EFFECTS OF PROLONGED ISOLATION OF THE SKIN ON CUTANEOUS SENSITIVITY

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ABSTRACT

In recent years considerable experimental interest has been shown in the behavioural consequences of an absence of visual and auditory stimulation (sensory deprivation) versus exposure to constant visual and auditory stimulation (perceptual deprivation). Although short durations have not revealed any behavioural differences between these two conditions, it is known that durations of several days or more produce both behavioural and physiological differences. This thesis represents an extension of this comparative research into another sense modality, cutaneous sensitivity. Sensory environments, analogous to those used in vision and hearing, are employed. The purpose of this study is to determine the effects of a prolonged absence of cutaneous stimulation upon various measures of skin sensitivity and, to determine whether these effects are similar to those resulting from exposure to constant cutaneous stimulation.

Thirty-six male subjects were randomly assigned to three experimental conditions. The first condition involved the occlusion of a small area on the volar surface of the non-preferred forearm, while the second involved a continuous stimulation of the same area. In the third condition, which was included as a control, a plastic ring was bandaged to the arm in such a manner

that the test area could receive normal stimulation. Each condition lasted seven days. Measures of tactual acuity and thermal and pain sensitivity were taken before and after the experimental conditions. These cutaneous measures were also taken after periods of 24- and 48-hours following removal of the experimental apparatus.

It was found that the three groups differed reliably in tactual acuity after the seven day experimental period. The no stimulation condition resulted in an increase in acuity while constant stimulation brought about a decrease. These changes were still present two days later. No changes were observed in the control group. Thermal and pain sensitivity were not affected by the different conditions.

In keeping with the visual and auditory studies it is evident that the behavioural consequences of a prolonged absence and continuous presence of cutaneous stimulation are not similar. Although a peripheral explanation of these phenomena is possible, it seems more likely that the changes found in sensitivity are due to modifications in central neural functions.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

CHAPTER I

THE PROBLEM AND INTRODUCTION

I. STATEMENT OF THE PROBLEM

In a recent symposium on sensory deprivation (Kubzansky & Leiderman, 1961), several discussants commented on the need to study systematically the behavioural consequences of an absence of sensory stimulation (sensory deprivation) from those of constant unpatterned stimulation (perceptual deprivation). Several such comparative studies have been reported but they all concern vision and hearing. In general these studies have involved a comparison of the behavioural effects of darkness and silence versus unpatterned light and noise. They have shown that the effects of the two conditions differ both qualitatively and quantitatively.

This thesis represents an extension of this comparative type of research into another sense modality, namely cutaneous sensitivity. Its main purpose is to determine (a) the behavioural effects of a prolonged period of no tactual stimulation of a circumscribed area on the forearm, and, (b) whether these effects are similar to those resulting from the application of constant pressure to the same area.

II. INTRODUCTION

It has been known for many years that individuals exposed to an environment which is deficient in sensory and perceptual stimulation may show various behavioural alterations. For example, there are reports which indicate that explorers, inhabitants of the Arctic, and shipwrecked individuals who have been isolated for many days, often show certain unusual symptoms such as exaggerated emotional reactions, hallucinations, delusions, and a slowing of intellectual activity (Solomon et al., 1957). Little attention was paid to these largely autobiographical reports until a few years ago when two developments occurred which aroused considerable scientific interest in the effects of reduced environmental stimulation. The first concerned the so-called "brainwashing" procedures employed by the Communists for interrogation and indoctrination purposes. Surveys have shown that one of their favourite techniques involves placing the prisoner in a small cell which is either dark or constantly illuminated for days on end. The second development was the arrival of the space age. The occupants of the space vehicle will not only have to live in very restricted quarters but, more important, they will be isolated from their accustomed surroundings. Their sensory environment, particularly during weightlessness, will be quite different from that existing on earth.

