an exclamation or at least some disturbance in breathing. With one subject the arm movement was of very limited extent and was accompanied by a stiffening of all the muscles of the body without extended movement.

The strength of stimulus necessary to evoke the reaction differed considerably for the different subjects. It was found too that a rather weak stimulus might call out a marked reaction the first three or four times it was given, and little or none after that. It was possible, however, to find a stimulus of moderate strength which would evoke a much more persistent reaction. There was no means of knowing, of course, whether the reaction might not diminish or even disappear with sufficient habituation, but, after a possible initial drop, there was no perceptible diminution in the course of twenty or thirty tests, and it seemed probable that the reaction might be counted on to persist through a fairly long series.

Seven persons, four men and three women, served as subjects throughout the experiment proper. Six of these were graduate students in psychology; one was a university graduate with some psychological training. There were, besides these, five subjects who took the preliminary training in relaxation but did not, in the time at our disposal, attain a sufficient degree of skill to serve in the experiment, and three others who learned to relax sufficiently well but were unable for various reasons to continue further.

The preliminary training in relaxation covered a period of about three months, during which the subjects came three times a week for an hour and a half each time. It was given by Dr. Edmund Jacobson, according to a method which he has developed for use in clinical and investigative work.[1] Essentially, the method is as follows. The subject begins with a single muscle or muscle group, usually the flexors of one arm. He bends his arm against resistance offered by the experimenter and notices the sensations from the muscles. He is then told to "let the arm go" and as he does so he observes the dwindling of the muscle sensations. With practice he is able to observe that these sensations persist faintly for some time after his first attempt to relax the arm, and that by letting it go still further he can further diminish the intensity of the sensations. In this way relaxation becomes progressive; it may take as long as fifteen minutes to relax one muscle group to the point where no sensations of contraction are appreciable. The subject is next taught to recognise sensations from other muscles; the chief muscle groups of the body are taken up in turn, with special attention to fine contractions in the regions of the face, eyes, tongue, and throat. As the subject begins to practise a new group he simultaneously relaxes the groups previously practised, until finally he relaxes the whole body at once.

There are several means by which an observer may judge of the subject's progress. If he is thoroughly relaxed, his posture will be limp, his breathing regular, and there will be a complete absence of even the slightest observable movements during a long period of time. If he is not well relaxed there may be rigidities of posture and irregular breathing, and there will certainly be occasional movements such as slight twitching of hands or feet, swallowing, winking of eyelids, eye movements, or twitching of the facial muscles.

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1 Jacobson, 3, 4, and 5.

The experience of our subjects confirmed Dr. Jacobson's previous observation that any considerable degree of relaxation tends to induce sleep. At the beginning, our subjects did not tend to sleep during the practise period, but as soon as they learned to relax fairly well they almost invariably went to sleep before the period was over. They themselves believed that the tendency to sleep at any particular time depended on their success in relaxing. There was an exception in the case of one subject (Subject G) who from the beginning was in the habit of sleeping during the practise hour. He never learned to observe closely the sensations from different muscles, or to relax different muscle groups at will. His method was as he expressed it the natural one of "just lying down and relaxing"; and this procedure usually led almost immediately to his going to sleep. However, as there seemed no doubt, when one observed him, that he actually did succeed in getting fairly well relaxed, it was decided to use him in the experiment.

After the subjects had attained a degree of skill in relaxing thought to be sufficient for our purposes, they were given a preliminary series, varying in length with different individuals from 20 to 80 reactions. The purpose of this was to determine a strength of stimulus appropriate for each one. The series began in each case with a stimulus too weak to elicit an arm movement; the intensity was then gradually increased to a point where this reaction was regularly called forth. It was thought desirable to obtain a reaction which should be not only regular in its appearance but also fairly pronounced, in order to give scope for the registration of pronounced differences, if such were found, under the different experimental conditions. With certain subjects this was an easy matter, as the arm movement increased markedly with increasing intensity of the stimulus. With others, the movement increased very little after its first appearance; even if the stimulus was strengthened to the point of being extremely painful the added response took the form of a general stiffening of all the muscles instead of a more extended arm movement. Subjects D, F, and to some extent Subject C, were of this type. With these subjects the experimenter was forced to be content with a response of very limited extent. With Subject G it was necessary to decrease the intensity below the point chosen in the first part of the preliminary series, for the response to this stimulus increased to a marked degree in succeeding trials.

It was originally intended to use a stimulus of 50 sigma duration for all subjects, and to keep the intensity of the stimulus constant for each subject throughout the experiment. It was found at the outset, however, in the case of Subject D that a stimulus lasting 95 sigma evoked a more pronounced response than could be elicited by the shorter one. With Subject C the apparatus was once accidentally set, after the series had been some time in progress, to give a stimulus lasting as long as the hand switch was in. The result was a stimulus more pronounced than any previously obtained; a new contact was accordingly added to the apparatus, making possible a stimulus lasting 400 sigma. At the same time the duration of the stimulus used for Subject F was changed from 50 to 400 sigma; and with subjects A and E, whose series had not yet begun, the longer stimulus was used from the outset.

With Subject E the extent of the reaction diminished in the course of the series, and the intensity of the stimulus was increased in order to secure a greater movement. The stimulus was also increased for Subject A in the course of the series; in this case the purpose was to keep her from going to sleep when she was relaxing. Thses changes in intensity and duration of the stimulus do not affect the validity of the results, for all comparisons are confined to groups of reactions taken from a single subject under constant conditions of stimulation, and differing only in respect to the conditions under investigation.

Table 1 shows the duration of the stimulus used for different subjects and in different series, and gives the data for the factors which determined its intensity. This depended on the strength of the primary current, and the point at which the secondary coil was set; the table gives the first in amperes, the second in terms of the scale of the inductorium. A decrease in the scale reading means an increase in the strength of the induced current, but the two are not proportional in amount; the change in intensity which occurs when the coil is moved over any given distance on the scale varies with the original position of the coil, but is always larger than the change in scale reading would seem to indicate.

Before the galvanometer was introduced the strength of the primary current was kept constant for each subject. With the galvanometer in use it was fixed, at the first sitting, at the point indicated in the table; after this it was corrected each day, by a method already described, on the basis of the galvanometer readings, so that actually the readings for the strength of the primary current varied slightly around the figure given in the table.

Table 1

Subject	Series	Number of Reactions	Primary Current, Amperes	Scale Reading, Inductorium	Duration of stimulus in sigma
A	I A	94	.2 *	10.2	400
A	I b	100	.2 *	9.0	400
B	I	200	.35	7.0	50
C	I a	74	.2	6.0	50
C	I b	90	.2 *	6.0	400
D	I	200	.35	7.0	95
E	I a	117	.2 *	7.0	400
E	I b	80	.2 *	6.5	400
F	I a	79	.2	6.0	50
F	I b	100	.2 *	6.5	400
G	I	184	.35	9.5	50
B	II	132	.2	6.0	50
C	II	100	.2 *	6.0	400
D	II	108	.2	6.0	95
G	II	74	.2	8.0	50

* Actual readings varied around this figure.

EXPERIMENT I. THE EFFECT OF GENERAL RELAXATION

Procedure

The series constituting Experiment I consisted of approximately 200 reactions for each subject. Half of these were taken under the condition of general relaxation, half with the subject in his ordinary or "normal" condition. The subjects came for one hour at a time, and in this period ten reactions were taken. Each subject came at a regular hour of the day, and the attempt was made to have a sitting every day, five days a week, until the series was finished; some interruptions, however, proved unavoidable.

In order to equalize for the two conditions any possible effects of habituation, the two conditions were employed alternately. This was done in one of two ways: either five reactions under one condition were followed immediately by five under the other, both conditions thus being represented at each sitting, or a whole sitting taken under one condition was followed, on the next working day, by a sitting taken under the other condition. With the first method, if the relaxed condition was given first at one sitting, the normal was given first at the next, and so on. The second method did away with the difficulty experienced by some subjects in getting out of the relaxed condition, once they had induced it.

At the beginning of each sitting the subject was strapped into the apparatus and was asked to raise his arm a few times to be sure that there was no interference with the upward movement. The general directions, given at the first two sittings and repeated occasionally in the course of the experiment were as follows:

"All that you are asked to do in this experiment is to maintain such conditions of relaxation or contraction as may be directed. Several times during the hour you will receive a slight electric shock in the fingers of your right hand. Please do not prepare to react to this shock in any particular way. If the natural reaction is a movement, let it come freely and spontaneously. Do not try to hasten it, or to inhibit it, or to influence it in any way. Try not to think about the coming stimulus.

If anything should happen to make you expect the stimulus just when it actually arrives, please report the fact."

For the relaxed condition the instructions were:

"Please relax as completely as you can; do not stop until you are told to. If the stimulus disturbs you, begin relaxing again as soon as it is over. You will be given plenty of time to get well relaxed before any stimulus is given."

For the normal condition:

"Do not relax this time. You are not asked to do anything in particular except to be sure that you are not relaxing. Please keep this in mind, and if necessary move a little occasionally to be sure that you are not relaxing unconsciously. You may talk as much as you like."

The stimuli were given without warning, from three to five minutes apart. The experimenter watched the subject's progress in relaxing, and refrained from giving any stimulus until a fairly high degree of relaxation had been established; the degree that could be expected varied, however, with the skill of the subject. With the normal condition the experimenter watched for signs of relaxation, and if they appeared, reminded the subject of the instructions, and tried to engage him in conversation. Care was taken, however, not to give a stimulus while the subject was moving or talking.

The experimenter observed the subject's reaction, noting what bodily response occurred in addition to the arm movement. At the end of the hour the subject was questioned as to his success in carrying out the instructions, and a note was made of any observations he had to offer. In the case of relaxation the subject was asked whether he had been asleep or not; if there was any doubt on this point, in the mind of either subject or experimenter, he was questioned further, as to the number of stimuli he could remember, and any other points that might throw light on the question.

Results.

Extent of Movement and Reaction Time. The results of Experiment I are summarized in Tables 2 to 4. The results for Subjects A, B, C, D, E, and F are alike in their general features and can be considered together; those for Subject G are radically different and must be reserved for later discussion.

Tables 2 and 3 deal, in different ways, with the extent of movement for the two conditions; Table 2 gives the number of cases in which this is reduced to zero--that is, in which the stimulus failed to elicit any response large enough to be registered, --and Table 3, the average extent of movement with these "zero" cases excluded. It will be seen at once from Table 2 that with relaxation all six subjects failed in a considerable proportion of cases to give any measurable reaction, while with the normal condition this occurred only once, with one subject. Similarly, Table 3 shows that the average extent of the movement, when it did occur, was less for all subjects with relaxation than normally.

It will be noticed that no measure of variability is included in the tables. The results were highly variable, and such a measure would have given no indication that the differences found were significant. Their reliability can be tested, however, in another way. Tables 5 to 15 show the average values for each condition for each sitting, making it possible to compare in each case the average for the relaxed condition with the normal average for the same sitting--or, in series where the two were not given on the same day, to compare the average for one condition with that for the other condition at the sitting immediately following. This method gives a total of 68 comparisons for the six subjects, and in 66 of these the extent of movement is less with the relaxed than with the normal condition.

In regard to reaction time the results are apparently somewhat less consistent for the different individuals. Table 4, which gives the average reaction time in sigma, shows that for Subjects A, B, C, and E the average time is longer with relaxation than with the normal condition. That this is a significant difference appears from Tables 5, 6, 7, 8, 9, 11, and 12,---47 out of 48 separate comparisons showing the same relation. For Subjects D and F the case is different. Table 4 shows that for Subject D the

Table 2.

Experiment I. % of Cases without Movement for Normal and Relaxed Conditions

Subject	Series	Normal		Relaxed	
		No. of Cases	% without movement	No. of Cases	% without movement
A	I a	44	0	50	100
A	I b	50	0	50	92.0
B	I	100	1	100	36.0
C	I a	37	0	37	18.9
C	I b	45	0	45	48.8
D	I	100	0	100	75.0
E	I a	60	0	57	10.5
E	I b	40	0	40	25.0
F	I a	39	0	40	47.5
F	I b	50	0	50	66.0
G	I	92	0	92	28.2

Table 3.

Experiment I. Average Extent of Movement for Normal and Relaxed Conditions, Zero cases excluded.

Subject	Series	Normal		Relaxed	
		No. of cases	Average cm.	No. of cases	Average cm.
A	I a	44	5.55	0	----
A	I b	50	6.11	4	.67
B	I	99	8.12	64	1.17
C	I a	37	1.28	30	.91
C	I b	45	6.14	23	.75
D	I	100	1.99	25	.79
E	I a	60	2.70	51	.75
E	I b	40	1.68	30	.44
F	I a	39	.71	19	.37
F	I b	50	.88	17	.34
G	I	92	8.90	67	---- *

* Average could not be computed because in many reactions the extent of movement exceeded the capacity of the apparatus to record.

