# TACTUAL SENSITIVITY AS MEASURED BY A TECHNIQUE OF INTERMITTENT STIMULATION

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by
Lloyd Albert Shewchuk
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# ABSTRACT OF THESIS

The necessity for the present study was felt after a review of the literature revealed, that, although skin sensitivity has been subjected to considerable investigation, very few studies were done on the discriminatory ability of the skin, especially ones employing an intermittent or "flicker" method. The few studies that have utilized this technique were done several years ago and were largely of an exploratory nature employing only a few subjects. The purpose of the present study was two fold. The first was to describe a method of investigating the discriminatory or resolving power of the skin by means of a "flicker" technique. The second objective was to apply this technique to the measurement of the resolving power of ten different skin areas.

The flicker technique consists of producing an interrupted stream of air at a specified pressure whose frequency can be systematically increased until the subject reports a constant or fused sensation of pressure on some specified part of the skin. The frequency at which this constant sensation occurs is referred to as the critical frequency of percussion or the c.f.p.

This technique was applied to ten subjects in the measurement of the resolving power of the lower lip, tongue, thumb, finger-tip, forehead, neck, cheek, back of the hand, forearm, and upper arm. The results show that in all cases the graphs showing the relationship between c.f.p. and pressure consisted of two linear parts or limbs, but the point at which the second limb appeared varied for some individuals. It was also found that the more mobile areas of the skin, such as the lip, tongue, thumb, and finger-tip, were more sensitive to intermittent stimulation than the less mobile areas, such as the upper arm, forearm, hand, neck, and cheek.

In the discussion of results particular attention was paid to the significance of the two limbs and the variability of the subjects in their discriminatory ability on the various skin surfaces.

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# CHAPTER I

# THE PROBLEM AND INTRODUCTION

## I. STATEMENT OF THE PROBLEM

Biologically, the skin senses are of more importance to the individual than is either vision or hearing. Because of their importance they have been subjected to a considerable amount of experimentation. Most of the research, however, has been directed at such problems as the methods of dissociating the skin senses, a search for the specific receptors mediating the various skin sensations, or the measurement of the absolute sensitivity of the skin. One area of investigation which has been relatively neglected is that of the resolving power or discriminatory ability of the skin. What little work has been done is concerned with such problems as the minimum distance at which two points can be sensed as separate, the limits in discriminating the size or extent of objects pressed on the skin or the accuracy with which a stimulated point can be localized. One type of discriminatory ability, however, which has been almost totally neglected is that of the greatest number of separate "touches" which can be sensed as discrete. It is this type of discriminatory ability which will be investigated in the present study.

The purpose of the present study is two fold. The first is to describe a method of investigating the discriminatory or resolving power of the skin by means of a "flicker" technique analogous to that employed for a great many years in vision in the measurement of c.f.f. or the critical flicker frequency. This technique consists of producing an interrupted stream of air at a specified pressure whose frequency can be systematically increased until the subject reports a constant sensation of pressure on some specified part of the skin. The frequency at which this constant sensation occurs is referred to as the c.f.p. or the critical frequency of percussion. The second aim is to apply this technique to the measurement of the resolving power of ten different skin areas, viz., tongue, lower lip, cheek, forehead, neck, finger-tip, thumb, back of the hand, forearm, and the upper arm.

## II. INTRODUCTION

The necessity for the present study was felt after a review of the literature revealed that, although skin sensitivity has been subjected to considerable investigation, very few studies were done on the discriminatory ability of the skin, especially ones employing an intermittent or "flicker" method. This type of technique has proved to be one of the most valuable methods ever devised in the study of visual processes and there is every indication that it can prove as valuable in the study of tactual sensitivity. The few studies that have utilized this technique in the measurement of the skin senses were done over twenty years ago and they were largely of an exploratory nature employing a handful of subjects. No further work using this method has been done since that time. One possible reason for this is that the apparatus which was used was not very reliable and furthermore, required several weeks of practise before the subjects were able to give consistent results. The technique which has been devised for this study is a considerable improvement over the earlier ones and has the virtue of being able to give consistent readings after only a few practise trials.

The thesis begins with a discussion of the historical background of the problem and goes on to present some of the more important research findings in this area. Following this introductory section, the apparatus and procedure used in this experiment are described. The results are then presented followed by a discussion of their implications. Finally, the concluding section summarizes the results and conclusions drawn from this investigation.

## III. HISTORICAL BACKGROUND

Historically, the research on the skin senses can be grouped into four main categories, viz., the search for ways of dissociating the skin senses, determination of specific receptors mediating the senses, measurement of absolute sensitivity of different skin areas, and finally a measurement of its discriminatory ability. These topics will be dealt with in turn.

# METHODS OF SEPARATING THE SKIN SENSES

One of the earliest lines of research on the skin senses was concerned with determining the number of separate skin senses which exist. Five general methods have been used. The earliest of these was the method of punctate exploration of the skin, followed by anesthesia, cutting or blocking a nerve, mapping after removal of successive layers of skin, and establishing differential chronaxies.

Between the years 1883 to 1885, Blix, Goldscheider and Donaldson (30), searching for specific nerve energies, found that radically different stimuli applied to different points or spots on the skin gave specific sensations of warmth, cold and pressure. Later, in 1894, von Frey (17) found that the sense of pain could be differentiated in a similar manner. Other investigators also showed that mapping the skin with small stimulators generally showed points of high sensitivity for each of the four modalities with relatively insensitive regions in between. This phenomenon was called the punctate sensitivity of the skin. This finding enabled von Frey (18), in 1896, to establish the modern theory of four cutaneous modalities each being served by separate receptors and nerve pathways. By comparing the distribution of different end organs in different regions of the body with differences in cutaneous sensitivity in these regions, he was able to conclude that

Meissner corpuscles acted as the receptors for touch, the Krause end bulbs for cold, the Ruffini cylinders for warmth, and the free nerve endings for pain.

A much more tedious method of separating the skin senses utilizes direct currents of low amperage which drive an anesthetic directly into the skin (7). Sensitivity of the skin is tested at intervals during the process of anesthetizing and again during the recovery phase. Generally, some dissociation is evident in every case.

A complete loss of skin sensitivity may be produced by cutting or crushing a nerve or by injecting it with alcohol (7, 20, 23, 28). Although all these methods have the advantage of producing long delayed recovery periods, alcohol injection has the added advantage of not requiring surgery or producing permanent injury. Both in original loss and in regeneration, clear evidence is found of some dissociation of touch, pain, warmth, and cold.

A few investigators (7, 28, 31) have produced dissociation by removing successive layers of skin. An area of the skin is first explored with small stimulators to locate points of maximum sensitivity to touch, cold, warmth, and pain. Successive layers of skin are then removed by either surgical or chemical means. After each layer has been removed and has healed, the area is remapped for points of maximum sensitivity. The original map is then compared with each of the maps obtained during removal of skin layers.

In the few cases in which this method has been applied, dissociation was always evident.

Chronaxy is the minimum time for a current of double the threshold strength to produce a clear sensation of some skin modality. In all studies of chronaxy, touch, cold, warmth, and pain are produced by the same type of stimulus applied to different areas of the body, usually with significant statistical differences between the four sensations. All these studies support the idea that four separate skin senses do exist (7, 28).

## METHODS OF ISOLATING RECEPTORS AND STUDYING RECEPTOR PROCESSES

Numerous studies have been made to determine the specific receptors which mediate each of the four skin senses. The first of these is the indirect or correlational approach (25). This procedure consists in selecting some area of the skin and then plotting the location and number of pressure, cold, warm, and pain spots. This skin area is then excised, stained, and examined under a microscope to determine the type and number of receptors. Finally the number of each of the receptors is compared with the number of each of the points of maximum sensitivity. This approach can be illustrated by reference to an experiment by Bazett <u>et al</u> (10) on the male prepuce. He found that there are about 15 cold spots per square centimeter and about I warm spot per square centimeter.

The count for the number of Krause end bulbs and Ruffini cylinders in the prepuce is just about the same as the number of spots, hence the authors believed that Krause end bulbs are the receptors for cold and Ruffini cylinders the receptors for warmth. It should be pointed out that such a correlation of numbers may be quite accidental, even for the special area studied. Correlation studies of this nature were responsible for the view that pain is mediated by free nerve endings, pressure by hair bulbs and Meissner corpuscles, cold by Krause end bulbs, and warmth by Ruffini cylinders.

The second approach to the study of specific receptors is the direct or biopsy approach (25). This method consists of plotting the exact location of a cold, warm, pain, or touch spot and then excising the skin <u>directly</u> under a particular spot and examining it under the microscope. This type of study should be quite decisive and several such experiments have been carried out. However, the results indicated that rarely, if ever, could specific encapsulated end organs or receptors be found under any of the plotted spots. What these investigators did find, however, was a complex vascular and free nerve ending system under each of the spots. These biopsy experiments would seem to suggest that free nerve endings rather than encapsulated end organs serve as the mediators of the various cutaneous sensations. If encapsulated organs are involved they possibly act as auxiliaries to free nerve endings in certain regions of the skin.

## ABSOLUTE SKIN SENSITIVITY

Having disposed of the problem of the number of cutaneous sensations and their receptor basis we will now turn to the question of skin sensitivity to light pressure or touch with which this thesis is more directly concerned. First, we will examine absolute skin sensitivity or the least energy or stimulation required before a sensation is just felt, and secondly the question of tactual discrimination will be discussed.

One of the main methods for studying absolute skin sensitivity is by mechanical deformation of the skin. Various instruments have been used to produce this effect, but perhaps the earliest is the now famous limen gauge devised by von Frey in 1896 (18). It is an instrument through which pressure can be applied mechanically to any spot on the skin at a predetermined rate of loading. A kymograph activates it and a scale indicates the pressure applied to the skin. The stimulus is usually a blunt wooden point on a lever-arm. Later, in association with Kiesow, he invented his second instrument, the stimulus-hair (19). This hair which is about an inch in length is fastened onto a wooden handle. The free end of the hair is pressed vertically against the skin so as to barely bend the hair. By substituting a delicate weighing balance for the skin surface and finding the diameter of the hair, it is possible to measure the pressure exerted per square millimeter on the skin. By preparing a graded series of such hairs it is possible to ascertain the threshold of any spot on the skin. It was observed that to produce the experience of touch, the critical factor is the bending or distortion of the skin and not pressure as such. Pulling a stimulator glued to the skin produces sensations identical to those obtained by pressing down gently on the same stimulator. It was also found that the threshold for pressure sensation depended upon the locus of stimulation. The list below shows the absolute tactual sensitivities, in grams per square millimeter, for ten different skin areas. It can be seen that the tip of the tongue is the most sensitive skin area requiring only 2 grams per square millimeter of pressure for the subject to experience the sensation of touch while the thick parts of the sole require a pressure of 250 grams per square millimeter.

Tip of the tongue - 2 grams per sq. mm.
Tip of the finger - 5
Back of the finger - 5
Front of forearm - 8
Back of the hand - 12
Calf of leg - 16
Abdomen - 26
Back of forearm - 33
Loin - 48
Thick part of sole - 250

No way has been found to estimate the total amount of skin distortion in any meaningful fashion, but the depth of its depression can be measured. The most precise determinations in this respect has been made by von Bagh (8, 9), who used two different techniques. In one, weights are placed on a balanced arm bearing a stimulator resting on the skin. In the other, the stimulator is forced into the skin to a measured depth. With both methods, measurements are made of the minimum depression necessary to elicit a sensation of touch, and the minimum difference in depression which could be detected.

The second main method which has been used to study absolute skin sensitivity is the use of a vibratory device placed directly on the skin. As early as 1894 von Frey (17) found that interrupted electrical currents gave whirring or hammering sensations at pressure spots. The pressure spots registered the vibratory character of the stimulus up to as many as 100 pulses per second, and this was true whether the pulses were electrical or mechanical, the latter being produced by a vibrating tuning fork.

Within the twentieth century, numerous investigators (7, 20, 22, 24) have explored the possibility of using intermittent stimulation as a means of studying tactual sensitivity. The most adequate apparatus utilizes radio oscillators, with control of both frequency and amplitude of vibration and with liberal possibilities of amplification. Although alternating currents applied directly to the skin produce similar effects to those obtained with mechanical vibration, the actual nature of the stimulation is different.