As a direct consequence of these post-war developments, a number of studies involving an experimental reduction of sensory and perceptual stimulation have now been performed. Several excellent surveys of this literature are available (Solomon *et al.*, 1961; Fiske, 1961; Biderman & Zimmer, 1961). Without becoming too deeply involved in the sensation-perception issue, most of these studies can be sub-divided into sensory deprivation and perceptual deprivation experiments. These two categories are used in the sense advocated by Kubzansky (1961) in which sensory deprivation refers to an attempt at "an absolute reduction in variety and intensity of sensory input" e.g. experiments involving darkness and silence, while perceptual deprivation refers to "reduced patterning, imposed structuring, and homogeneous stimulation", e.g. use of translucent goggles, white noise, constant hum. These experiments (e.g. Zubek *et al.*, 1962) have shown that the behavioural consequences of a prolonged absence of sensory stimulation (sensory deprivation) are not similar to those following constant unpatterned stimulation (perceptual deprivation). This finding, however, only applies to the visual and auditory sense modalities. No others have been studied. The present experiment differs from previous work in that it represents an extension of this comparative type of research into another sense modality, cutaneous sensitivity.

The thesis will begin with a review of the relevant experimental literature. Following this, the experimental procedure will be described. The results will then be presented and evaluated.

III. HISTORICAL BACKGROUND

This review of the literature will begin with a brief summary of the sensory and perceptual deprivation experiments with particular attention being given to possible differences in their behavioural consequences. This will then be followed by the very scanty experimental literature involving interference with the level of cutaneous sensation.

Visual and Auditory Deprivation Studies

A survey of the literature indicates that for short durations there appear to be few or no behavioural differences between sensory and perceptual deprivation. For example, Rosenbaum, Dobie and Cohen (1959) found no significant differences in an experiment involving recognition thresholds for 5-digit numbers after 5- to 30-minute periods of constant darkness and similar periods of unpatterned light. Similarly, Freedman and Greenblatt (1959) in an 8 hour isolation experiment reported no differences between blackout and unpatterned light conditions in the production of hallucinatory-like imagery or in the kind and amount of cognitive effects. There were, however, more distortions of simple forms under constant unpatterned light. In a further study Freedman and Held (1960) reported no significant differences between the two conditions for "perceptual lag" after very short exposures.

In contrast to the short term experiments, a survey of the studies involving durations of several days or more indicates that sensory and perceptual deprivation are not equivalent behaviourally. In the pioneer studies at McGill involving up to four days of perceptual deprivation (diffuse light and noise), it was found that the experimental subjects were impaired in most of the intellectual abilities (Bexton, Heron & Scott, 1954; Scott, Bexton, Heron & Doane, 1959). Similar results were obtained in the Manitoba 7-day experiments, also employing diffuse light and noise (Zubek _et al._, 1962). On the other hand, the behavioural consequences of sensory deprivation are much less severe. This is clearly shown in some further work at Manitoba where a 7-day period of darkness and silence impaired only a handful of intellectual abilities (Zubek, Sansom & Prysiazniuk, 1960). These results are supported by a preliminary study on 4 days of sensory deprivation, carried out by the U.S. Army Human Resources Research Office, in which no noticeable impairments were observed on intellectual and learning tests, including auditorily administered tests during isolation (Meyers, Forbes, Arbit & Hicks, 1957). Similarly, Levy, Ruff, and Thaler (1959) found no striking changes in performance on intellectual tests after periods of up to a week. Finally, the results of the Princeton studies substantiate the findings that the behavioural consequences of sensory deprivation are less severe than perceptual deprivation. In fact, Vernon and Hoffman (1956) have found a significant improvement in rote learning ability, and Vernon and McGill (1957) report a suggestion of improvement in this ability.

Not only are more intellectual abilities impaired by perceptual deprivation but also more sensori-motor tasks. For example, both visual and auditory vigilance are affected by perceptual deprivation while only visual vigilance is impaired by sensory deprivation (Zubek, Pushkar, Sansom & Gowing, 1961; Zubek _et al_., 1962).