Table 4.

Experiment I. Average Reaction Time for Normal and Relaxed Conditions.

Subject	Series	Normal		Relaxed	
		No. of cases	Average sigma	No. of cases	Average sigma
A	I a	34	169.4	0	----
A	I b	38	163.1	4	222.0
B	I	94	125.1	61	165.8
C	I a	32	120.4	25	142.1
C	I b	42	129.5	18	156.2
D	I	79	188.0	20	173.7
E	I a	53	117.4	43	145.0
E	I b	29	128.0	22	150.0
F	I a	37	120.0	16	137.8
F	I b	36	188.4	17	142.2
G	I	82	189.7	53	182.0

Table 5.

Experiment I. Averages for Successive Sittings[1], Subject A, Series I a.

Extent of Movement		Reaction Time	
Normal	Relaxed	Normal	Relaxed
5.80	0	191.4	----[2]
5.05	0	179.9	----
6.02	0	149.6	----
4.70	0	158.6	----
6.35	0	149.7	----

1 In tables 5 to 15 zero cases are excluded.

2 In this and the following tables blanks in this column indicate a group of reactions in which either there was no movement of measurable extent (see column 2) or no reaction time which could be accurately read.

Table 6.

Experiment I. Averages for Successive Sittings, Subject A, Series I b.

Extent of Movement		Reaction Time	
Normal	Relaxed	Normal	Relaxed
6.74	.2	139.3	300
6.71	.8	151.8	251
7.19	1.4	156.2	165
4.27	0.0	208.9	----
5.65	.3	140.7	172

Table 7

Experiment I. Averages for Successive Sittings, Subject B

Series I

Extent of Movement		Reaction Time	
Normal	Relaxed	Normal	Relaxed
4.86	.93	135.6	170.0
9.70	.50	122.8	155.0
2.26	0	167.0	-----
6.38	2.92	142.6	163.3
5.54	.53	130.4	176.3
11.26	2.87	119.8	151.0
11.38	1.76	105.8	144.2
6.50	1.12	122.6	156.8
4.78	1.38	129.2	144.8
11.48	.82	113.6	163.5
7.32	.50	113.6	171.4
11.52	1.10	103.6	144.0
8.84	.96	111.4	153.0
10.70	.87	130.0	245.5
4.66	.90	129.8	162.0
12.14	.20	127.0	171.6
8.50	.30	123.5	188.5
6.08	0	145.0	-----
6.68	.10	126.2	176.6
10.48	.10	119.2	189.0

Table 8.

Experiment I. Averages for Successive Sittings, Subject C,

Series I a.

Extent of Movement		Reaction Time	
Normal	Relaxed	Normal	Relaxed
1.88	1.12	108.7	142.2
1.90	2.15	110.6	138.3
1.67	.82	115.0	142.6
1.52	.65	118.6	146.6
.40	.70	133.0	128.5
1.17	.65	118.2	159.5
.64	.47	141.6	143.0
1.24	.36	117.5	154.0

Table 9.

Experiment I. Averages for Successive Sittings, Subject C,

Series I b.

Extent of Movement		Reaction Time	
Normal	Relaxed	Normal	Relaxed
4.48	.40	109.0	170.5
2.82	1.27	110.6	135.0
6.46	.37	121.4	153.3
5.22	.50	137.7	147.5
8.98	1.35	129.6	150.0
7.80	.15	152.6	174.0
7.84	0	133.6	-----
4.86	.25	140.4	158.5
6.86	.90	130.7	173.0

Table 10.

Experiment I. Averages for Successive Sittings, Subject D,

Series I.

Extent of Movement		Reaction Time	
Normal	Relaxed	Normal	Relaxed
2.57	1.22	177.7	153.6
1.76	1.20	154.0	167.0
2.05	.51	166.7	239.0
2.06	.90	160.8	161.6
3.10	0	142.2	-----
1.94	0	198.7	-----
1.57	.20	151.2	-----
1.20	.65	151.2	172.0
1.54	1.50	141.7	179.0
1.92	0	151.5	-----
1.32	0	207.2	-----
1.26	0	153.2	-----
1.18	.7	258.0	168.0
.90	0	162.5	-----
1.96	.22	278.0	172.6
3.22	0	216.6	-----
2.66	0	244.0	-----
2.54	.5	229.0	185.0
2.52	.8	234.0	-----
2.30	0	210.3	-----
1.94	1.0	289.5	-----

Table 11.

Experiment I. Averages for Successive Sittings, Subject E, Series Ia.

Extent of Movement		Reaction Time	
Normal	Relaxed	Normal	Relaxed
6.21	2.06	108.9	144.9
3.82	.44	133.5	144.0
1.16	.65	112.2	143.6
2.83	.43	117.8	138.1
.72	.26	115.9	150.4
1.49	.32	117.4	149.7

Table 12.

Experiment I. Averages for Successive Sittings, Subject E, Series I b.

Extent of Movement		Reaction Time	
Normal	Relaxed	Normal	Relaxed
1.07	.34	122.6	143.2
1.99	.36	126.3	156.6
2.13	.67	130.4	148.6
1.54	.30	132.8	174.0

Table 13.

Experiment I. Averages for Successive Sittings, Subject F, Series I a.

Extent of Movement		Reaction Time	
Normal	Relaxed	Normal	Relaxed
.75	.32	116.3	141.6
.88	.37	125.9	138.0
.53	.40	119.6	135.0
.64	.42	117.6	134.4

Table 14.

Experiment I. Averages for Successive Sittings, Subject F, Series I b.

Extent of Movement		Reaction Time	
Normal	Relaxed	Normal	Relaxed
.68	.20	124.8	145.3
.62	.52	179.5	138.0
1.08	.33	191.0	140.0
..91	0	172.8	-----
1.12	.30	258.8	152.0

Table 15.

Experiment I. Averages for Successive Sittings, Subject G, Series I.

Extent of Movement		Reaction Time	
Normal	Relaxed	Normal	Relaxed
8.50	-----	198.0	144.2
12.10	-----	149.4	137.0
9.82	-----	181.0	157.0
11.00	-----	156.0	154.2
7.86	-----	186.8	185.2
9.62	-----	185.2	183.7
9.44	-----	172.4	199.0
11.70	-----	183.2	164.6
10.98	-----	143.2	165.0
8.17	-----	143.5	159.0
9.06	-----	255.0	204.0
8.60	11.95	184.6	297.5
6.48	8.85	254.8	-----
9.02	-----	207.2	184.5
7.10	-----	217.0	202.7
7.42	0	188.0	-----
7.08	9.53	215.2	242.6
8.02	0	173.4	-----
7.58	-----	206.6	190.5

average reaction time is longer with the normal condition than with relaxation, and for Subject F the average, though longer for the relaxed condition in Series I a, is longer for the normal in Series I b. A closer analysis of the results is necessary to show whether these averages represent consistent tendencies.

In the first series taken, Subject F gave results similar to those of other subjects. The average reaction time was longer with relaxation than without, and the difference was consistent for all of the separate comparisons shown in Table 13. In the second series, which differed from the first in that the stimulus was increased in duration and slightly decreased in strength, the average reaction time is longer for the normal condition. Table 14 shows that this relation holds for three of the four separate comparisons, the difference increasing as the series progresses.

The frequency distributions shown in Figures 3 and 4 throw further light on the question. The values for the relaxed condition are distributed quite similarly for the two series, the range in both cases being from 121 to 170 sigma. It is the values for the normal condition which differ. In Series I b these fall into two distinct groups. The first group consists of times somewhat longer than the corresponding ones of Series I a but still tending to be shorter than those for the relaxed condition of Series I b; the average reaction time for this first group is 134.0, that for the relaxed condition of the same series, 142.2. The second and smaller group consists of much longer times; they average, in fact, more than twice the length of the first group. These peculiarly long reaction times appear chiefly in the latter part of the series, and it is they which account for the relatively long average time under the normal condition.

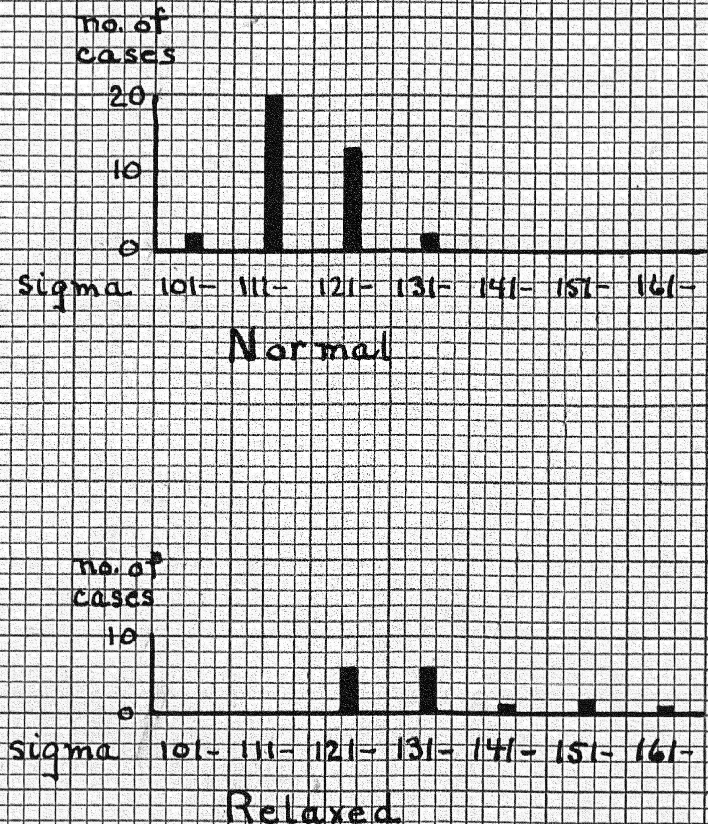


Fig. 3. Frequency Distributions, Reaction Time
Subject F, Series Ia

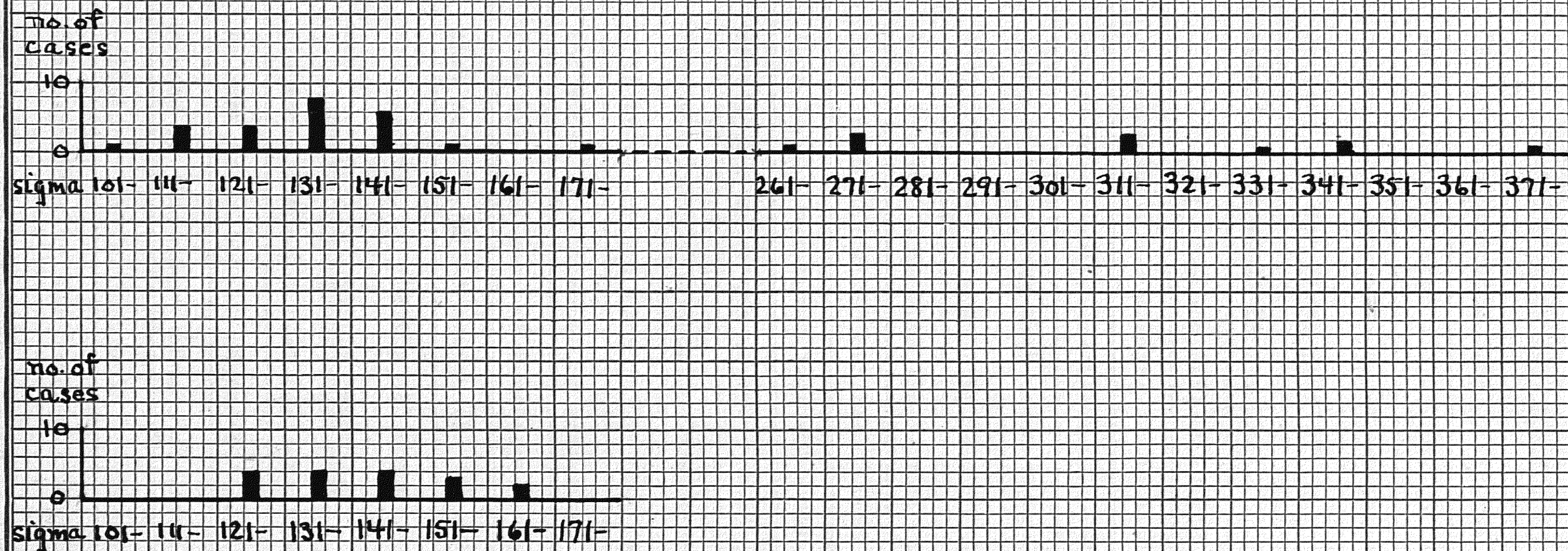


Fig. 4 Frequency Distributions, Reaction Time

Subject F, Series Ib

The results for Subject D show similar characteristics. The average reaction time is longer for the normal condition, but Table 10 shows that this relation holds for only four out of nine comparisons, and that three of these lie in the last half of the series. If the first half of the series were considered alone, the relationship would be reversed.