Therefore, experimenters now use an oscillator to generate the desired frequency and the analog of a dynamic speaker to transform the electrical oscillations into mechanical vibrations.

The majority of studies employing this technique have been primarily concerned with finding the absolute or the lower threshold, i.e., when vibration is just felt. It has generally been found that separate touches can be sensed as discrete up to a frequency of about 20 cycles per second, although there are great individual differences as to the exact point. Some experimenters have placed it as low as 10 cycles per second; others place it as high as 80 (20). Knudsen (24), taking as a criterion the entrance of a "tingling" sensation, as opposed to the feeling of separate shocks, got an average lower limit of 15.3 cycles per second. Once again, however, great individual differences were evident. Most studies agree that the maximum sensitivity is in the region of 250 cycles per second, but the upper region is not known with certainty because of the technical difficulties involved in moving the skin at such high frequencies (20, 21).

Thresholds in terms of amplitude of movement of the skin can be measured accurately with a binocular microscope, using a slightly mistuned stroboscopic light to slow down the apparent movement. Thresholds thus determined are much lower for touch spots than for areas insensitive to touch, indicating that the same receptors mediate both touch and vibration (20, p.279).

## TACTUAL DISCRIMINATION

The greatest bulk of experimental investigations of the skin senses can be grouped under the heading of tactual discrimination, e.g., establishment of differential thresholds, measurement of tactile extent and linearity, establishment of two-point thresholds, and more recently, the establishment of the critical frequency of percussion during intermittent stimulation.

Studies on differential discrimination in tactual sensitivity are concerned with determining the minimal increment in energy or pressure which must be added to a stimulus before the subject will report that it feels different. Studies have shown that this depends upon a number of variables. The major variable is, of course, the locus of stimulation. In general, those parts of the body surface displaying high absolute sensitivity show small values of increment, while those of lower absolute sensitivity show high values (7, 20, 23). Other variables which affect the measurement of the stimulus increment are the duration of the initial pressure prior to the addition of the increment and the speed with which the increment is applied. When Weber's Law is applied to this method, it is invariably found that the relation between the increment and the stimulus pressure is not constant as is required. Relatively larger values are shown at low pressures and smaller values throughout the middle range of pressures (20).

Studies on discrimination of extent and linearity are concerned with how well the difference in length of two stimulus edges pressed against the skin can be discriminated. A series of studies has demonstrated that the tactile discrimination of differences in length does not follow Weber's Law. In tactile extent, it is the absolute increment and not the percentage difference which remains constant. Danesino (14, 15, 16) showed this to be true both for continuous lines and for a series of points arranged in a straight line. He attempted to relate this to diverseness of local signs by showing that the difference limen for extent is approximately equal to the minimum distance between two successive stimulations necessary for them to be perceived as distinct. Ricci (27) found approximately the same magnitude for the difference limen when the standard stimulus was applied to one forearm and the comparison stimulus to the other as when both were applied to the same region. In the limen for the linearity of three points, Oberto (26) found a similar relation. Regardless of the distances between the points, the necessary displacement of one for it to be perceived as out of line remained a constant number of millimeters.

Two-point threshold studies are primarily concerned with how far apart two points simultaneously touching the skin must be in order to be clearly sensed as separate. As most experiments bear out, this is not a simple matter to determine. Introspectively, the change from one to two points is not clear cut but involves a series of transition figures, such as ovals and dumbbells (7, 30). It is suggested that this is due to the "set" of the subject. As in the case of absolute sensitivity, the magnitude of the two-point threshold depends upon the bodily region stimulated (7, 30). This is clearly shown in the list below where the two-point threshold, in millimeters, is given for ten different skin areas. It can be seen that the two-point threshold is smallest in the relatively mobile areas of the skin, such as the tip of the tongue, fingers and lips, and largest for the less mobile areas such as the forehead, neck, and upper arm (12, 30).

| | |
|---|---|
| Tip of the tongue | - 1 mm. |
| Palmar side of the finger | - 2 |
| Red part of lips | - 5 |
| Metacarpus of thumb | - 9 |
| Cheek | - 11 |
| Forehead | - 23 |
| Back of the hand | - 31 |
| Forearm | - 40 |
| Neck | - 54 |
| Upper arm | - 68 |

In the past all investigations concerned with the tactual discriminatory or resolving power of the skin have been limited to measurements of vibratory sensitivity, two-point thresholds, differential thresholds, and discrimination of extent and linearity. Most of these studies have been carried out using the traditional methods of stimulation, such as the two-point compass, graded series of stimulus hairs, and electrical stimulation. The usefulness of these techniques, however, was soon exhausted when different parts of the body were compared and classified for sensitiveness.

A much more fruitful method of measuring the resolving power of the skin was developed in 1924 by Allen and Hollenberg (3), whereby it was possible to stimulate the skin surface with interrupted bursts of air under certain pressures. Their apparatus was relatively simple. It consisted of a pressure tank from which protruded a nozzle which emitted a jet of air. The air stream was interrupted by a disk mounted on the axle of an electric motor. The speed of the disk was governed by a rheostat and a leather brake and the frequency of the air bursts were recorded by means of a speed counter and a chronograph. Thus they were able to measure the duration of a single stimulation at the frequency at which the bursts were fused into a constant sensation. This value was called the critical frequency of percussion.

With this apparatus measurements were made of the discriminatory ability of the finger-tip of two subjects. In making their measurements, a constant routine was followed: the right index finger was placed in a stand situated 2.3 cms. from the nozzle which was 1.5 mm. in diameter. The disk was placed between the finger and the nozzle. The air pressure was then adjusted to any desired value and the disk set into rotation. The frequency was gradually increased until the subject reported a fused sensation.

The results of this investigation showed that there were actually two points of fusion at any one pressure value, the first being much more apparent than the second. When c.f.p. values were plotted against pressure values each of the two fusion curves showed two distinct limbs. Allen and Hollenberg stated that the first fusion point represented superficial skin sensitivity and the second deep sensitivity.

Although this technique achieved its purpose of delivering intermittent bursts of air at any desired frequency and pressure, its main drawback was that consistent and reliable readings could not be obtained until after considerable practise. The authors reported that at least a week of daily practise sessions of several hours duration were required before any kind of consistent readings could be obtained.

In 1925, Allen and Weinberg (5) extended the study to include the lower lip. The same apparatus was used as in the previous investigation carried out by Allen and Hollenberg. Unfortunately, they again only used two subjects and thus the results obtained have very limited value. However, as in the previous study, two fusion points were again evident at all pressure values studied.

Once again, the two curves showing the relation between c.f.p. and pressure showed two distinct limbs.

In 1936, Bellows (11) used a technique very similar to Allen and his collegues in an attempt to verify their results. His apparatus was very similar to Allen's except for a few minor modifications which increased the efficiency of obtaining measurements. One such modification was that he measured the air blast by means of a scale balance so that the weight of the air blasts could be obtained. In this way he was able to calculate the pressure falling on the stimulated area.

Bellows found that only one fusion value existed for any one pressure value. When the c.f.p. was plotted against pressure, he found that two distinct limbs or branches were present in the curve. The slope of the second branch was much steeper than the first. Large individual differences were evident, with variations of up to 26.7 revolutions per second from subject to subject.

Not unlike the technique of Allen et al, this method also required considerable preliminary training before consistent results could be obtained. Bellows reported the necessity of using practise sessions of from one to five weeks duration and even then some of the subjects could not be used because of excessive variability in their scores. In the end only three subjects were used, each receiving five trials on five different pressure values.

The only other investigation employing intermittent air bursts was carried out on the frog by Adrian _et al_ in 1931 (1). They used intermittent air bursts to stimulate a single sensory nerve fibre of a frog. Their apparatus was similar to that used by Bellows five years later, except that a dentist's drill was used to rotate the disk. Since only frogs were used in this investigation, and since a single nerve was stimulated rather than the skin, their results are not particularly relevant to the problem under discussion, i.e., human tactual sensitivity.

Thus it is clear that very little work has been done on the resolving power of the skin using an intermittent form of tactual stimulation. What work has been done is of an exploratory nature involving very few subjects. Furthermore, the apparatus which was used was not too reliable and required considerable practise on the part of the subjects before consistent readings could be obtained.

The present study is chiefly concerned with describing a technique, similar to that used in previous investigations, but one which will eliminate the need for lengthy practise periods. It is also proposed to apply this technique to a larger number of subjects in the measurement of the resolving power of ten different skin areas.

# CHAPTER II

## EXPERIMENTAL METHOD AND RESULTS

### I. EXPERIMENT I

The Problem

The preceding chapter has reviewed various methods which have been used to measure tactual sensitivity. Perhaps the most profitable and potentially useful of these techniques is one employing intermittent bursts of air of varying frequency. The usefulness of this technique has never been fully explored. One possible reason for this is that lengthy practise sessions are required before subjects are able to make reliable and consistent judgments. The purpose of Experiment I is to outline an improved technique of intermittent stimulation using air under pressure, where the need for lengthy practise sessions has been eliminated.

Apparatus

A diagram of the tactile stimulator together with the various components that make it up is shown in Figure 1. Briefly, it consists of a large compressor tank which can be filled up with air to a maximum load of 100 lbs. per square inch. A copper tube (A1) leads from the tank pressure gauge (TP) to a stimulus pressure regulator (PR) by means of which the pressure of the outgoing air can be set at any value from 1 to 60 lbs. per square inch. This value can be read from a pressure gauge (SP). Since the stimulus

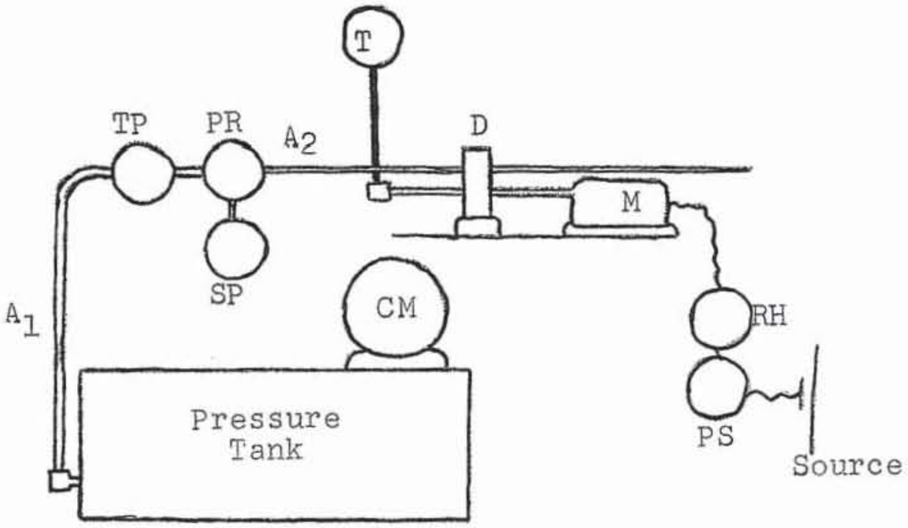

Figure 1 Diagram of the Tactile Stimulator.

$A_1$ - Copper tube (0.5 cms. dia.)
$A_2$ - Copper tube (0.2 cms. dia.)
CM - Compressor Motor
D - Disk enclosed in bronze air-tight casing.
M - Electric Variable Speed Motor (0 to 7500 r.p.m.)
PR - Pressure Regulator
PS - Powerstat
RH - Rheostat
SP - Stimulus Pressure Gauge
T - Tachometer
TP - Tank Pressure Gauge

pressure values which are used are always well below the maximum load in the pressure tank many stimulus trials can be given before the tank has to be refilled. From the pressure regulator a second copper tube (A2) conducts the air to a bronze air-tight casing enclosing a rotating metal disk (D) with two openings which interrupt the incoming stream of air. From the disk casing the air continues in bursts along a tube to a coupling on the outside of the apparatus to which nozzles of various diameters can be attached. The metal disk is rotated by a small electric motor (M) whose speed is controlled by a powerstat (PS) and rheostat (RH) joined in series. A mechanical tachometer (T) is connected to the motor to record the speed of the rotating disk in revolutions per minute. The r.p.m. readings are then converted into bursts per second by means of a conversion table.

### Preliminary Procedure

Subjects were fitted with earplugs and N.R.C. type earmuffs in order to reduce the noise of the apparatus. A stand was erected to hold the left index finger steady at a distance of 0.50 cms. from the nozzle whose diameter was 0.60 mm. A thin film of petrolatum was applied to the finger-tip to protect it from the drying action of the air bursts. The tank was then filled to its maximum load of 100 lbs. per sq. in. and the stimulus pressure gauge set at some specified value up to 60 lbs. per sq. in. (the highest reading on the dial). The frequency of the air bursts was gradually increased until the subject reported a constant pressure sensation. This value was called the c.f.p. or the critical frequency of percussion. The stimulus pressure gauge was then set at another value and the frequency of the bursts was again increased until fusion was reported. Since the subjects had difficulty in differentiating the bursts at pressures below 10 lbs. per sq. in., all measurements were confined to a range from 10 to 60 lbs. per sq. in., at intervals of 5 lbs. After various preliminary observations were made, four graduate students were selected. Each subject was given one practise trial on 5 different values within this range. Following the practise session, each subject was given 15 trials on each of the 11 pressure values. These trials were spread over intervals of from 10 seconds to 2 days. An analysis of the data showed that the variability in reading averaged only 4.2 bursts per second, both over short and long periods of time. Furthermore, it was found that reliable readings could be obtained after as few as five practise trials. An analysis was also made to determine possible order effects in pressure presentation. In some cases readings were taken when the stimulus pressure was increased progressively from 10 to 60 lbs. per sq. in., in other cases when it was decreased progressively from 60 to 10 lbs. A randomized order of presentation was also tried. No significant differences in reading were found for the different orders of presentation.

The final preliminary observations were concerned with attempting to verify some perplexing results reported by Allen and Hollengerg (3). These investigators reported the existence of two fusion points for every stimulus pressure used. They reported that increasing the frequency of air bursts beyond the first fusion point causes the sensation to again become interrupted. On further increasing the frequency a second point of fusion is reached. However, this point is not as satisfying as the first, so to speak, but it is definitely measurable. When this procedure was repeated in the present experiment, all four subjects reported the existence of two fusion points although two of the subjects reported that the second point was more satisfying than the first. The increment in frequency required to produce the second fusion point averaged about 8 bursts per second. These two points were also reported when the frequencies were presented in a descending order, i.e., from high frequencies to low frequencies. Six other subjects were then used. Five of these always reported both fusion points while one experienced the second point only occasionally. The procedure was next repeated on the skin of the forearm. In this case three out of the four subjects reported no second fusion point while the fourth experienced it only occasionally. These conflicting results prompted a close check of procedure and apparatus which resulted in no hint as to the possible reason for the results until it was decided to test the subjects in another room away from the compressor tank, using a 6 foot long connecting hose. Due to pressure loss in the connecting hose it was impossible to take readings under 20 lbs. per sq. in. With this experimental arrangement, all the subjects (12) reported the presence of only one fusion point, regardless of which part of the body was stimulated. Furthermore, the trial to trial variations in c.f.p. were even less than with the previous setup. In most cases, the differences between trials, even after little practise, were of the order of one burst per second.

Experimental Procedure

Ten university students, five males and five females, were used as subjects in this experiment. They were fitted with earplugs and N.R.C. type earmuffs and seated at a table in a room adjoining the tactile machine. The volar aspect of the terminal phalanx of the left index finger was placed in a stand at a distance of 0.50 cms. from a nozzle 0.60 mm. in diameter. A thin film of petrolatum was applied to the finger-tip. Each subject was given one practise trial on each of 9 stimulus pressures ranging from 20 to 60 lbs. at intervals of 5 lbs. per sq. in. Each trial consisted of increasing the frequency of the air bursts until the subject reported a constant or fused sensation. As before, this value was referred to as the c.f.p. or the critical frequency of percussion. Following the practise trials, each subject was given one trial, separated by 10 second rest intervals, on each of the nine pressure values. This was then followed by at least a six minute rest period. This procedure was repeated until five trials had been given on each of the pressures. On the following day five more trials were given resulting in a total of 10 trials for each subject on each of the nine pressure values.

## Results

The main findings of the investigation are summarized in Figure 2 where critical frequency of percussion or c.f.p. is plotted against stimulus pressure. It can be seen that the graph consists of two linear parts or two limbs, with the change in slope occurring at 45 lbs. pressure. Both limbs of all the curves in this study were fitted for best of fit by means of a regression equation.

Figures 3 and 4 show the individual performances of the ten subjects, five males and five females. The main reason for plotting separate graphs was to show the large individual differences which exist in the discriminatory or resolving power of the skin. At 20 lbs. pressure the c.f.p. values for the female subjects range from 10 to 33 bursts per second and for the males from 5 to 27. These differences are even more pronounced at the higher

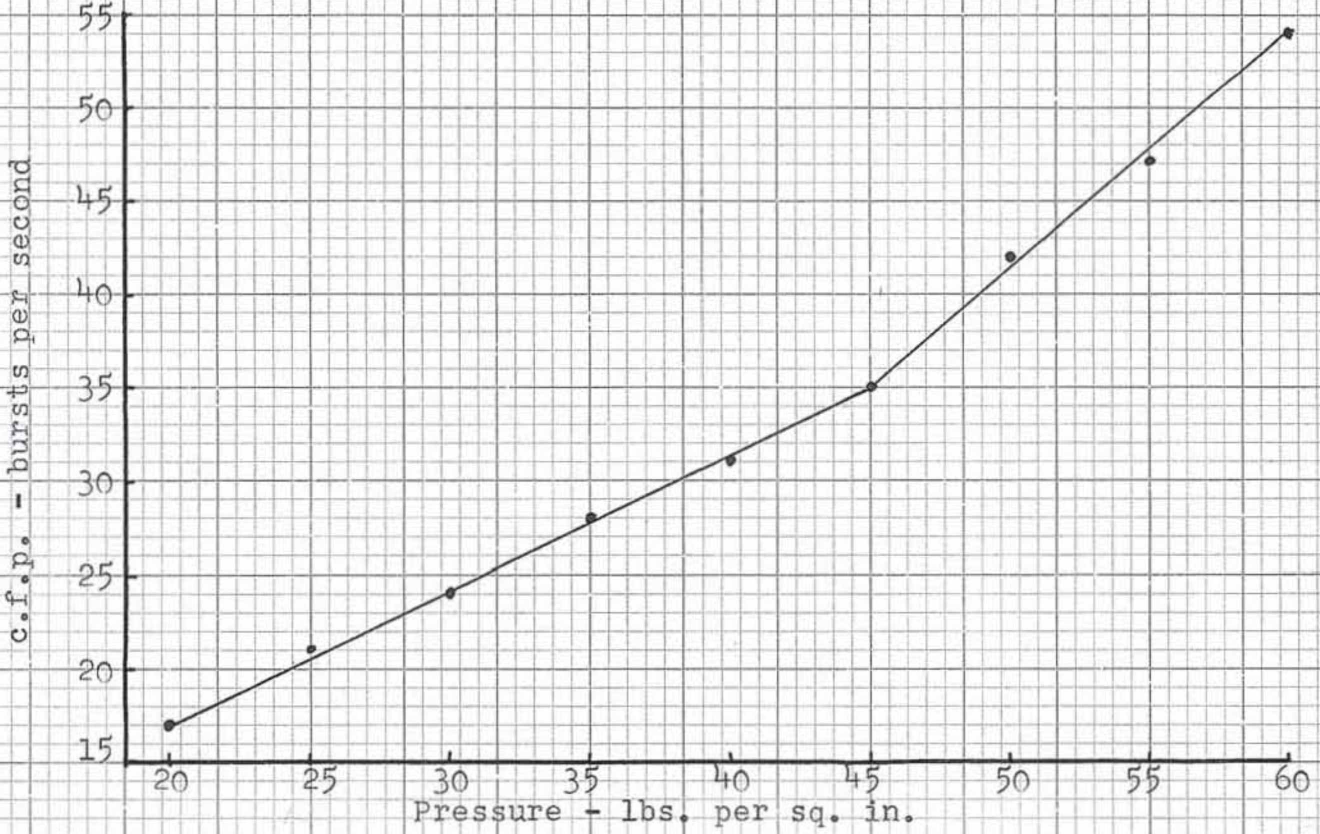

Figure 2 Relationship between c.f.p. and stimulus pressure on the finger-tip of ten subjects. Each point is the mean of 100 measurements, 10 from each of 10 subjects.

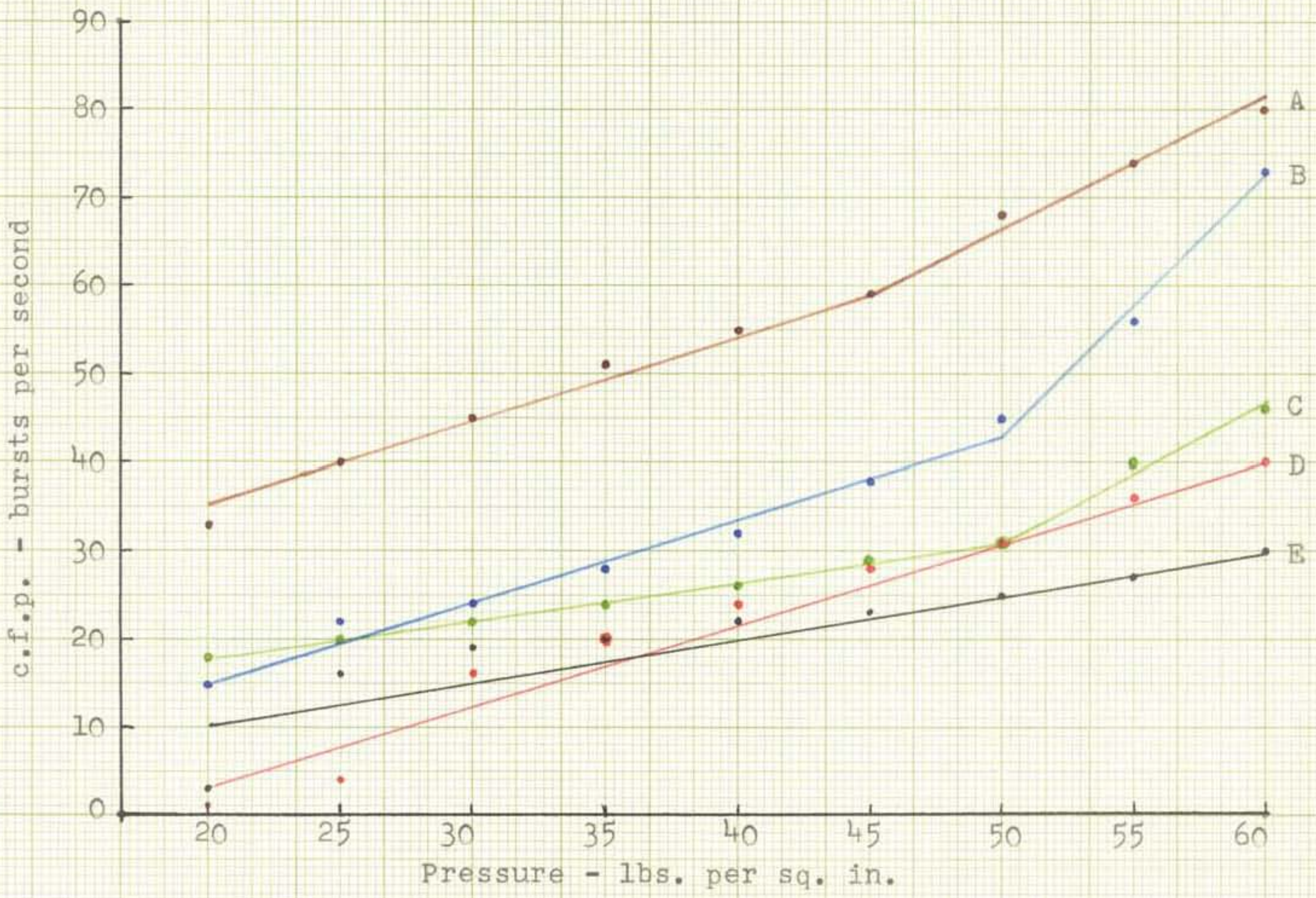

Figure 3 Relationship between c.f.p. and stimulus pressure for five female subjects (A, B, C, D, E). Each point is the mean of ten measurements.