The frequency distribution in Figure 5 shows one group of reaction times tending to be distinctly shorter than those for the relaxed condition--averaging 166.8 as against 173.7--and a smaller group of very long times. As with Subject F, it is these exceptionally long times, appearing late in the series, which account for the long average time with the normal condition. These results suggest that while these two subjects, like the others, tended at first to show longer reaction times with relaxation than without, they later developed, under the normal condition, a different form of reaction, characterized by a greatly lengthened reaction time. This peculiarity will be discussed more fully when we come to the consideration of individual differences of response. It is brought up here only to show that the general tendency of relaxation to lengthen the reaction time as well as to lessen the extend of movement, extends, in at least some degree, to all six subjects.

General Bodily Response. It has already been mentioned that the arm movement called forth by the stimulus was usually accompanied by some other bodily response, and the question arises whether a decrease in the extent of arm movement indicated a generally diminished reaction. As far as could be observed, this was uniformly the case. The experimenter observed, and at first described in writing, the general bodily reaction following each stimulus; and it very soon became clear that the general reaction diminished to a marked degree

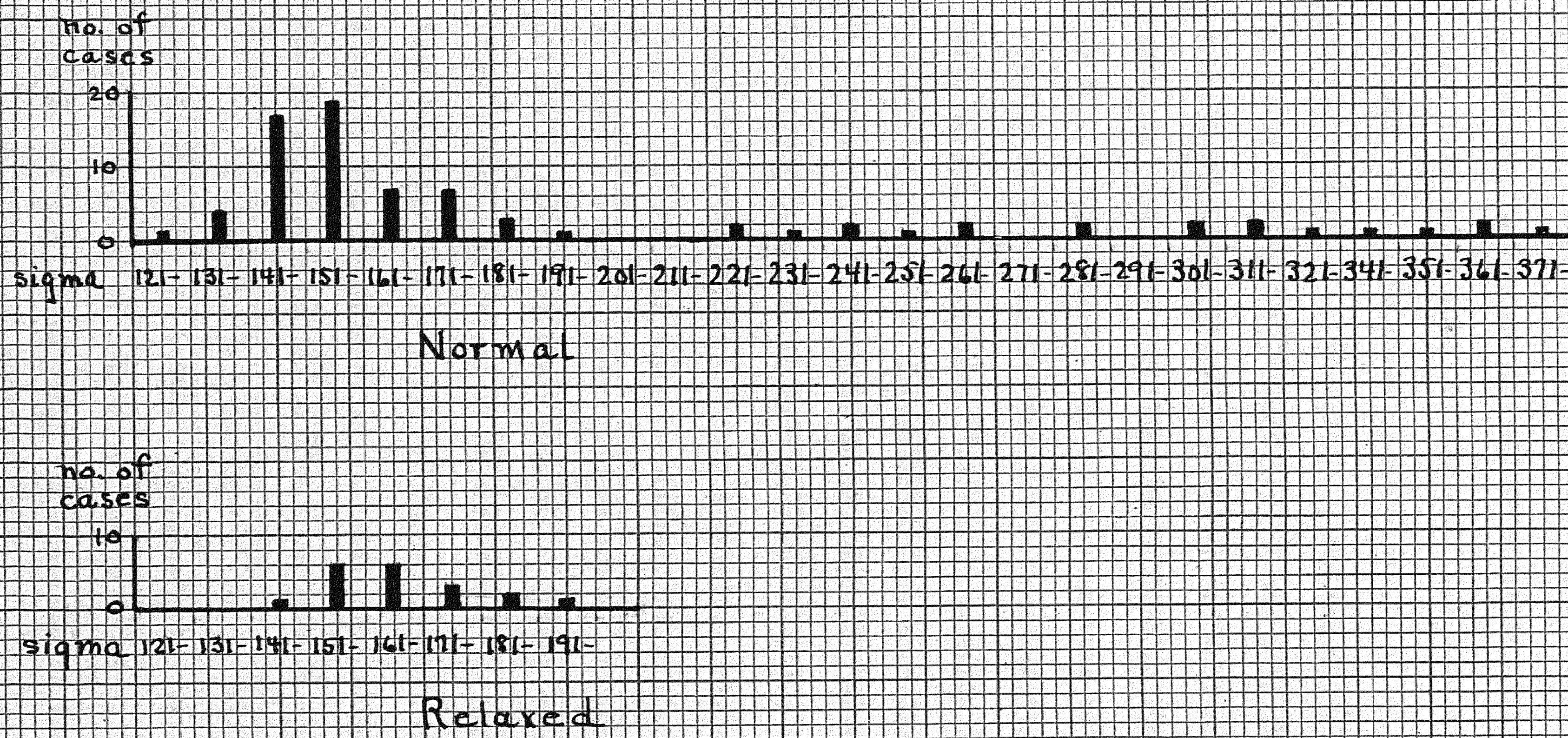


Fig. 5 Frequency Distributions, Reaction Time
Subject D Series I

with the decrease of the arm movement under the condition of relaxation. Sometimes when there was no observable arm movement there could still be detected a change in the rhythm of breathing, or the subject might later report a flicker of the eyelids; but such disturbances were always minimal, and often absent altogether.

Subjective Effect. A further difference between the results obtained with the two conditions appears in the reports of the subjects. Without being questioned on the point, each subject (Subject G still excepted) reported the stimulus as less painful, less disagreeable, or apparently weaker, with relaxation than without. After the first sitting with relaxation Subject A remarked that the stimulus seemed much weaker than before. Subject B reported it as stronger and more painful when she was not relaxed than when she was. Subject C characterized it as dull when he was relaxed, knife-like under the normal condition; he said, "When I am relaxed I don't get any kick out of it." Subject D reported it as much less disagreeable and apparently weaker when he was relaxed than otherwise, and Subjects E and F thought that it was objectively weaker. Each subject remarked upon this subjective effect on more than one occasion, and they were all questioned about it at several different sittings as well as at the end of the series. With Subject B there were two occasions when relaxation did not diminish the painfulness of the stimulus; otherwise, with all subjects, the effect was reported as the invariable accompaniment of relaxation.

Effect of Sleep. It has been mentioned that the relaxed condition tended to induce sleep, and the question arises whether the supposed effects of relaxation may not have been due to sleep rather than to relaxation as such. As a matter of fact all of the subjects but one did fall asleep on one or more occasions, and in order to determine how far this factor may have been responsible for the results obtained, these have been tabulated separately for "sleep" and "waking." There is of course some difficulty in determining in every case whether the subject has been asleep or not; but the benefit of the doubt has always been given to sleep. If the subject was thought to have been asleep for any part of a sitting, all the reactions of that sitting were put under the sleep heading. The reactions under that head include all those of sittings 1) where the subject said he had been asleep, 2) where he was not sure w whether he had slept or not, and 3) where although the subject was not conscious of having slept the sitting seemed unusually short to him or he was confused about the number of stimuli received. In this way a number of waking reactions have doubtless been included under the sleep heading, but the reverse has, as far as possible, been avoided. Tables 16 and 17 compare the extent of movement for the two conditions, Table 18 the reaction time. These tables include only reactions taken with relaxation; no subject ever went to sleep under the normal condition. Both series for Subject E, and Series I a for Subject F are omitted, for they included no "sleeping" reactions.

So far as can be judged from the limited number of cases available, the differences found between the normal condition and the condition of relaxation taken as a whole, are exaggerated in the case of sleep. The method chosen, of including all doubtful cases with sleep, is a poor one for isolating the effect of sleep. Even so, this factor has a noticeable effect in increasing the number of zero reactions; and it is also to be noted that with sleep the subject often remained entirely unconscious of the occurrence of the stimulus, while this never happed when he was awake. On the other hand, this classification makes it certain that the original differences found between the

Table 16

Relaxed Condition: Per Cent of cases without movement with the subject waking or sleeping

Subject	Series	Waking		Sleeping	
		No. of Cases	% without Movement	No. of Cases	% without Movement
A	Ia	30	100	20	100
A	Ib	30	93	20	90
B	I	80	30	20	60
C	Ia	33	15	4	50
C	Ib	40	42	5	100
D	I	49	59	51	90
F	Ib	30	73	20	55
G	I	5	0	87	30

Table 17

Relaxed Condition: average extent of movement with the subject waking or sleeping

Subject	Series	Waking		Sleeping	
		No. of Cases	Ave. Cm.	No. of Cases	Ave. Cm.
A	Ia	0	-	0	-
A	Ib	2	.80	2	.55
B	I	56	1.29	8	.39
C	Ia	28	.92	2	.65
C	Ib	23	.75	0	-
D	I	20	.77	5	.86
F	Ib	8	.22	9	.46

Table 18

Relaxed Condition: average reaction time
with the subject waking or sleeping

Subject	Series	Waking: No. of Cases	Waking: Ave. Sigma	Sleeping: No. of Cases	Sleeping: Ave. Sigma
A	Ia	0	-	0	-
	Ib	2	232.5	2	211.5
B	I	53	164.4	8	175.5
C	Ia	23	140.6	2	159.5
	Ib	18	156.2	0	-
D	I	16	172.9	4	177.0
F	Ib	8	146.2	9	138.7
G	I	4	154.2	49	184.3

condition and that of relaxation do not depend to any considerable extent on the presence of sleep. This can be seen plainly if we compare the normal condition of Tables 2, 3, and 4 with the waking condition of Tables 16, 17, and 18. This comparison gives results substantially the same as the original comparison made in the earlier tables between the normal condition and relaxation as a whole. The differences in the second comparison are all in the same direction as in the original, and only slightly less in degree.

This attempt to isolate the effect of sleep has been based on the assumption that sleep and relaxation may be independent factors; there remains the possibility however that the effect of sleep may itself be due to a heightened degree of relaxation prevailing with that condition.

Individual Differences. Before considering the results for Subject G, it may be well to point out some individual differences among the subjects whose records have already been considered. Systematic comparison of the extent of movement for different subjects is prevented by the fact that the strength of the stimulus was not the same for all. It has been mentioned however that in the preliminary series certain subjects were found from whom no available stimulus could elicit a movement comparable in extent to those obtaining with other subjects. Subjects D and F throughout, and Subject C in Series Ia, retained this characteristically restricted movement; they also retained a mode of response peculiar to them - a tendency to react with a widespread stiffening of the muscles without extended movement of any part of the body. Observation of this reaction suggested that it represented movements vigorously initiated by numerous muscles but checked almost immediately by the contraction of their antagonists. It would seem that such a tendency might in itself be sufficient to explain the restricted arm movement; for a contraction of the antagonistic muscles might check this movement before it had reached its full course.

Certain observations suggested that this tendency may also have been related to other peculiarities of these subjects' reactions. In discussing the reaction times obtaining for the normal condition we have already had occasion to mention that with Subjects D and F, unlike the others, these values fell into two distinct groups; and a study of the graphic records of individual reactions showed a correlation between the length of the reaction time and the form of the arm movement. For these subjects the typical reaction curve for the normal condition is one with two summits. See Figs. 8 to 16.
In the majority of cases the first summit is lower than the second; its height varies from almost zero to approximately that of the second. These curves clearly indicate a double movement. In other cases there is a single summit, and in still others the first summit is followed by another so small that it is hard to tell whether it represents anything more than a mechanical rebound from the first

movement. With the reaction curves classified as double, single, and doubtful, their corresponding reaction times were listed as normal or lengthened, on the basis already determined from inspection of their frequency distribution. The result is shown in Table 19. No figures are given for Subject F, Series Ia; in this series all the curves were double, and there were no lengthened reaction times.

Table 19

Exp. I. Relation between Type of Curve and Reaction Time

Subject and Series	Type of Curve	No. of Reaction Times		
		Total	Normal	Lengthened
Subject D Series I	Double	53	52	1
	Single	11	2	9
	Doubtful	16	7	8
Subject F Series Ib	Double	24	23	1
	Single	10	1	9
	Doubtful	2	1	1

The close correlation between the long reaction times and the "single" form of curve suggests that the lengthened times are to be accounted for by the absence of the first movement represented in the double curve; and this in turn may be due to a contraction of antagonistic muscles giving, momentarily, complete inhibition of the upward movement of the arm. Varying degrees of such inhibition would account for varying heights of the first summit in the double curves; and a tendency on the part of the antagonistic muscles to contract before the impulse to upward movement is spent, might also explain the presence of two summits in the typical curve. This explanation was partly confirmed by a remark of Subject D, who said after one particularly delayed reaction, "I felt myself shrinking up and getting stiff that time before my arm moved."

So far we have discussed in detail only the records of Subjects D and F. Subject C was the only other to display the tendency to a general muscular stiffening, and a study of the graphic records showed that - with a very few exceptions in individual cases - he was also the only one to show similar double curves. In Series Ib all but three of the records were of the double type; and of the reaction times corresponding to the three exceptional "single" curves, two were somewhat outside the ordinary range, lying between 170 and 180 sigma while the range for all other reactions was from 101 to 150. With this subject the first part of the double reaction varied from a distinct but low summit to what was apparently merely the beginning of a very slow rise cut short by the beginning of a much sharper one. In all cases the first rise was small compared to the second, and was followed by it after a very short interval; apparently the inhibiting effect of the stiffening tendency was of short duration and was completely overcome in the second rise, for this was of the same order of magnitude as that found with other subjects. The subject himself did not notice the tendency to "stiffen up" in this series, though he had spoken of it several times in Series Ia; yet the latter shows very few double reactions, and no correlation between the type of curve and the length of the reaction time. There is of course no apparent reason why a tendency to contraction of antagonistic muscles should necessarily give a curve showing a second upward rise after the first was checked. It might simply check the first movement before its full height was reached; and apparently this is what took place in Series Ia, for the average extent of movement there is very small compared to that of the later series.

To conclude, we have pointed out an apparent tendency toward the contraction of antagonistic muscles observed with Subjects D, F, and C, and have suggested that this tendency may be directly related to

1. the unusually restricted movement found throughout with Subjects D and F and in Series Ia with Subject C,
2. the "double" form of curve peculiar to the records of the same subjects,
3. the exceptionally long reaction times found in these same series with such exceptional reactions as were

of the "single" type.

Subject G. The results for Subject G are in striking contrast to those with relaxation, so far presented. Almost all of the reactions of this subject fell at one of two extremes: either the stimulus elicited no measurable response, or the reaction was far greater in extent than under the normal condition. Tables 2 and 3, and Fig. 6, summarize these results. The average extent of movement for relaxation cannot be given, for the reaction in the majority of cases exceeded the recording capacity of the apparatus. The frequency distributions of Figure 6, however, show how decidedly the "relaxed" reactions exceeded the normal. The reaction times, as one might expect from this fact, are longer for the normal than for the relaxed condition, though the difference is small and not as well established as in other cases. Table 15 shows that the relation holds for only 11 out of 16 separate comparisons, and Figure 7 shows the high variability of the values. Observation indicated that in this as in other cases the extent of the general bodily response was closely correlated with that of the arm movement; the subject's facial expression especially showed that he was much more disturbed by the stimulus when he was relaxed than otherwise.

This subject's procedure during the period of training, has already been described. He "just lay down and relaxed," and very soon went to sleep. When he tried to relax without sleeping he

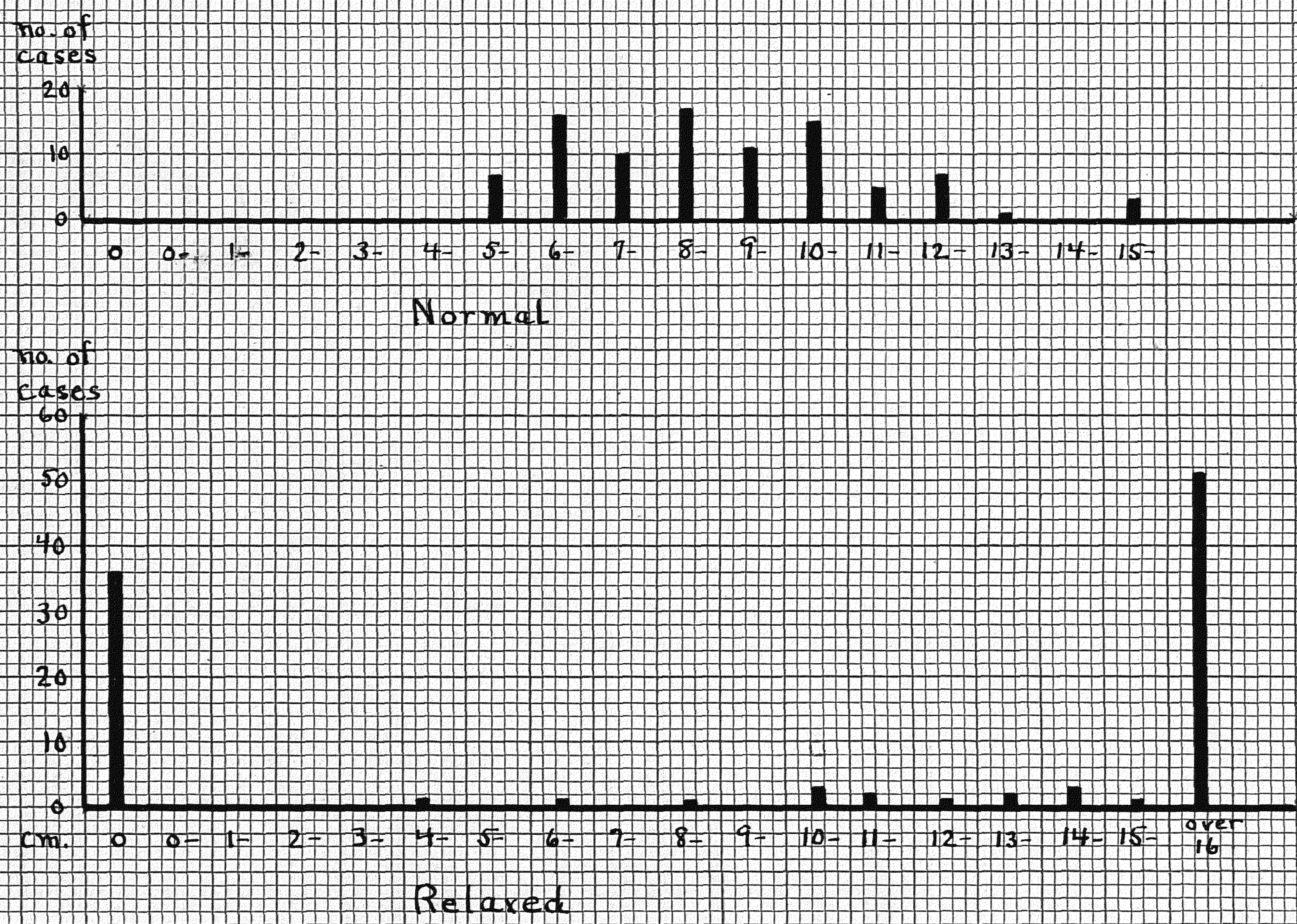
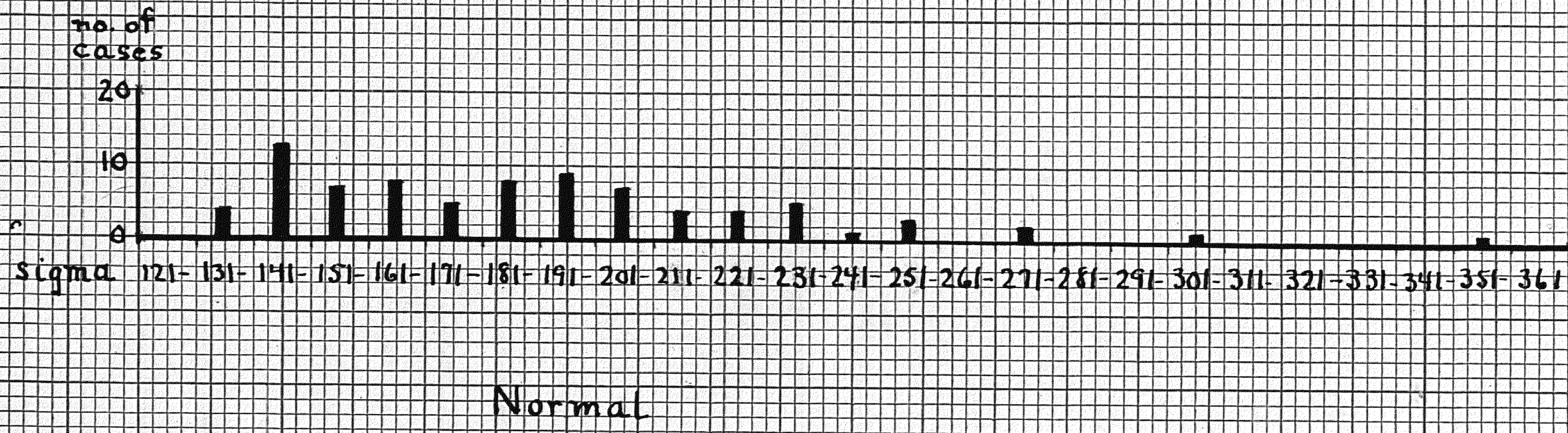


Fig. 6 Frequency Distributions, Extent of Movement

Subject G, Series I



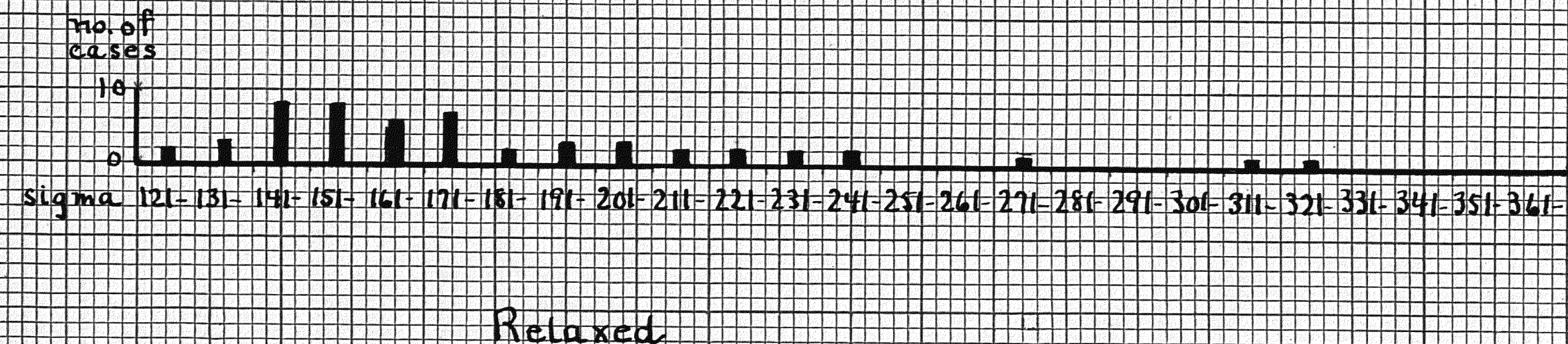


Fig. 7 Frequency Distributions, Reaction Time
Subject G. Series I

found it almost impossible, and actually there was only one sitting where he did not sleep. The results of this sitting did not differ from the others except that the reaction time was even shorter than usual; this figure however is based on only three reactions.

When asked whether the stimulus was more disagreeable with relaxation or without, Subject G replied that it was much worse when he was relaxed. He said however that when he was relaxed he never felt the stimulus itself; it was his own arm movement, apparently, that woke him up, and it was being disturbed that he found so disagreeable. This remark did not apply of course to the time when he was not asleep; at that sitting he reported the stimulus as just the same as usual (with the normal condition), neither more nor less disagreeable.

Subject G showed no sign of the tendency to a widespread stiffening of the muscles observed with some subjects; the arm movement was an extended one even with the normal condition, though the stimulus was much less intense than that used with most subjects. The graphic records contained no such double curves as did those of certain other subjects; nor did they show any other objective peculiarities which could be correlated with those already discussed.

EXPERIMENT II: THE EFFECT OF PARTICULAR CONDITIONS OF CONTRACTION OF THE MUSCLES OF THE REACTING ARM

Procedure

At the conclusion of Experiment I a second experiment was undertaken with four of the same subjects to determine the effect of particular conditions of contraction of the right arm. These conditions were (1) the normal condition, (2) pressing down with the forearm, (3) lifting up with the forearm so as partly to support its weight, and (4) leaving the arm in the normal position but making it rigid. As heavy demands had already been made upon the subjects' time, this series could not be carried as far as would otherwise have been desirable.