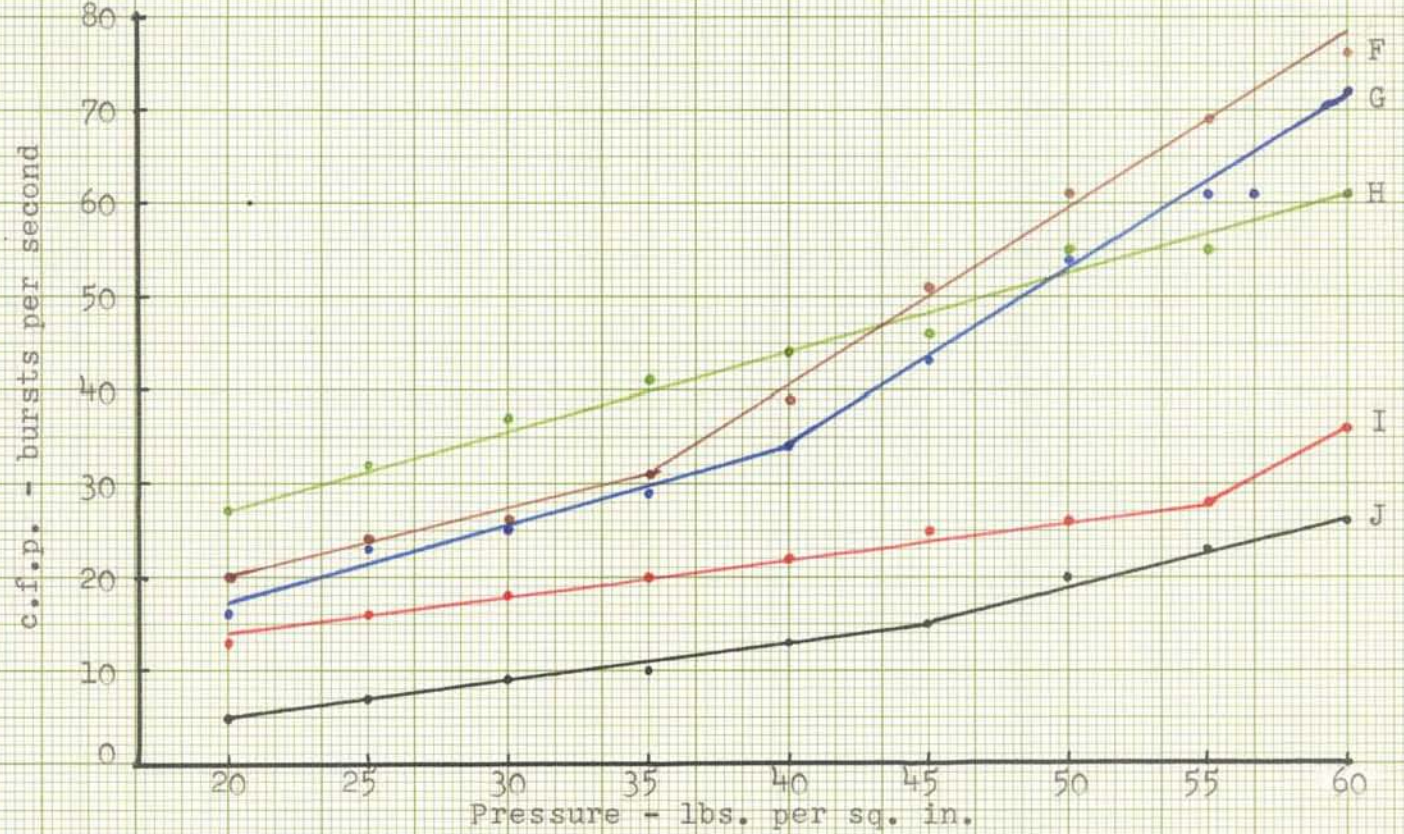

Figure 4 Relationship between c.f.p. and stimulus pressure for five male subjects (F, G, H, I, J). Each point is the mean of ten measurements.

pressure levels. For example, at 60 lbs. the c.f.p. values for the females range from 30 to 80 bursts per second and for the males from 25 to 75. No significant sex differences are present ($t = 1.01$, $p > .10 < .20$). In addition to the differences in c.f.p. there are also large variations in the slope of the second limb of the curve. For example, curves B, C, F and G show a steep upward slope while curves A, D, E and J show only a slight slope. Finally, there are also individual differences as to the pressure at which the second limb appears. For example, one subject shows the second limb at 35 lbs. (F), three at 50 lbs. (B, C, D) and one shows no second limb (H). In the latter case presumably the second limb would have appeared beyond 60 lbs. if measurements had been taken at these higher pressures.

Table I below shows the variability of each subject for nine pressure values in terms of standard deviation scores. It can be seen that the variability for the ten subjects on all pressure values ranges from 0.8 to 4.7 bursts per second, with a mean of 2.0 bursts per second. For individual pressures the variability ranges from 0 to 8.3 bursts per second. Although the day to day variations are very slight ($F = 0.136$, $p > .05$), longer intervals produce large differences, e.g., when six of the subjects were tested one month later, an average difference of 7.7 bursts per second was found, with the retest being higher ($t = 6.54$, $p < .01$).

TABLE I

VARIABILITY FOR TEN SUBJECTS IN TERMS OF S.D. SCORES FOR NINE PRESSURE VALUES

| | Pressure - lbs. per sq. in. | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| Subj. | 20 | 25 | 30 | 35 | 40 | 45 | 50 | 55 | 60 | Av. |
| A | 1.0 | 1.8 | 1.8 | 1.4 | 1.1 | 1.0 | 1.7 | 2.4 | 2.2 | 1.6 |
| B | 1.9 | 1.0 | 1.3 | 1.0 | 1.5 | 0.8 | 0.8 | 1.7 | 1.5 | 1.3 |
| C | 0.4 | 1.0 | 0.8 | 0.8 | 0.8 | 0.3 | 1.1 | 0.8 | 1.0 | 0.8 |
| D | 1.5 | 1.3 | 2.4 | 1.5 | 2.4 | 1.5 | 1.9 | 1.6 | 1.9 | 1.7 |
| E | 2.7 | 3.1 | 3.2 | 3.2 | 3.4 | 4.0 | 3.7 | 3.9 | 3.7 | 3.4 |
| F | 1.6 | 1.2 | 1.6 | 3.1 | 2.2 | 3.4 | 1.8 | 2.4 | 3.3 | 2.2 |
| G | 2.9 | 0.8 | 1.6 | 0.6 | 0.8 | 0.8 | 1.8 | 1.9 | 2.0 | 1.4 |
| H | 3.2 | 4.9 | 4.8 | 3.3 | 3.8 | 6.5 | 4.8 | 4.7 | 8.3 | 4.7 |
| I | 1.8 | 2.1 | 1.9 | 2.2 | 1.9 | 1.8 | 1.8 | 1.4 | 2.1 | 1.9 |
| J | 1.0 | 1.0 | 0 | 0.8 | 0.8 | 1.0 | 0.9 | 1.6 | 2.0 | 1.0 |
| Av. | 1.8 | 1.8 | 1.9 | 1.8 | 1.9 | 2.1 | 2.0 | 2.2 | 2.8 | 2.0 |

## II. EXPERIMENT II

### The Problem

The results of Experiment I show that consistent and reliable measurements of tactual sensitivity can be obtained by using a method of intermittent stimulation involving bursts of air under various pressures and delivered at various frequencies. The purpose of Experiment II is to apply this technique to the measurement of tactual sensitivity of ten different body areas, viz., tongue, lip, cheek, forehead, neck, finger, thumb, hand, forearm, and upper arm.

Experimental Procedure

Ten university students, five males and five females, were used as subjects in this experiment. They were fitted with earplugs and N.R.C. type earmuffs and seated at a table in a room adjoining the tactile machine. Ten different areas of the body were tested. These were: tip of the tongue, middle of the red part of the lower lip, right side of the cheek, middle of the forehead, back of the neck, volar aspect of the terminal phalanx of the left index finger, metacarpus of the left thumb, back of the left hand, left forearm midway between the elbow and the wrist, and the left upper arm midway between the elbow and the shoulder. Suitable stands were erected to hold each body area in a fixed position so that only the slightest movement was possible. All areas were placed 0.50 cms. from a nozzle of 0.60 mm. diameter. A thin film of petrolatum was applied to each body area under study to protect it from the drying action of the air bursts. In making measurements a constant routine was followed: each subject was given a practise series consisting of one trial on each of three stimulus pressures -- 20, 40, and 60 lbs. per sq. in. -- on any three of the ten skin areas. These three areas were selected at random for each subject. Each trial consisted of increasing the frequency of the air bursts until the subject reported a constant or fused sensation. Following this practise session a skin area was randomly selected and the subject was given one trial, separated by a 10 second rest interval, on each of the nine stimulus pressures (20, 25, 30, 35, 40, 45, 50, 55, 60 lbs. per sq. in.). After a six minute rest interval this procedure was repeated on the next skin area and so on until all ten skin areas had been tested. This entire procedure was then repeated on four consecutive days resulting in a total of five trials on each pressure for each of the ten skin areas -- for each subject. Each day the various skin areas were tested in a randomized order.

## Results

The main findings of Experiment II are summarized in Figure 5, where the c.f.p. for each of the ten skin areas is plotted against the stimulus pressure. It can be seen that all ten curves consist of two linear parts or limbs with each curve showing a change of slope at 45 lbs. pressure. This change of slope, however, is more pronounced for some body regions than for others, e.g., the tongue shows the steepest slope while the upper arm shows only a slight change of slope. Figure 5 also shows that the ten curves are grouped into two distinct clusters. The top cluster, representing high resolving power of the skin, consists of the lower lip, tongue, thumb, and finger-tip. The bottom cluster, representing on the other hand, poorer resolving power, consists of the back of the hand, forearm, upper arm, cheek, forehead, and neck. The mean separation

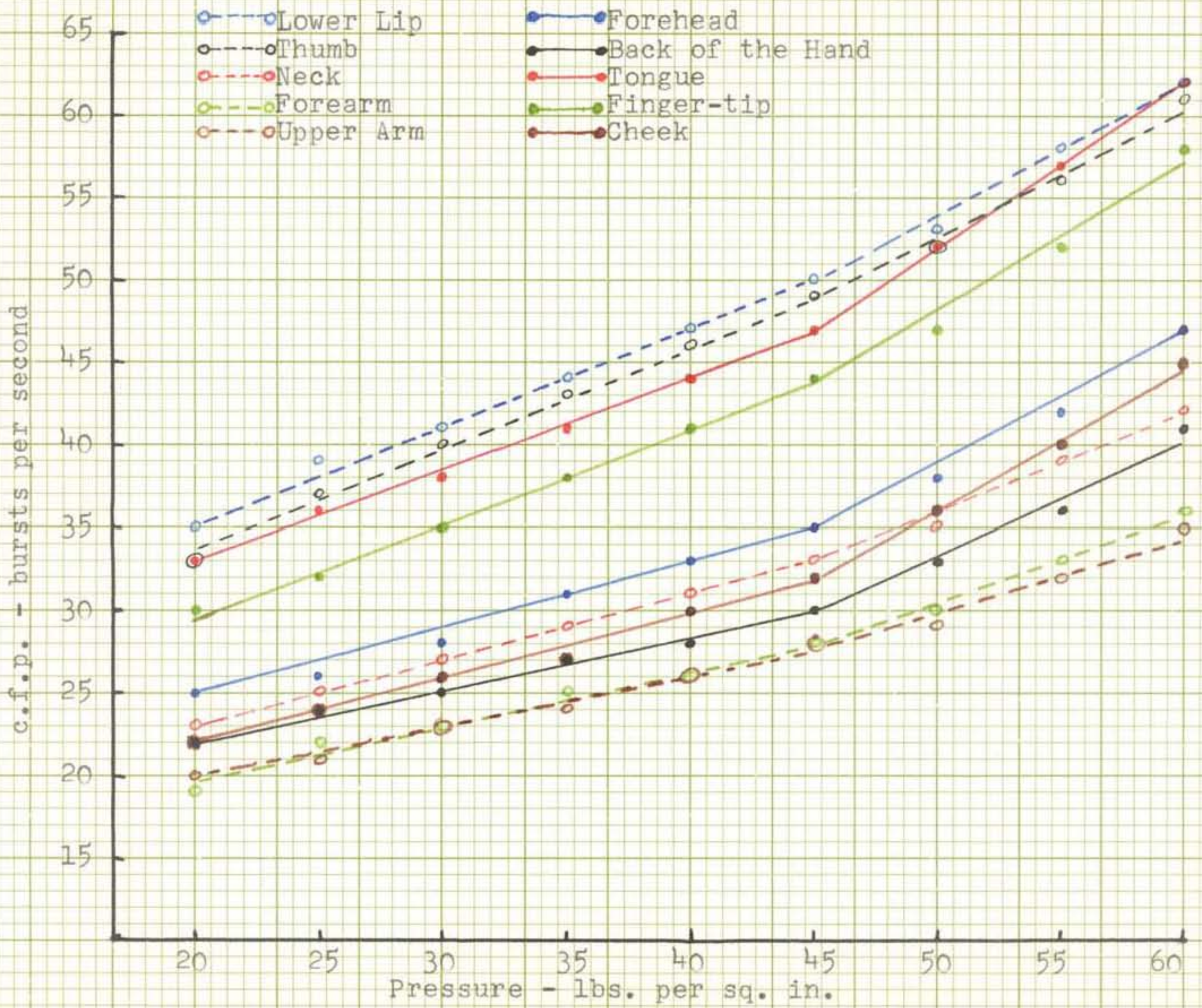

Figure 5 Relationship between c.f.p. and stimulus pressure for ten body areas on ten subjects. Each point is the mean of 50 measurements.

of the two groups of curves is 15.4 c.f.p. units.