The subject was shown that the pointer on the wall opposite him moved with his pressure on the scales;[1] and he practised with different degrees of pressure and of lifting until he had fixed in each case on a position of the pointer which he could maintain for two or three minutes without noticeable fatigue. He was then instructed as follows:

"When I say press down, please press down until the pointer reaches - (the position determined upon), and keep it there until a stimulus occurs. Do this with as little muscular effort as possible; do not make the whole arm rigid, but try to use only such muscles as are actually needed."

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1. See description of apparatus, p. 13.

Similar instructions were given for lifting up. For the rigid condition the instructions were to make the arm rigid by contracting all of the arm muscles; and the subject was asked to try to fix on a definite degree of contraction and to maintain as nearly as he could the same degree each time.

In giving these instructions it was assumed that the rule of reciprocal innervation of antagonistic muscles, demonstrated by Sherrington for reflex action, did not necessarily hold for all cases of voluntary contraction. Sherrington himself mentions the "synchronous excitation of antagonistic muscles in certain willed actions"[1] and references to instances of simultaneous contraction of antagonists are not uncommon in neurological literature. Our subjects had no apparent difficulty in following the instructions to make all the arm muscles rigid.

The general instructions, and those for the normal condition, were the same as in Experiment I. The subject was allowed to talk under all conditions.

The stimuli were given without warning, as in Experiment I. Two or three minutes before each stimulus (except for the normal condition) the experimenter said "Press down," "Lift up," or "Make your arm rigid," as the case might be. For the normal condition no instruction preceded the separate stimuli.

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1. Sherrington, Integrative Action of the Nervous System, p. 113.

The series varied in length with the different subjects from 74 to 132 reactions (see Table 1). It was hoped to take 16 reactions at a sitting, since no time had to be allowed for relaxation, but on some days there were delays which made this impossible, and the sittings actually varied in length from 8 to 16 reactions. The four conditions were equally represented at each sitting. Each stimulus was given under a different condition from the last, and the order of the conditions was changed with each sitting.

Results

The results are summarized in Tables 20 and 21. It can be seen at once that such differences as appear are smaller and less consistent than those found in Experiment I, owing partly no doubt to the smaller number of cases. There are certain tendencies however which appear to be fairly general. The tables show that:

1. When the subject is lifting up the reaction time is shorter than the normal, for all subjects. There is no consistent corresponding difference for the extent of movement, this being greater than normal for two subjects but less than normal for the other two.
2. When the subject is pressing down, the extent of

movement are less than normal, approximating the condition of pressing down; but the reaction times are shorter than normal, approximating those for lifting up.

As in Experiment I, the results show a high degree of variability, but the extent to which the above statements represent consistent tendencies may be judged from Tables 22 to 25. These tables give the ranking of the four conditions for each sitting in respect to extent of movement and reaction time, respectively. The greatest extent of movement and the shortest reaction time are given the first place. It appears from these tables that the statements based on the tables of averages hold true in the majority of cases for each subject with each condition. Taking together the results for the different subjects, it can be said that

1. There is no consistent difference for extent of movement between lifting up and the normal condition; for two subjects it is greater for lifting up in 12 out of 19 cases, for the other two it is less in 9 out of 12 cases.
2. The reaction time is shorter for lifting up than for the normal condition in 22 out of 31 cases.
3. The extent of movement is less for pressing down than for the normal condition in 25 out of 31 cases.

Table 20

Exp. II: Average Extent of Movement

Subject	Normal		Rigid		Up		Down	
	No. of Cases	Ave. Cm.	No. of Cases	Ave. Cm.	No. of Cases	Ave. Cm.	No. of Cases	Ave. Cm.
B	33	4.38	33	2.24	33	5.65	33	1.48
C	25	4.83	25	4.62	25	5.37	25	4.45
D	27	3.79	27	3.14	27	3.06	27	3.16
G	21	8.45	16	6.17	21	7.42	21	6.14

Table 21

Exp. II: Average Reaction Time

Subject	Normal		Rigid		Up		Down	
	No. of Cases	Ave. Sigma	No. of Cases	Ave. Sigma	No. of Cases	Ave. Sigma	No. of Cases	Ave. Sigma
B	30	114.7	26	111.0	25	109.3	22	122.7
C	22	121.4	22	114.4	19	113.7	21	126.5
D	23	149.3	23	129.7	26	135.3	17	165.2
G	17	166.6	14	163.0	17	165.3	19	195.1

Table 22

Exp. II, Subject B: Rank of four conditions (Up, Normal, Rigid, Down) at successive sittings

	Rank	Sitting									
		1	2	3	4	5	6	7	8	9	10
Extent of Movement	1	U	N	U	U	N	N	U	U	U	U
	2	N	U	N	N	U	U	Rg	N	N	N
	3	Rg	Rg	Rg	D	Rg	Rg	D	D	Rg	Rg
	4	D	D	D	Rg	D	D	N	Rg	D	D
Reaction Time	1	U	N	U	U	U[1]	Rg	U	U	Rg	Rg
	2	N	Rg	N	N	Rg[1]	U	D	Rg	U[2]	N
	3	Rg	U	Rg	Rg	N	N	Rg	N	D[2]	U
	4	D	D	D	D	D	D	N	D	N	D

1- Tied for 1st place 2- Tied for second place

Table 23

Exp. II, Subject C: Rank of four conditions (Normal, Up, Rigid, Down) at successive sittings

	Rank	Sitting								
		1	2	3	4	5	6	7	8	9
Extent of Movement	1	D	U	N	U	N	D	U	Rg	U
	2	N	Rg	U	N	U	N	Rg	U	Rg
	3	U	N	D	Rg	D	U	N	N	D
	4	Rg	D	Rg	D	Rg	Rg	D	D	N
Reaction Time	1	Rg	Rg	Rg	U	Rg	Rg	U	N	D
	2	N	U	D	Rg	U	U	D	U	U
	3	D	N	U	D	N	N	Rg	D	N
	4	U	D	N	N	D	D	N	Rg	Rg

Table 24

Exp. II, Subject D: Rank of four conditions (Normal, Up, Rigid, Down) at successive sittings

	Rank	Sitting						
		1	2	3	4	5	6	7
Extent of Movement	1	N	N	N	D	U	D	U
	2	U	Rg	U	N	N	N	N
	3	Rg	D	Rg	Rg	D	Rg	D
	4	D	U	D	U	Rg	U	Rg
Reaction Time	1	Rg	N	Rg	N	Rg	Rg	Rg
	2	D	U	U	U	U	U	U
	3	N	Rg	D	Rg	N	N	D
	4	U	D	N	D	D	D	N

Table 25

Exp. II, Subject G: Rank of four conditions (Normal, Rigid, Up, Down) at successive sittings

	Rank	Sittings				
		1	2	3	4	5
Extent of Movement	1	N	N	N	U	N
	2	U	U	U	N	U
	3		Rg	Rg	D	D
	4	D	D	D	Rg	Rg
Reaction Time	1	N	Rg	N	U	Rg
	2	U	U	Rg	N	U
	3		N	U	Rg	N
	4	D	D	D	D	D

4. The reaction time is longer for pressing down than for the normal condition in 22 out of 31 cases.
5. The extent of movement is less for the rigid than for the normal condition in 25 out of 30 cases.
6. The reaction time is shorter for the rigid than for the normal condition in 20 out of 30 cases.

So far as we may judge from these results it appears then that preliminary lifting up, which employs presumably the same muscles as those used in the subsequent reaction, is favorable to an immediate movement, though it has no consistent effect on the extent of movement; pressing down, which employs antagonistic muscles is decidedly unfavorable to both quick and extended movement. The condition of rigidity, designed to secure preliminary contraction of both sets of muscles, lessens the extent of movement but also reduces its latent time.

No differences were reported in the subjective effect of the stimulus for the conditions obtaining within Experiment II. Subject D however noticed a striking difference between its effect in this experiment and in Experiment I. He said that in the second experiment all the stimuli were intensely disagreeable; perhaps those with the "down" and "rigid" conditions were the worst, but they all, including those with the normal condition, increased in unpleasantness from the beginning to the end of each hour. His attention was on the stimulus much more than in the other series, and when it came he felt a wave of heat over the whole body. In order to make sure that this difference was really due to the changed conditions, two sittings with alternating normal and relaxed conditions were given at the close of Experiment II. The subject reported that the stimulus now seemed like that of the first experiment; it was only mildly disagreeable even when he was not relaxed. This fact suggested that for this subject the effect of relaxation extended beyond the time when relaxation was consciously maintained, affecting his attitude in the normal condition as well.

SUMMARY AND DISCUSSION

The outstanding facts of Experiment I may be briefly summarized as follows:

When reactions to a shock from an induced current are taken under a normal condition and under one of general muscular relaxation, it is found that with most subjects the movement is more extended, the reaction time shorter, and the apparent intensity and unpleasantness of the stimulus greater, under the normal condition than under relaxation. With relaxation there is a certain percentage of cases where no measurable movement occurs. These conclusions hold true whether the subject is asleep or awake under the relaxed condition; the differences are slightly more pronounced if he is asleep.

An exception was found in the case of Subject G. The condition of relaxation gave for him, as for other subjects, a certain number of cases in which no movement appeared; but if movement did occur, it was more extended, and the reaction time was shorter, with relaxation than normally. When the subject was asleep - and this included almost every case with relaxation - he reported that he did not feel the stimulus at all; he was conscious only of his own response. In the few cases when he was relaxed but awake, he said the stimulus was subjectively the same as under the normal condition.

In Experiment II the effects of particular conditions of contraction of the reacting arm were compared with that of the normal condition. Here it was found that preliminary lifting up, as compared with the normal condition, was favorable to short reaction times; it had no consistent effect however on the extent of movement. Pressing down was distinctly unfavorable both to extended and to immediate movement. The rigid condition gave a movement reduced in extent but also shorter in reaction time than the normal. The subjects reported no differences in the subjective effect of the stimulus for the conditions obtaining within Experiment II. In this experiment Subject G gave results conforming to those of the others.

Particular results from Experiment II cannot be directly compared with those from Experiment I, because the strength of the stimulus was not the same for the two. It is apparent however that the differences found in Experiment II between the normal and particular conditions of contraction are less both in degree and in consistency than those found in Experiment I between relaxation and the normal. This is true even for pressing down, which differs more from the normal than do any of the other local conditions of contraction; that is to say, while pressing down is less favorable to a quick and extended movement than the normal condition, it is on the whole not so inferior to the normal in this respect as is the condition of relaxation. It appears then that any of these conditions of contraction as compared with general muscular relaxation favors short reaction times and extended movement; though the degree to which this is true varies with the particular condition of contraction. Similarly, any condition of contraction increases, as compared with relaxation, the apparent intensity or disagreeableness of the stimulus.

In discussing the results of Experiment II we have only local conditions to take into account. The factors involved are the degree of contraction of the muscles directly concerned in the reaction movement, and the degree of contraction of their antagonists. It is generally recognized that preliminary contraction of a given muscle facilitates its reaction; and this was in general the effect of lifting up with the forearm. With pressing down we have the active contraction of muscles opposed to the reaction, and the probable accompanying relaxation of the muscles concerned in it, a condition which would naturally be expected to hinder the reaction movement. The effect of such a factor in the case of voluntary movement has been well shown in a reaction time experiment conducted by R. D. Williams (12). In this experiment graphic records were taken of the preliminary adjustment of the reacting hand, and it was found that if the subject was pressing down when the stimulus came he tended to react with a slight involuntary downward jerk before the final upward movement. No actual downward movement appeared in our records, but the resistance of the spring was such that a downward movement would have to be of considerable force in order to register. If part of the nervous energy released by the stimulus went into a downward pressure preceding the final movement, it would explain the result actually found - lengthened reaction time and reduced extent of movement. In the light of Williams' experiment, this seems the most probable explanation.

The condition of rigidity, which involved a heightened degree of contraction both in the reacting muscles and in their antagonists, gave results in which a reduced extent of movement was not accompanied, as it was ordinarily, by a lengthened reaction time. What really happened with this condition is not clear, and could probably be determined only by graphic registration of the contraction of the individual muscle groups.

In Experiment I we are dealing with a condition which is not confined to the muscles of the reacting arm, but affects the whole body. That both sensory and motor conditions may affect ensuing movements is generally acknowledged. It is recognized in the case of voluntary movements in the so-called law of dynamogenesis; in the case of reflexes, it appears in the well-known phenomena of reinforcement of the knee-jerk by contractions in other parts of the body or by sensory stimuli (Lombard, 8). The closest analogy however to the conditions of the present experiment is found in the work on sleep. Recent workers in this field (Pieron, 9, Kleitman, 6, Coriat, 2) have emphasized particularly the muscular relaxation accompanying sleep and the efficacy of such relaxation in producing its onset. The tendency of our own subjects to go to sleep when they relaxed has already been mentioned, and Dr. Jacobson has described the same thing in his papers on relaxation (3, 4, 5). Along with relaxation there also appears in sleep a general diminution of reflex excitability; this is the conclusion reached by Pieron after an exhaustive review of the literature. Sometimes this reduced excitability has been shown by lengthened reaction times (Pieron, Tarchanoff, 11), sometimes by absence or reduced extent of the reaction (Rosenbach, 10, Lombard, 8, Bowditch and Warren, 1, Lee and Kleitman, 7), and sometimes by a rise in the threshold of excitation (Tarchanoff, Pieron). In contrast to the diminution of excitability which appears with sleep through the greater part of its course, Rosenbach found a temporary stage in which irritability was increased; this might appear just before the subject went to sleep and persist for a few minutes while his sleep was still light. Pieron reported a similar temporary increase just before the subject woke up.

The parallel between the results found with sleep and those of the present experiment grows even closer when one recalls that in both cases muscular relaxation and lowered reflex irritability are accompanied by a decreased sensitivity to sensory stimuli. A theory frequently put forward in regard to sleep is that this raising of the threshold for both reflexes and sensation is due to the shutting off of incoming sensory impulses; part of the impulses shut off come from external stimuli and part from the muscles, these last being reduced by the process of relaxation. Stimuli from both these sources were reduced, in the present experiment, in the case of relaxation, for the subject relaxed with eyes closed, and the room was kept quiet except for the monotonous sound of the motor. This theory may receive some support from the fact that in the present instance the effect could be produced by quiet and relaxation alone, without the actual occurrence of sleep.

The question remains why relaxation should in most cases lower but in some cases markedly increase excitability; does this increase, found with one subject only, show a real difference in the effect of relaxation on this individual, or is it due to some unanalyzed difference in the kind or degree of his relaxation? Certain considerations suggest the latter view. In 28 per cent of the cases in Experiment I - that is, in the cases showing no movement - this subject gave results similar to those of the others. In the second experiment his results were entirely conformable with the others. It will be remembered, finally, that he used a somewhat different method of relaxation from that of the other subjects. The temporary increase in irritability found by Rosenbach at the beginning and by Pieron at the end of sleep suggest the possibility of a similar intermediate stage of relaxation. It may be that in the cases of increased reaction, this subject had not attained a degree of relaxation comparable to that of other subjects or to his own condition at other times. This idea is put forth merely as a suggestion, however, for the present experiment offers no objective data which would support it.

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The Effect of Certain Conditions of Muscular Contraction and Relaxation on the Non-voluntary Response to an Electric Shock

Abstract of a Dissertation
Submitted to the Faculty of the
Graduate School of Arts and Literature
In Candidacy for the Degree of
Doctor of Philosophy

In the Department of Psychology
By
Margaret Miller

The general problem of this experiment was to determine the effect of different conditions of muscular relaxation and contraaction on the non-voluntary response to an electric shock. The stimulus was applied to two fingers of the right hand, and the response measured was the quick upward jerk of the arm which followed. The stimulus was given without warning and the subject was instructed not to attempt any voluntary control of the reaction.

The problem was suggested by Dr. Edmund Jacobson, and the persons who served as subjects received preliminary training from him in inducing relaxation. At the end of this training they were able to assume and to maintain a state of general muscular relaxation which differed radically, in the judgment of subjects and experimenter, from the ordinary muscular condition.

The stimulus was an induced current lasting a fraction of a second, and the apparatus was designed to keep this current constant in intensity, rate of interruption, and duration. Graphic records of the reaction permitted the calculation of both the extent of the

movement and the reaction time.

Experiment I

In the first experiment, reactions taken with the subject in his ordinary condition were compared with those taken when he was in a state of general muscular relaxation. Seven persons, four men and three women, served as subjects. The series consisted of 200 reactions for each subject. In order to equalize for the two conditions any possible effects of habituation, five (or in some cases ten) "normal" reactions were followed by an equal number of "relaxed" reactions, and so on throughout the series. The experimenter noted what bodily response occurred in addition to the arm movement, and further notes were made, at the end of each sitting, of the subject's observations.

The results for six of the seven subjects were alike in their general features and can be discussed together; those for the seventh will be considered later.

The effects of the two conditions may first be compared in regard to the presence or absence of measurable arm movement. Under the normal condition there was only one case, with one subject, where the stimulus failed to elicit a measurable response. With relaxation, however, all six subjects showed a certain percentage of cases in which no movement appeared. This percentage varied from 16 to 96 for different subjects.

In the cases where the arm movement did appear with relaxation, it was markedly reduced in extent, as compared with the normal, and this relation appeared with all six subjects. For the individual showing the least difference, the ratio of the average normal reaction (measured in centimeters on the drum) to the average relaxed reaction, was 2 to 1. The greatest such ratio was 9 to 1. That this difference between the averages was significant was shown by taking averages from smaller numbers of cases. The first five (or in some cases ten) normal reactions of a given subject were compared with his first five (or ten) relaxed, and so on through the series. Of a total of 68 such comparisons, 66 showed the extent of movement to be greater with the normal condition than with relaxation.

In regard to reaction time the results are less consistent for different subjects. For four subjects the reaction time is longer for relaxation than for the normal condition, by ten to thirty per cent. Comparing the two conditions sitting by sitting, we find that this relation holds true for 47 out of 48 cases. With the other two subjects the time was slightly shorter for relaxation than for the normal condition, but this result was by no means consistently found throughout the series. If the first three quarters of the series had been considered alone, the reaction time would have been judged longer, for both subjects, with relaxation than without. A study of the frequency distribution for the normal condition showed a small group of extremely long times occurring in the last quarter of the series; the distribution with relaxation was more nearly normal. It could be fairly concluded that the result shown by the averages was due not to any shortening effect of relaxation, but to some factor which caused at certain times an unusual delay of the normal reaction. Inspection of the graphic records suggested an explanation of this factor, but space does not permit its discussion here. The general conclusion regarding reaction time was that relaxation tended to prolong it beyond that of the normal condition.

It has been mentioned that the arm reaction was accompanied by movements in other parts of the body, and the question arises whether a decrease in arm movement indicated a generally diminished reaction. So far as could be observed, it invariably did. When there was no arm movement apparent there might still be seen, sometimes, a flicker of the eyelids or a change in the rhythm of breathing, but these were always minimal and often disappeared altogether.

A further difference between the effects of the two conditions appears from the reports of the subjects. Without being questioned on the point each subject reported the stimulus as less painful, less disagreeable, or weaker, with relaxation than without. Each person remarked upon this fact on more than one occasion, and each one was questioned about it at several later sittings as well as at the end of the series. All reported that they had not expected any such effect.

At the end of each sitting with relaxation an attempt was made to determine whether the subject had fallen asleep at any time during the hour. This happened on one or more occasions with all but one of the subjects. In order to determine how far the results obtained might be dependent on the factor of sleep, a table was made excluding all sittings where there seemed any possibility that the subject had been asleep. The conclusions drawn from the original tables all held good for this one; the differences were in the same direction and only slightly less in degree.

It remains to report the results for the seventh subject. With relaxation, almost all of this subject's reactions fell at one of two extremes. Either - as in 28 per cent of the cases - there was no arm movement at all, or else there was a movement far greater in extent than that found with the normal condition. The reaction times are shorter for relaxation than for the normal condition, and observation indicated that the general bodily response was closely correlated in extent with the arm movement.

This subject was less skilled than the others in controlling his relaxation. He did not learn to observe the sensations from the muscles and to relax different muscle groups at will; he simply lay down and went to sleep. Yet there seemed no doubt, to an observer, that he was actually more relaxed under this condition than under the normal. When he tried to relax without sleeping he found it almost impossible, and there was only one sitting where he did not sleep.

In regard to the apparent strength and character of the stimulus this subject reported that it was "worse" when he was relaxed than otherwise. He said however that he never felt the stimulus itself; it was his own movement that he was conscious of, and it was being disturbed that he found so disagreeable. On the one occasion when he did not sleep, he reported that the stimulus felt just the same as with the normal condition.

Experiment II

At the close of Experiment I a second experiment was undertaken with four of the same subjects to determine the effect of certain conditions of contraction of the reacting arm. These were

1. the normal
2. lifting up with the forearm so as to support part of its weight; this movement employed presumably the same muscles as those used in the subsequent reaction movement
3. pressing down with the forearm, a movement employing antagonistic muscles
4. holding the arm in the normal position but making it rigid - a condition designed to employ both sets of muscles.

The series varied in length with the different subjects from 74 to 132 reactions. Except for the different muscular conditions employed, the procedure was the same as for Experiment I.

The results were less conclusive than for the first experiment, but certain tendencies appeared to be general. The results may be summarized as follows:

1. When the subject is lifting up, the reaction time is shorter than the normal; this is true for all subjects. There is no consistent corresponding difference for the extent of movement, this being greater than normal for two subjects but less than normal for the other two.
2. When the subject is pressing down, the extent of movement is less and the reaction time longer than normal, for all subjects.
3. With the rigid condition the values for the extent of movement are less than normal, approximating the condition of pressing down; but the reaction times are shorter than normal, approximating those for lifting up. This is true for all subjects.

None of the differences found between the conditions of Experiment II were nearly as great as those found in Experiment I. It could be concluded therefore that the extent of movement was less and the reaction time longer with general relaxation than with any of the other conditions employed in the present experiment.

It is to be noted that in this experiment Subject G - the seventh subject of Experiment I - showed results in entire conformity with those of the other subjects.

Discussion

The results of Experiment II call for little discussion, since it is readily apparent that a preliminary or preparatory contraction of the reacting muscles would be expected to facilitate reaction, while the contraction of their antagonists would hinder it. Graphic registration of the contraction of the individual muscle groups would be necessary to determine just what happened in the case where the arm was made rigid.

In Experiment I we are concerned with a condition which is not confined to the muscles of the reacting arm but which affects the whole body. The closest analogy to the conditions of this experiment is found in certain work on sleep. Recent workers in this field have emphasized the muscular relaxation accompanying sleep and the efficacy of such relaxation in producing its onset. Along with relaxation there also appears in sleep a general diminution of reflex irritability and a decrease of sensitivity for sensory stimuli. In the present experiment similar results have been produced by relaxation alone, without the accompaniment of sleep.

The case of Subject G raises the question whether there may be genuine individual differences in the effect of relaxation on different persons, or whether there was some unanalyzed peculiarity in the kind or degree of his relaxation. The latter view is suggested by the following facts: that the results for this Subject in Experiment II showed no individual peculiarities, that in Experiment I certain of his results - i.e. the 28% of cases showing no movement - were conformable with those of other subjects, and that he used a different method in relaxing from that of other subjects.