Table II shows the rank order of skin sensitivity and variability of ten body areas in c.f.p. units. It can be seen that the lower lip is most sensitive with an average c.f.p. value of 47.9 and the upper arm least sensitive with an average c.f.p. value of 26.5. There are significant differences between all the skin areas except the neck and the cheek where the average difference is only 0.2 c.f.p. units (t = 0.20). The thumb is most variable in its sensitivity with a standard deviation of 2.50 and the upper arm least variable with a standard deviation of 1.40.

TABLE II

SENSITIVITY AND VARIABILITY OF TEN BODY AREAS IN C.F.P. UNITS

| Body Area | Average c.f.p. | Rank Order of Sensitivity | Variability S.D. | Rank Order of Variability |
|---|---|---|---|---|
| Lower Lip | 47.9 | 1 | 2.21 | 3 |
| Thumb | 46.3 | 2 | 2.50 | 1 |
| Tongue | 45.5 | 3 | 1.94 | 5 |
| Finger-tip | 41.8 | 4 | 2.33 | 2 |
| Forehead | 34.9 | 5 | 1.56 | 8.5 |
| Neck | 31.5 | 6 | 1.69 | 7 |
| Cheek | 31.3 | 7 | 1.56 | 8.5 |
| Hand | 29.6 | 8 | 2.20 | 4 |
| Forearm | 27.1 | 9 | 1.87 | 6 |
| Upper Arm | 26.5 | 10 | 1.40 | 10 |

When a rank-order correlation is applied to this data, a Rho of 0.68 is obtained indicating that the most sensitive areas of the skin are also the most variable. Generally, each individual subject shows a rank order of sensitivity similar to the average for the group as a whole. Thus when rank-order correlations are calculated between individual orders of sensitivity and the average order of sensitivity, Rho's of .57 to .99 are obtained.

Figures 6 to 15 show the individual performances of the ten subjects on the ten different body regions. Large individual differences are evident on all areas tested, e.g., on the lower lip (Figure 6) the c.f.p. values for the various subjects ranged from 38 to 84 at 60 lbs. pressure and from 19 to 49 at 20 lbs. pressure. The smallest individual differences were found on the forearm (Figure 14) where the values ranged from 28 to 46 at 60 lbs. pressure and from 16 to 24 at 20 lbs. pressure. In every case the individual differences were larger at the higher pressures than at the lower.

It is interesting to note that in most cases there are two linear parts or limbs for the curves of each subject on any one skin area, but the point at which the second limb begins varies for some individuals. For example, in Figure 8, most individuals show a break in the curve at 45 lbs. pressure, but there are cases where the break occurs at 50 lbs., 40 lbs., and in some instances, where there appears to be no break at all. However, in the latter instances, it is assumed that a break would occur at pressures beyond those used in this experiment. This

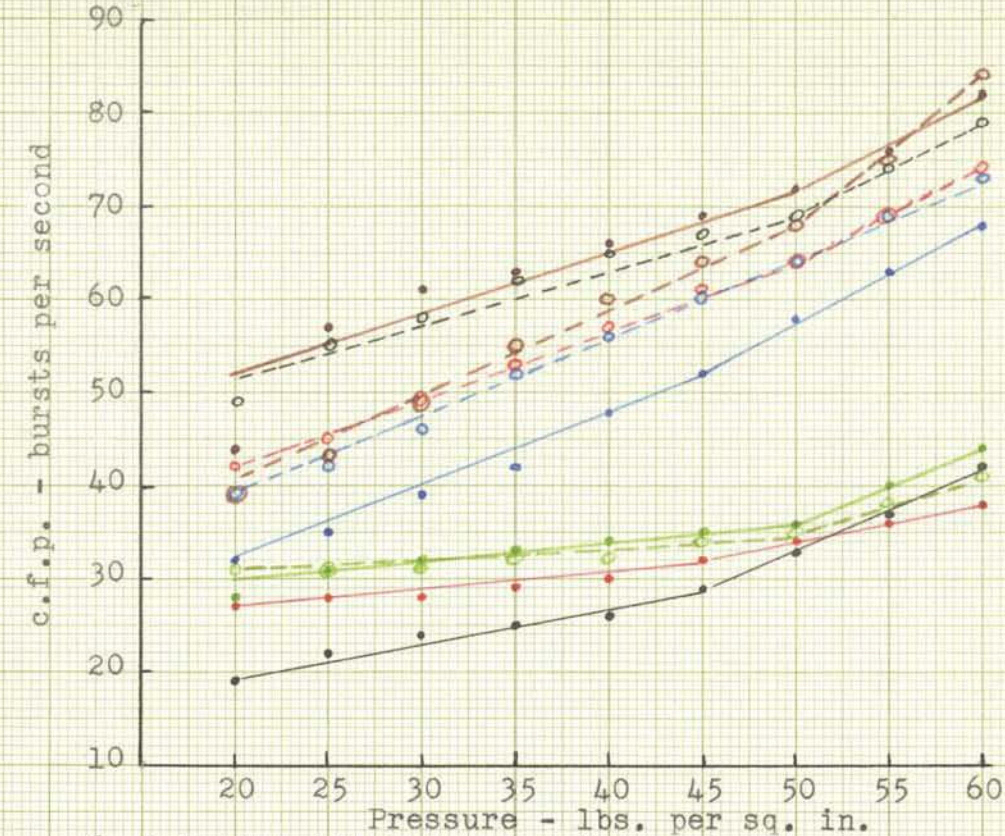

Figure 6 Relationship between c.f.p. and stimulus pressure on the lower lip of ten subjects.

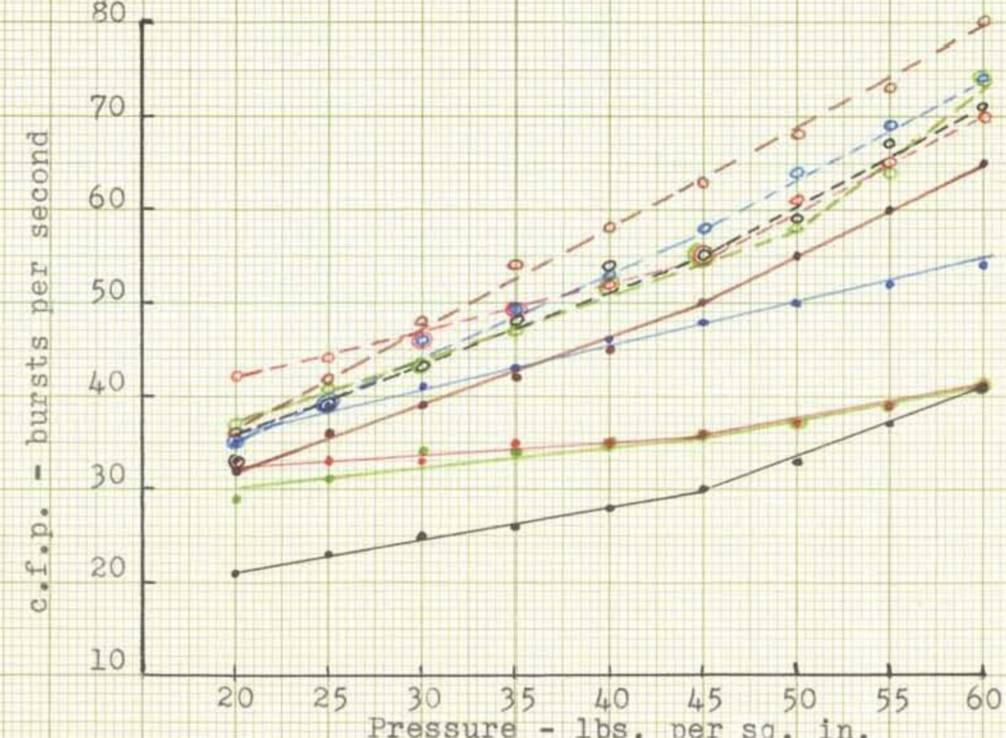

Figure 7 Relationship between c.f.p. and stimulus pressure on the thumb of ten subjects.

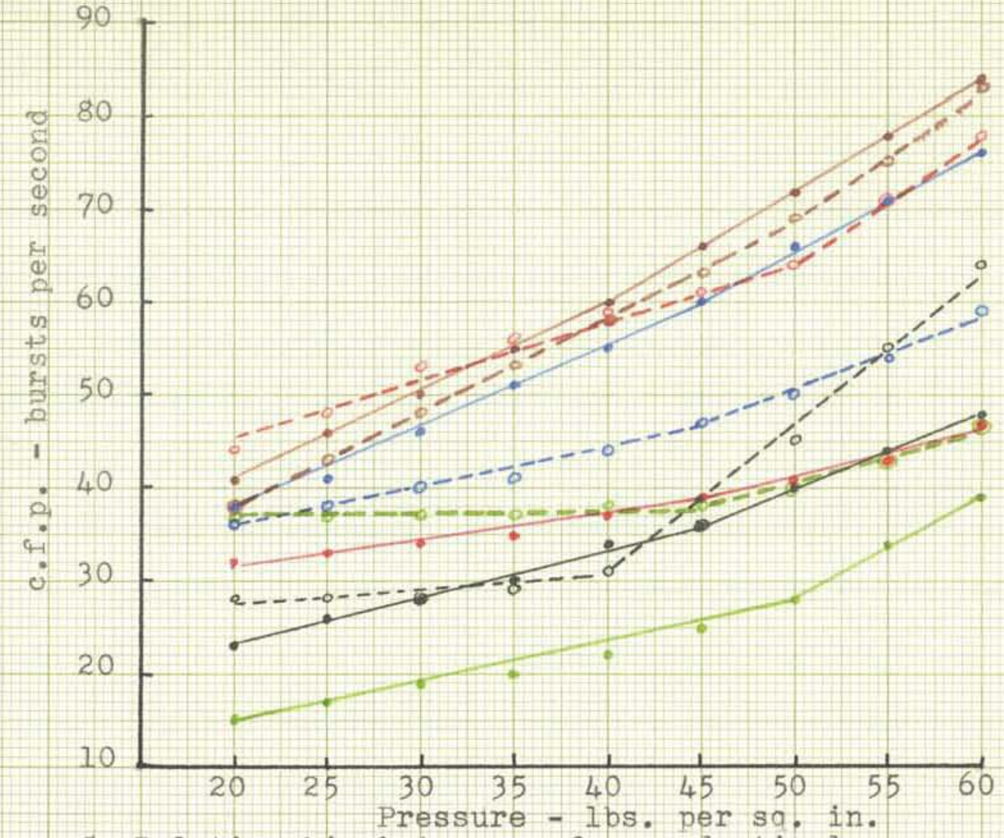

Figure 8 Relationship between c.f.p. and stimulus pressure on the tongue of ten subjects.

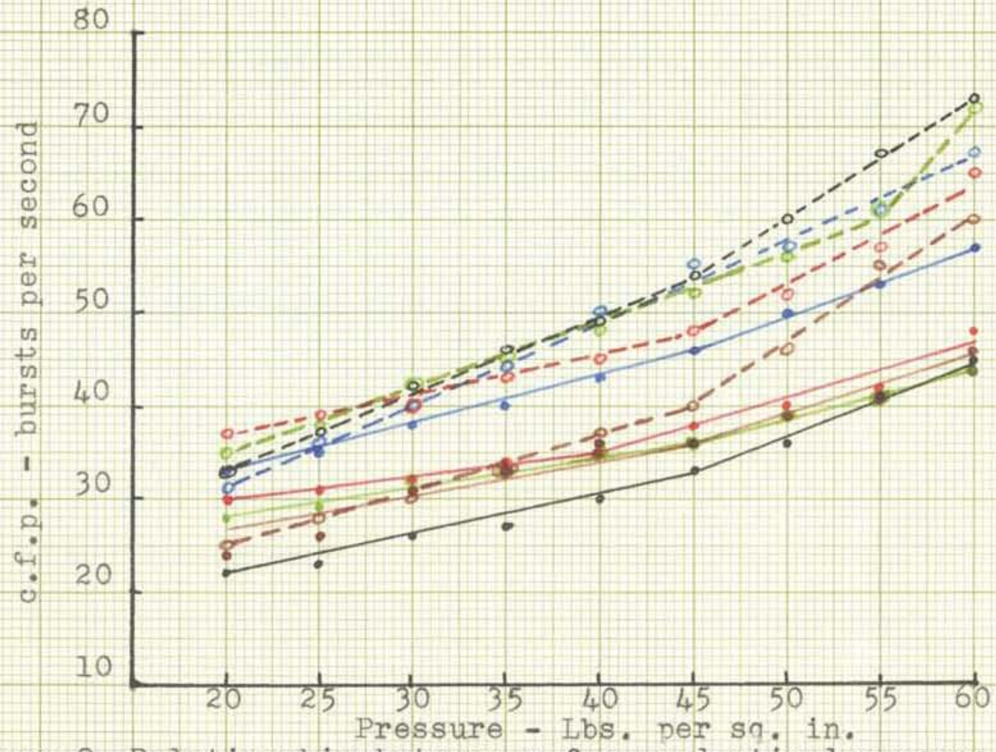

Figure 9 Relationship between c.f.p. and stimulus pressure on the finger-tip of ten subjects.

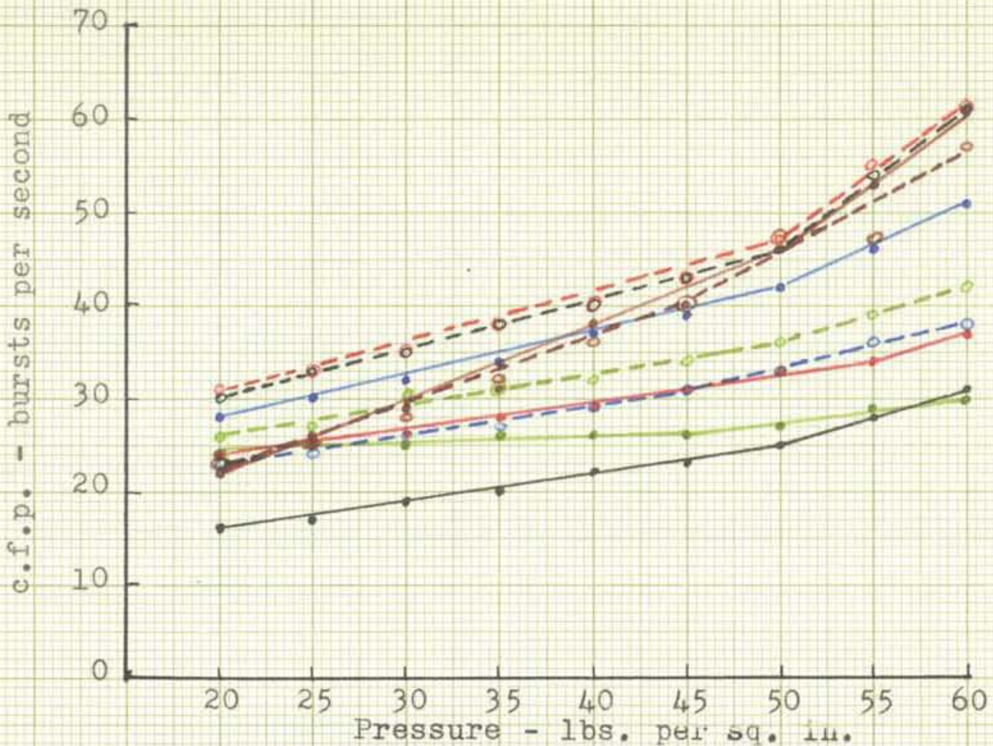

Figure 10 Relationship between c.f.p. and stimulus pressure on the forehead of ten subjects.

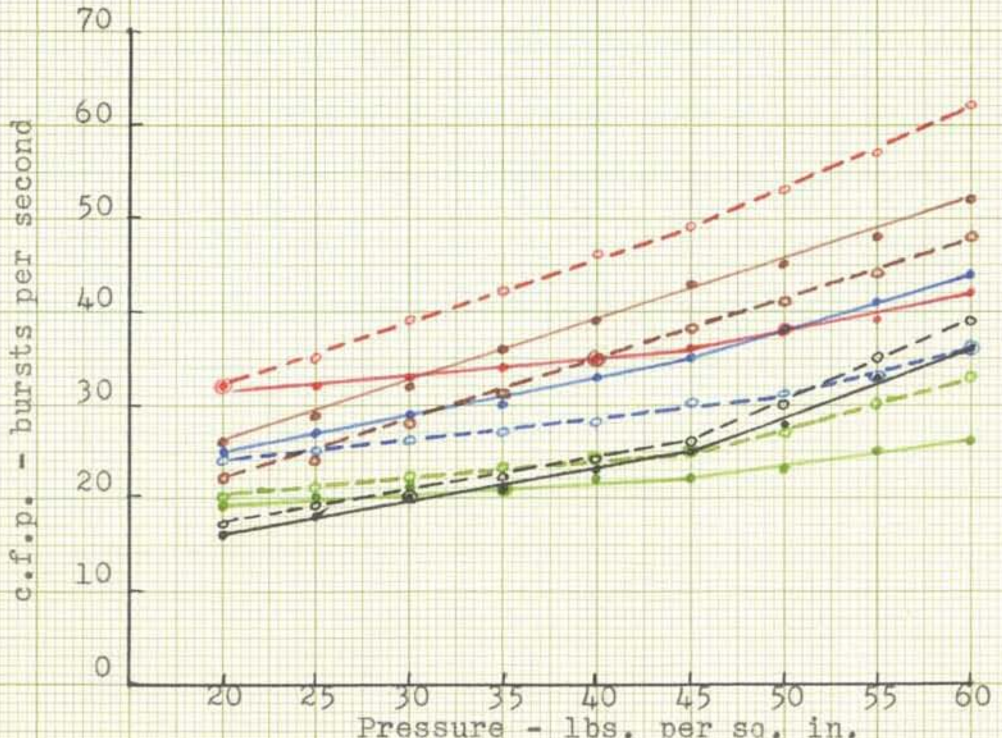

Figure 11 Relationship between c.f.p. and stimulus pressure on the neck of ten subjects.

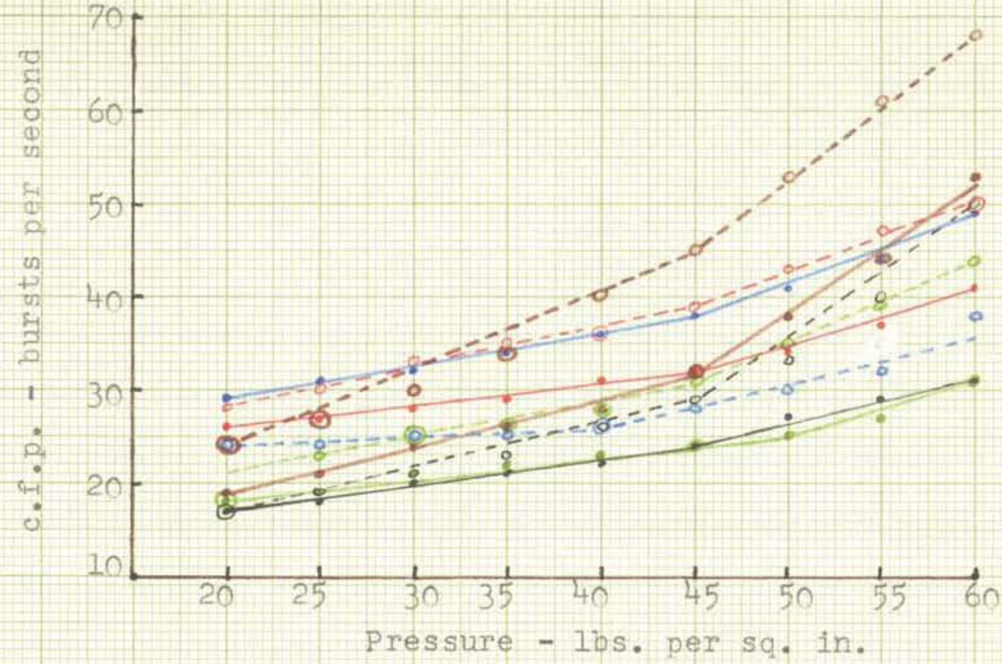

Figure 12 Relationship between c.f.p. and stimulus pressure on the cheek for ten subjects.

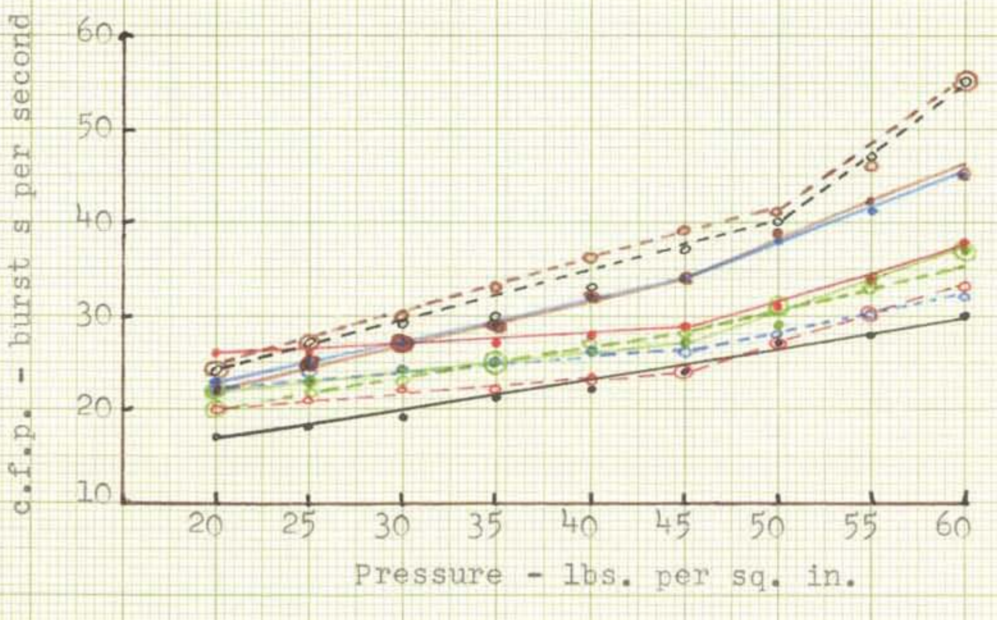

Figure 13 Relationship between c.f.p. and stimulus pressure on the back of the hand for ten subjects.