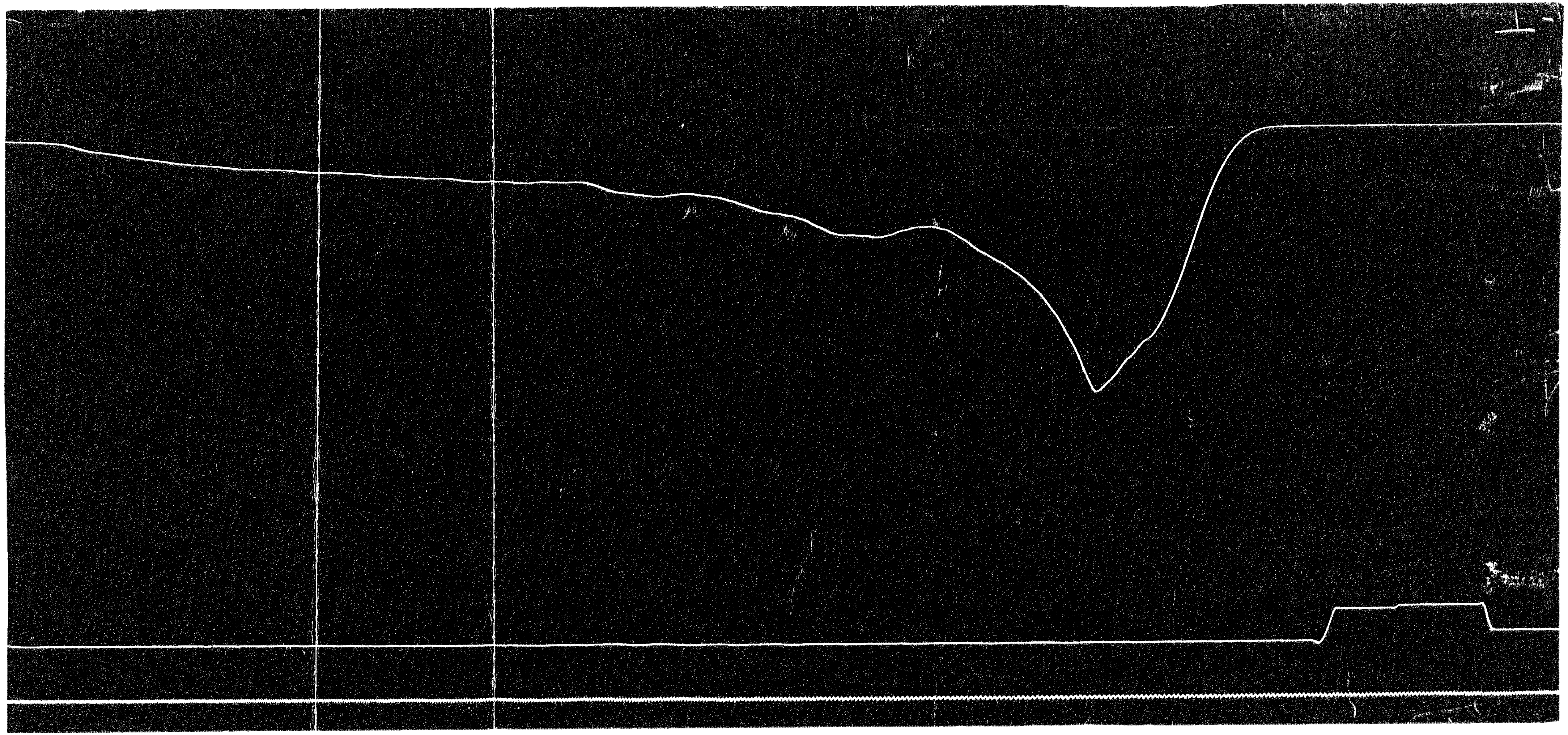

Fig. 8
Subject F
Double Curve

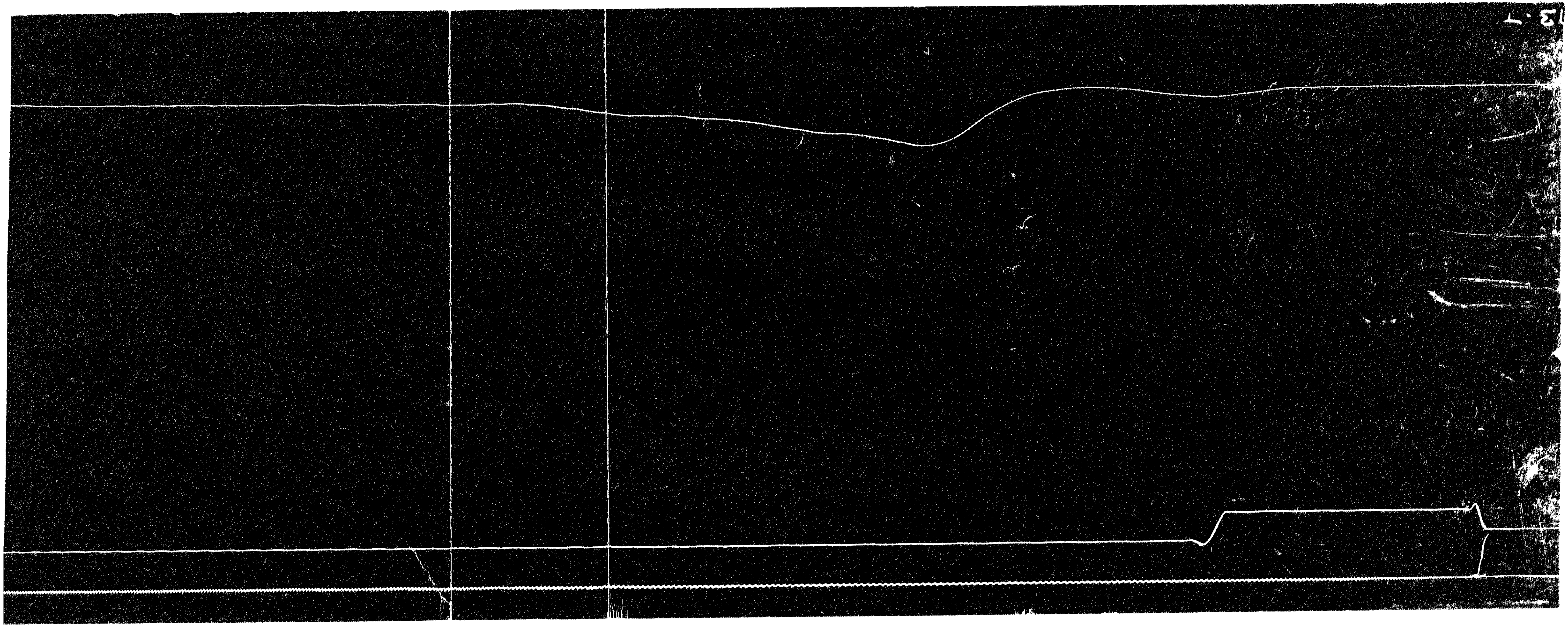

Fig 9
Subject F
"Single" Curve

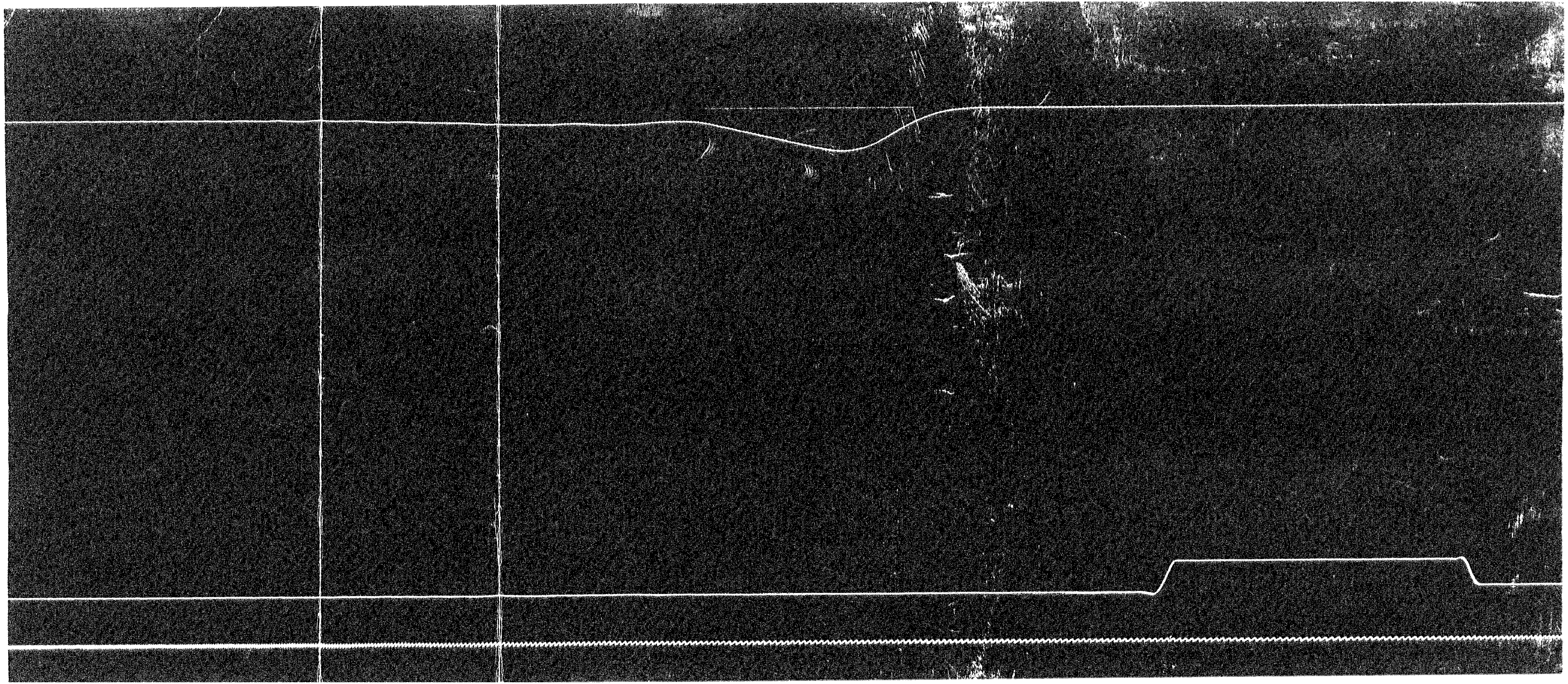

Fig. 10
Subject D
Double Curve

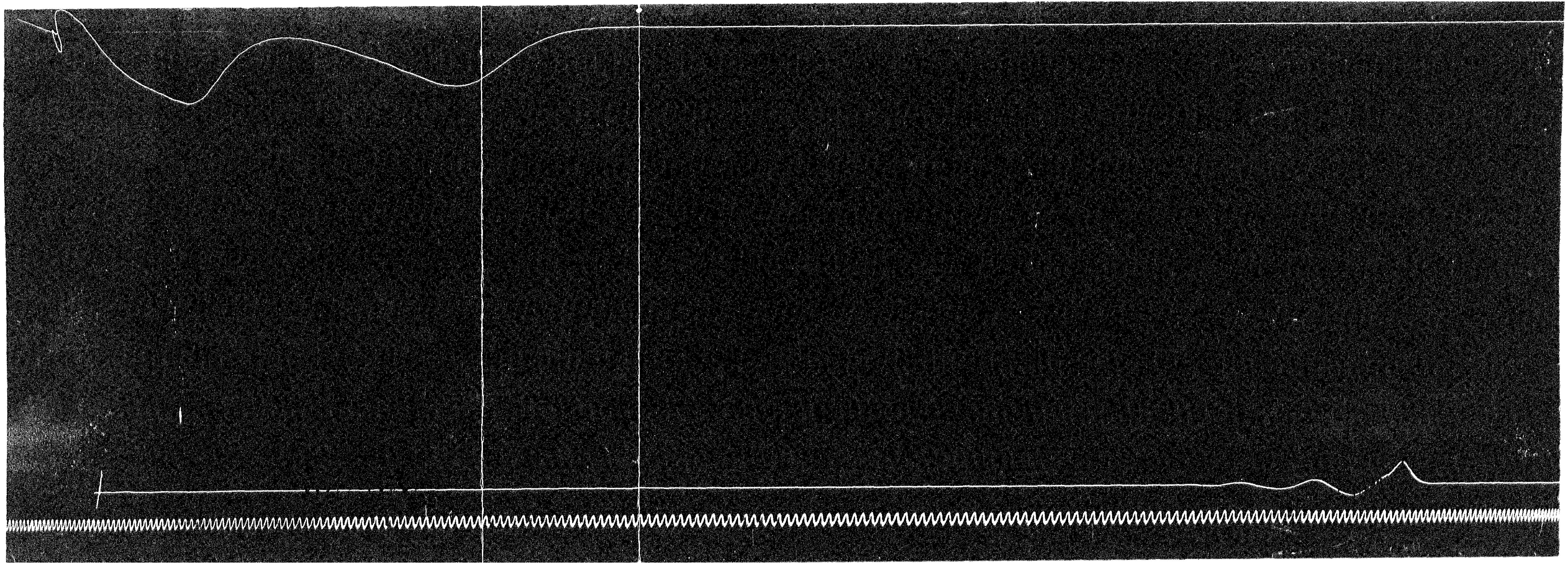

Fig 11

Subject D.