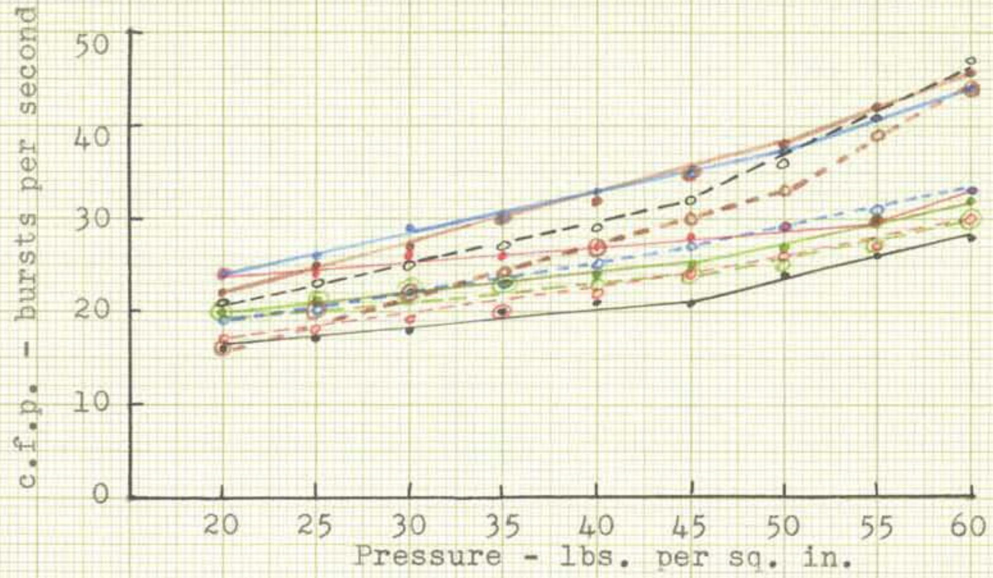

Figure 14 Relationship between c.f.p. and stimulus pressure on the forearm for ten subjects.

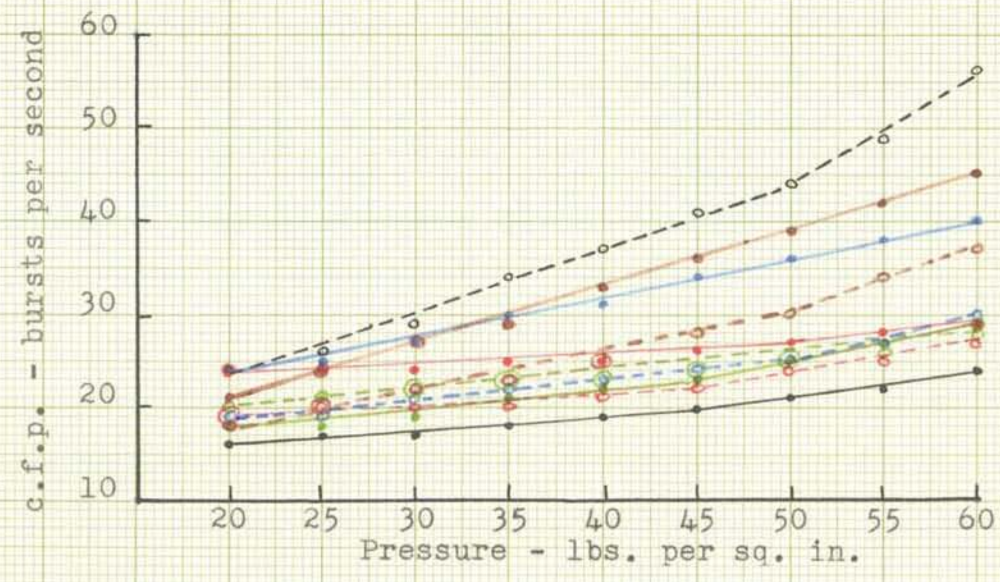

Figure 15 Relationship between c.f.p. and stimulus pressure on the upper arm for ten subjects.

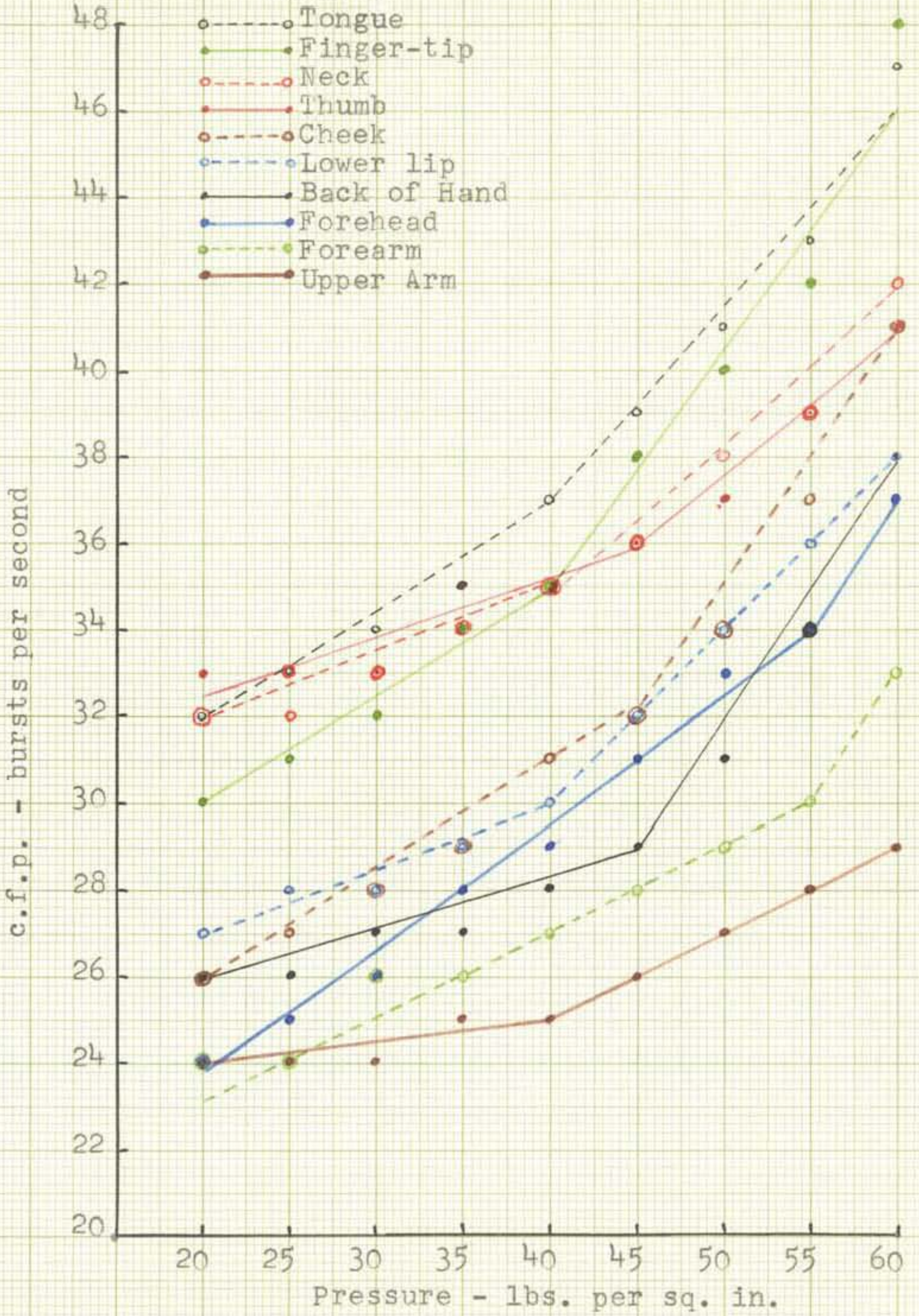

Figure 16 Relationship between c.f.p. and stimulus pressure on ten different skin areas for one subject (C).

variability of the point at which the second limb begins is evident on most of the body areas studied. Furthermore, it can be seen that the amount of slope of the limbs differs for each individual on the same body area. However, in every case where a definite break occurs, the slope of the second limb is steeper than that of the first.

Figure 16 shows the performance of one subject on all ten areas of the body. It can be seen that there are two linear parts for each of the curves representing a different body area. In most cases the break in the curves appear at 45 lbs. pressure, (back of the hand, cheek, thumb, neck), but there are instances where the break occurs at 55 lbs. (forearm and forehead), and 40 lbs. (upper arm, lower lip, finger-tip, and tongue). It can also be seen that the slope of the two limbs varies for each body area, e.g., the finger-tip shows the steepest slope for both linear parts while the upper arm shows the least slope. Similar performances are evident for the remaining subjects.

Marked sex differences are also evident on the body regions studied. Table III shows that significant sex differences occur for all skin areas except the upper arm. In general, the most sensitive areas of the body show the greatest sex differences and the least sensitive skin areas, the smallest differences. For example, the finger-tip, thumb, lower lip, and the tongue show differences of 11.0, 15.0, 12.4, and 5.5 c.f.p. units respectively while the back of the hand, forearm, and upper arm show

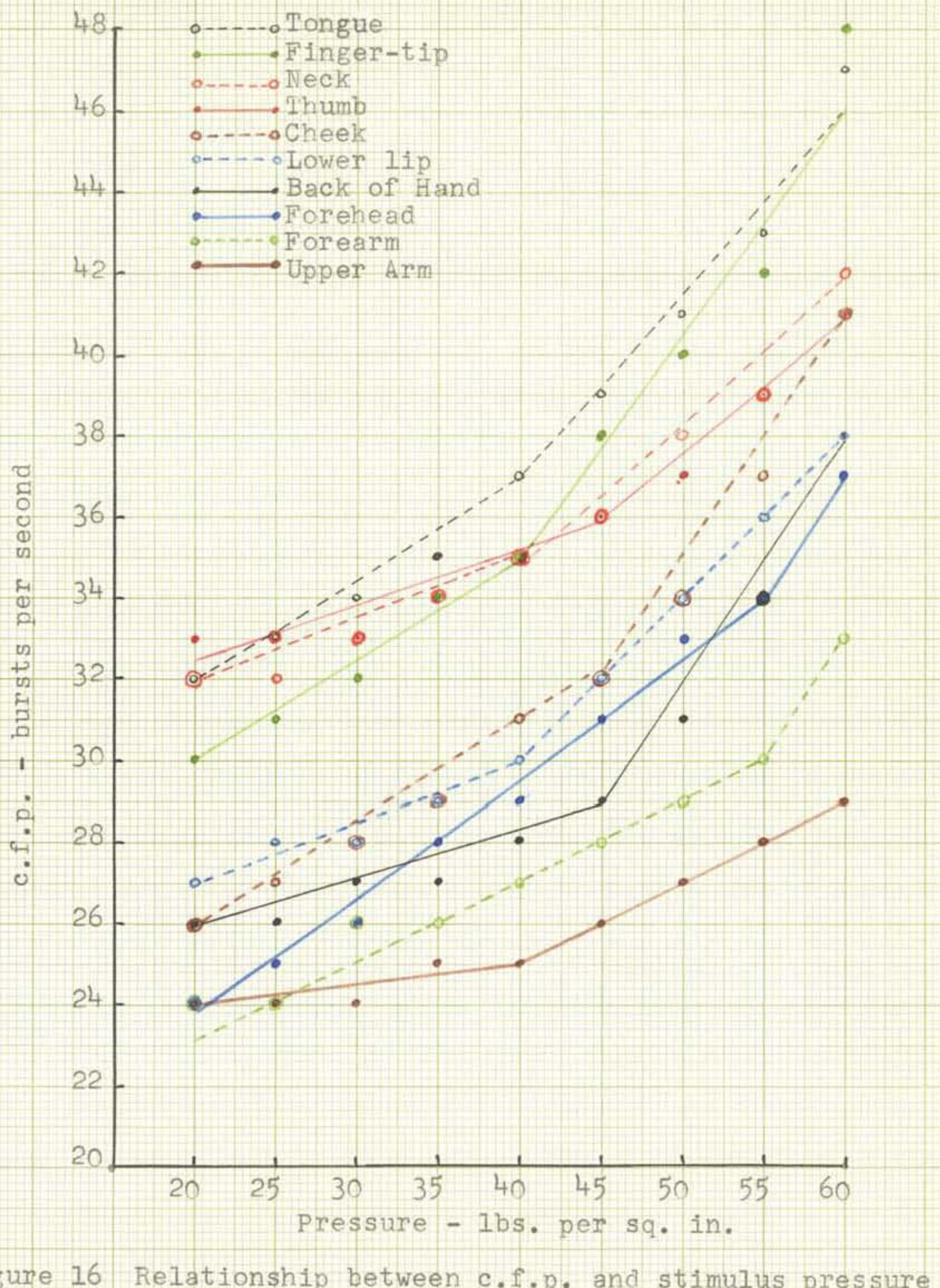

Figure 16 Relationship between c.f.p. and stimulus pressure on ten different skin areas for one subject (C).

differences of only 1.2, -1.6, and 0.1 c.f.p. units in that order.