Double Curve

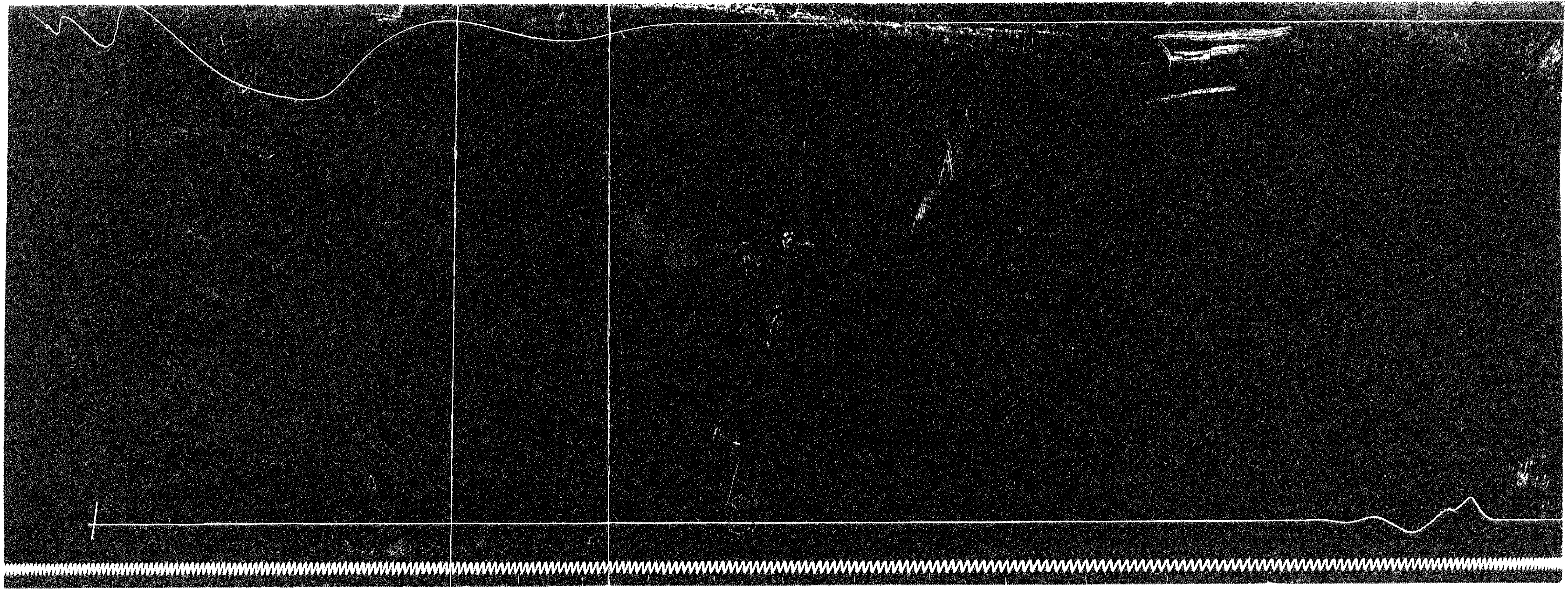

Fig. 12
Subject D.
Single Curve

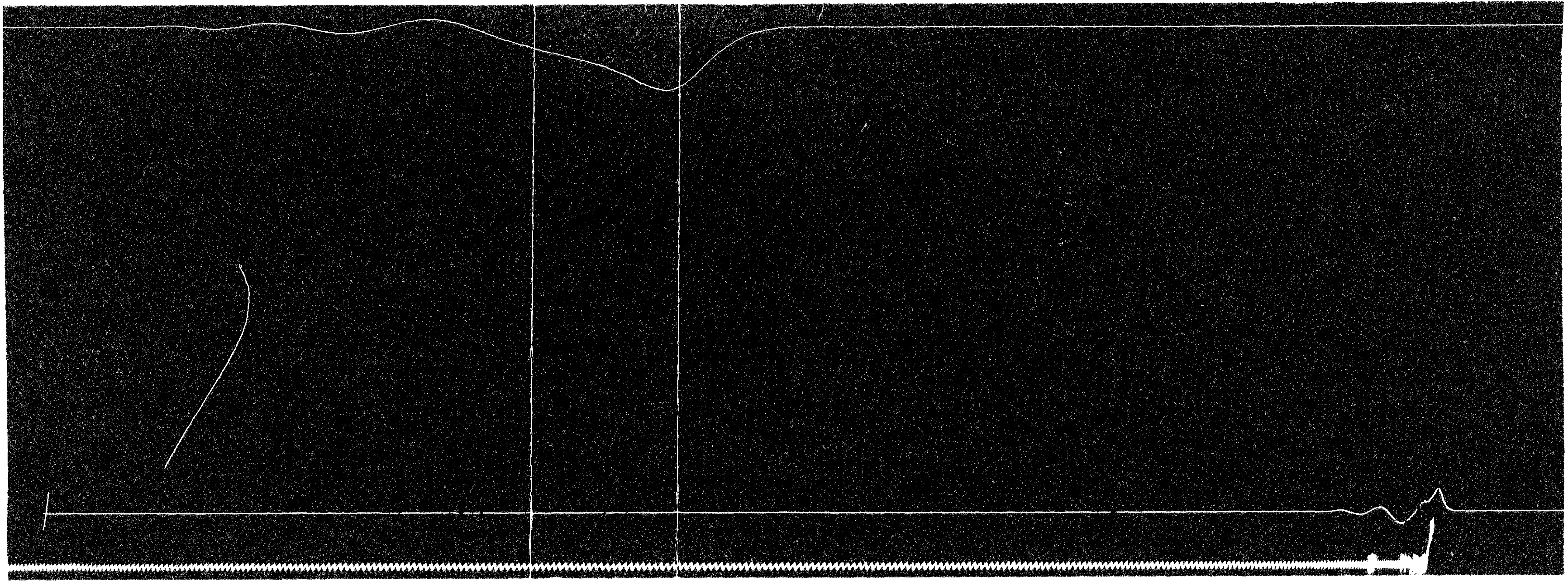

Fig. 13.
Subject C
Double Curve

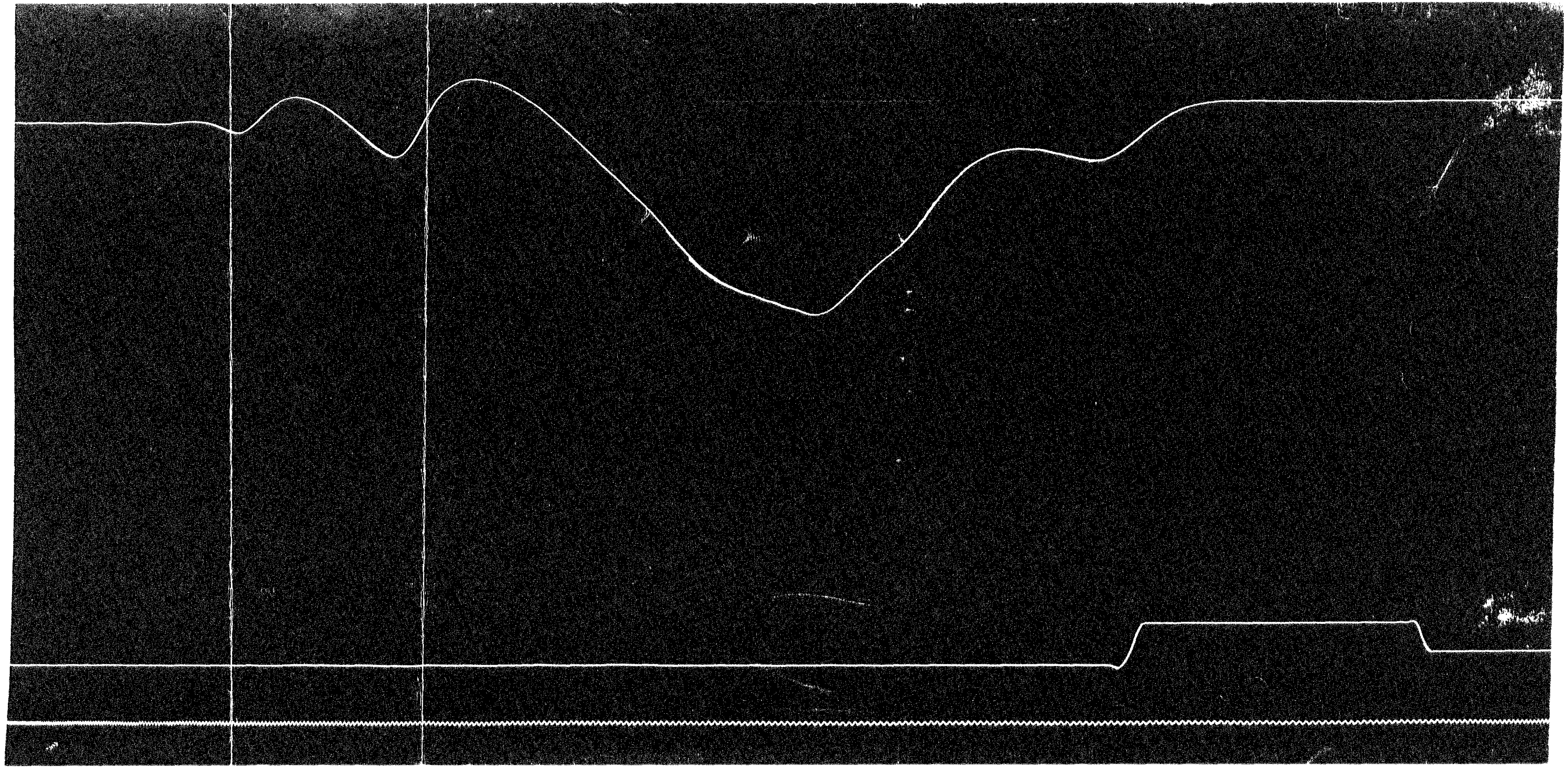

Fig 14.

Subject C.

Double Curve

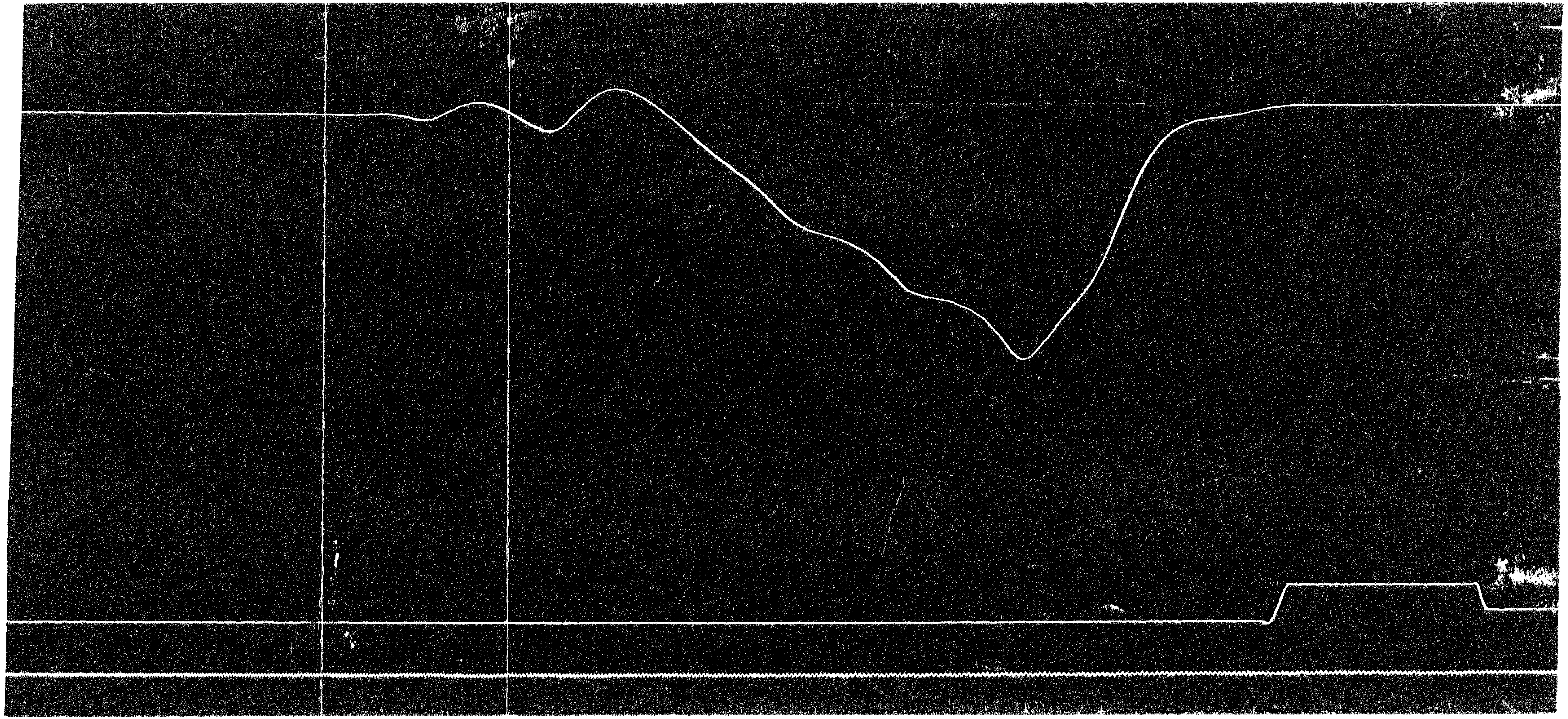

Fig. 15

Subject C.

Single Curve