TABLE III

SEX DIFFERENCES FOR TEN DIFFERENT BODY REGIONS

| Body Area | Sex | Average c.f.p. | Diff. | t | p |
|---|---|---|---|---|---|
| Thumb | M<br>F | 53.9<br>38.4 | 15.5 | 7.38 | .01 |
| Lower Lip | M<br>F | 53.9<br>41.5 | 12.4 | 15.83 | .01 |
| Finger-tip | M<br>F | 47.2<br>36.2 | 11.0 | 6.75 | .01 |
| Forehead | M<br>F | 36.8<br>30.8 | 6.0 | 7.98 | .01 |
| Tongue | M<br>F | 48.1<br>42.6 | 5.5 | 12.00 | .01 |
| Cheek | M<br>F | 33.2<br>29.2 | 4.0 | 4.18 | .01 |
| Back of Hand | M<br>F | 30.0<br>28.8 | 1.2 | 3.53 | .01 |
| Neck | M<br>F | 31.9<br>30.8 | 1.1 | 2.32 | .05 |
| Forearm | M<br>F | 26.2<br>27.8 | -1.6 | 4.85 | .01 |
| Upper Arm | M<br>F | 26.4<br>26.3 | 0.1 | 0.25 | .90 * |

* Not Significant

In every instance, the c.f.p. values for the males are significantly higher than for the females, except on the forearm where the females show an average c.f.p. value 1.6

units higher than the males ($t = 4.85$, $p < .01$) and on the upper arm where the sex difference is not significant ($t = 0.25$, $p > .90$). Thus these results suggest that males have a greater tactual discriminatory ability than females on eight of the areas studied. These sex differences, however, should be considered tentative since only five males and five females were used.

# CHAPTER III

## DISCUSSION OF RESULTS

The purpose of this study was a two-fold one. The first was to construct an apparatus for investigating the discriminatory or resolving power of the skin. The second objective was to employ this apparatus in the measurement of the resolving power of ten different skin areas.

The tactile stimulator, which produces an interrupted stream of air at any specified pressure or frequency, has proved easy to use and is capable of providing consistent readings after only a few practise trials. It is a considerable improvement over the apparatus used by Allen and Hollenberg (3) and Bellows (11), which, while having the merit of simplicity, yielded consistent and reliable readings only after a considerable amount of practise. Allen and Hollenberg report that at least a week of daily practise sessions of several hours duration were required before any kind of consistent readings could be obtained. Similarly, Bellows reported the necessity of practise sessions of up to five weeks duration and even then some of the subjects could not be used because of excessive variability in their scores. One possible reason for the poor reliability of their measurements may lie in their use of a rotating sectored disk in the immediate vicinity of the skin surface. With this type of arrangement, the whirling motion of the disk would produce air currents in the vicinity of the skin surface and thus affect the reliability of the measurements. In the present study this variable was eliminated by placing the rotating disk inside the apparatus. A second possible reason is that the vibration produced by their apparatus may have acted on the stimulation area. This was largely eliminated in this study by conducting the tests in an adjoining room. Finally, the stimulus pressures used in the present study may have been greater than those used by Allen _et al_ and Bellows.

One of the main findings of the present study is that the curve showing the relationship between c.f.p. and pressure is composed of two linear parts or limbs. Furthermore, this curve is essentially the same for all ten skin areas tested. Since a few of the curves show only a slight indication of a second limb, one may raise the question as to whether a second limb actually exists. That it does exist is indicated by several factors. First, even after only one trial on any skin area, representing one reading at each pressure value, approximately eighty percent of the subjects show a small but nevertheless a noticable change in slope of the first linear part of the curve at the higher pressures. Secondly, since the trial to trial variation in scores is small, even small deviations in the slope of a curve can be considered to be of practical significance. Finally, these factors taken in conjunction with the results of Allen and Hollenberg and Bellows, who also found two distinct limbs, confirm the present findings that the curves showing this relationship are composed of two linear parts.

These findings of the existence of two limbs in the sense of touch is in keeping with other studies employing the flicker technique in other sense modalities. Allen and his associates (2, 4, 6, 29) used the flicker method of stimulation in studying the senses of sight, hearing, taste, pain, warmth, and cold and found that, in all these senses, the graphs showing the relationship between the flicker frequency and the intensity of stimulation are composed of two distinct limbs. Other investigators (12, 13, 20), studying visual processes in terms of critical frequency, have all reported the existence of two limbs in the graphs showing the relationship between c.f.f. and changes in light intensity. It would appear, therefore, that the two limbs are common for all the sense modalities when stimulated intermittently.

The main difference between the previous studies and the present one concerns the question of the existence of one or two fusion points. The results of the present study indicate that only one fusion point exists and that the two fusion points reported by Allen and Hollenberg were likely due to an artifact, possibly to vibrations produced by the machine or by using a rotating sectored disk in the immediate vicinity of the skin area. The fact that only one genuine fusion point can be experienced seems to be in keeping with the findings of Bellows who, in commenting on the second fusion point, stated that "we did not find it definitely measurable". Unfortunately, Bellows did not elaborate on this statement and consequently it is not clear whether his subjects did not experience this phenomenon, or whether they experienced it but their second fusion scores were too variable to suit the experimenter.

One of the most striking findings in the present experiment concerns the large individual differences in the c.f.p. values of the various skin areas. The amount of variation from subject to subject depends partly upon the region of the body stimulated, e.g., differences of up to 46 bursts per second from subject to subject were found on the lower lip while a maximum difference of only 19 bursts per second was found on the upper arm. Bellows reported individual differences of up to 26.7 bursts per second on the lip while Allen and Weinberg (5) reported slightly smaller differences on the same area. Allen and Hollenberg suggest that the disparity in age of their subjects (one being double the other) may account for the differences in sensitivity. The age variable, however, is not a significant factor in the present study since all of the subjects were of approximately the same age (21 - 29 years). Neither are occupational differences believed to be a factor since all of the subjects were university students.

In addition to the large individual differences displayed in the c.f.p. values, differences were also shown in the slope of the second limb. Some individuals displayed rather sharp increases in sensitivity at the higher pressures while others showed little or no increase. Furthermore, the point at which the second limb began also varied from individual to individual. Thus although most individuals showed a break in the curve at 45 lbs. pressure, for some this second limb appeared at 35 lbs. and for others at 40, 50, or 55 lbs. pressure. This was evident on all the ten skin areas studied. Bellows and Allen and Hollenberg found similar results on the lip and the finger-tip. Bellows suggests that these individual differences in c.f.p. values and the slope of the second limb could be due to "...either (1) the phenomenal criterion of vanishing flicker frequency [c.f.p.] shifts differently for the different subjects, or (2) that differences in sensitivity (receptor, neurological differences) exist from subject to subject" (11, p. 726).

Although the individual differences were large, the individuals reproduced their c.f.p. values with marked consistency. Thus in Experiment I of the present study, the average variability for each of the subjects at all the pressure values ranged from 1.0 to 3.4 bursts per second with a mean variation of only 2.0 bursts per second. This is considerably better than Bellows mean of 8.1 bursts per second. In Experiment II, variability depended upon the body region stimulated, i.e., variability was greatest for the more mobile areas such as the lip, tongue, thumb, and finger-tip and the smallest for the less mobile areas, e.g., forehead, neck, cheek, back of the hand, forearm, and upper arm. This difference is undoubtedly due to the presence of tiny uncontrolled movements which occur much more readily in the more mobile regions of the body and whose presence makes it more difficult to determine an exact fusion point.

In the present study it was found that subjects showed better discriminatory ability on the more mobile areas of the body than on the less mobile areas. Thus the c.f.p. values were higher on the lower lip, thumb, tongue, and finger-tip than they were on the upper arm, forearm, back of the hand, cheek, neck, and forehead. These results are in line with those reported by Bellows, who, in some exploratory experiments found higher c.f.p. values for the lips than for the arms, neck, or back. These results are also in keeping with those obtained by the classical two-point threshold method (12, 30, see list on page 14 of Chapter I) where the more mobile skin areas are more sensitive than the less mobile ones. The physiological basis of this difference in discriminatory ability is undoubtedly related to differences in receptor concentration. It is a well established fact that the receptors for touch are much more numerous per unit area in the lower lip, tongue, thumb, and finger-tip than in such areas as the arms, face and neck (12, 25, 28).

One final question which should be raised is the significance of the two limbs in the curve showing the relation between c.f.p. and pressure. The sudden change of slope is most interesting for it suggests the activation of some other sensory system. That this may be so is suggested by the research on visual flicker where the graph showing the relationship between c.f.f. and changes in light intensity is also made up of two limbs. In this case, the lower limb is believed to be due to rod action and the upper limb to the action of the cone receptors (12, 13). In the present experiment it is believed that the lower limb represents light pressure sensitivity and the upper limb, deep pressure sensitivity. It is a well known fact that two such pressure systems do exist for even after the skin itself has been completely anesthetized, subcutaneous pressure sensitivity remains long after cutaneous sensitivity has disappeared. One possible way to test this hypothesis would be to apply certain anesthetics, which are known to inactivate the superficial skin receptors, to the different skin areas and then repeat the experiment.

An alternative hypothesis was suggested by Allen and his associates (2, 3, 4, 5, 6, 29) in their studies of the various sense modalities. They suggest that "this change of slope evidently represents a general property of the sensory nervous system, and in all cases is either an end-organ effect or a central synaptic effect. In the case of the eye the change in direction of the curve has always been attributed to a change from rod, or scotopic, vision to cone, or photopic, vision" but, "...in view of the occurrence of this peculiarity in the analogous curves for the other sense organs besides the eye, the effect cannot be ascribed to two kinds of receptors" (3, p. 361-362). They go on to postulate that in each sensory system there is some critical intensity of stimulation at which the rate of response to intermittent stimuli, or the sensitiveness of the sense organs, suddenly increases or decreases. In any event, further research is needed in order to clarify both hypotheses.

The results of the present study indicate that the flicker method of studying the tactual discriminatory ability of the skin is a reliable and worthwhile device. Furthermore, experiments analogous to those carried out on visual flicker and its relationship to various variables could easily be performed.

# CHAPTER IV

## SUMMARY AND CONCLUSIONS

The purpose of the present study was two-fold. The first was to describe a method of investigating the discriminatory or resolving power of the skin by means of a "flicker" technique. The second objective was to apply this technique to the measurement of the resolving power of ten different skin areas.

The "flicker" technique consists of producing an interrupted stream of air at a specified pressure whose frequency can be systematically increased until the subject reports a constant or fused sensation of pressure on some part of the skin. The frequency at which this constant sensation occurs is referred to as the critical frequency of percussion or c.f.p. Preliminary research with the apparatus indicated that it was easy to use and was capable of producing very consistent readings after few practise trials.

In an experiment to determine the c.f.p. of the finger-tip in ten subjects it was found that the relationship between c.f.p. and pressure consisted of two linear parts with the change in slope occurring at 45 lbs. pressure. Individual differences were large though the individuals reproduced their c.f.p. values with marked consistency over a period of several days.

The application of this technique to the measurement of tactual sensitivity of ten different body areas revealed that in all cases the curves showing the relation between c.f.p. and pressure consisted of two linear parts or limbs, but the point at which the second limb appeared varied for some subjects. However, in every case where a definite break in the curve occurred, the slope of the second limb was steeper than that of the first. Large individual differences were evident on all the areas studied. However, the subjects reproduced their c.f.p. values on each of the ten areas with marked consistency. It was also found that the more mobile areas of the skin, i.e., lower lip, tongue, thumb, and finger-tip were more sensitive to intermittent stimulation than the less mobile areas, such as the forehead, neck, cheek, back of the hand, forearm, and the upper arm. Tactual sensitivity was found to be more variable in the more sensitive regions on the body. Sex differences in sensitivity were evident on nine of the areas studied. These sex differences, however, are considered tentative since only five male and five female subjects were used.

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