In addition to these quantitative differences, these two conditions also differ in their qualitative effects. Thus, under conditions of prolonged sensory deprivation two of the tests indicating greatest impairment involved immediate memory, while under conditions of perceptual deprivation performance in some tests involving this ability seemed to be better (Zubek, Sansom & Prysiazniuk, 1961; Zubek et al., 1962). Again, Vernon and McGill (1961) have reported a study in which pain thresholds as determined by an electrical current technique were reduced following darkness and silence. In contrast, Zubek et al. (1962) found that radiant-heat thresholds were reliably increased after a period of diffuse light and noise.

These behavioural differences are also accompanied by differences in electrical activity of the brain. Zubek and Welch (1963) have found that exposure to perceptual deprivation conditions for seven days produced a significantly greater decrease in occipital lobe frequencies than did the same period of sensory deprivation. It is evident, therefore, from the behavioural and physiological data, that a prolonged absence of visual and auditory stimulation (sensory deprivation) and constant visual and auditory stimulation (perceptual deprivation) are not equivalent in their effects. In view of this, it might be expected that the behavioural effects of an absence of tactual stimulation might differ from those involving constant tactual stimulation.

Studies of Cutaneous Sensitivity

An examination of the literature reveals a total lack of experimental data on the effects of prolonged exposure to constant pressure. What data there is, is concerned with the problem of sensory adaptation, e.g. adaptation to pressure as a function of the duration of a constant adapting stimulus (Geldard, 1953). This literature, however, is not too relevant since durations of only seconds or minutes are involved. As far as the effects of an absence of tactual stimulation are concerned there is some relevant literature. Almost all of it, however, comes from several studies on unilateral amputees - subjects who may be viewed as possessing a limited degree of sensory deprivation since the afferent input from the amputated area has been permanently decreased, providing a decreased level of activity for that part of the somato-sensory cortex.

One of the most careful of these studies was performed by Teuber, Krieger and Bender (1949), who employed 36 male subjects with unilateral amputations above the knee. They reported that the two-point thresholds taken just above the stump were significantly lower than those taken on the homologous area of the sound limb. They also found that a gradient of decreasing difference existed when more proximal areas of the stump were tested. These results are interpreted by the authors as indicating central neural readjustments which result in a transference of some of the functional characteristics of the amputated area to the remaining portions of the limb.

Further evidence of increased sensitivity for amputated limbs has been collected by Haber (1955). Using a group of 24 "above elbow" amputees, he measured sensitivity to light touch (modified von Frey hairs), two point discrimination, and point localization at two points on the stump (2.5 cms. from the point of severance and 2.5 cms. from the head of the humerus) in addition to homologous areas of the intact limb. Twelve male subjects without amputations were also tested at the same points of both arms. All three measures taken indicated greater sensitivity for the stump, 2.5 cms. from the point of severance, as compared to the homologous area of the intact limb. Furthermore, when threshold comparisons were made between the stump arms of the amputee group and similar arms of the control group, statistically greater sensitivity was found in the amputee group. However, no reliable differences were found between the intact arms of the amputee group and similar arms of the control group.

Finally, Wilson, Wilson and Swinyard (1962) compared the two-point thresholds of congenital amputee children with that of normals. In keeping with the previous studies, they also observed a significant increase in sensitivity on the stump in relation to the intact arm as well as to the arms of control subjects. In contrast to Haber, however, they observed that the sensitivity of the intact limbs of the amputees was reliably greater than that of either limb of non-amputees. Central mechanisms, are, therefore, indicated. The apparent discrepancy between the two studies, however, is believed to be due to the use, by Haber, of traumatic rather than congenital amputees. The authors interpret their findings in terms of a differential input hypothesis. According to this theory "Loss of considerable portions of a limb....should considerably reduce the input to the somato-sensory cortex. Neural impulses arising from stimulation of the stump enter the somato-sensory cortex against a reduced background level of nervous activity as compared with the undiminished level on the contralateral side.

Therefore, a simulus applied to the stump, and to which the subject is attending, will be more readily discriminated than an equivalent stimulus to the homologous area of the intact limb."

If the theoretical interpretation of Wilson, Wilson and Swinyard's data is correct, then an extended functional decrease in cutaneous activity in a particular skin area should result in increased sensitivity of that area. Furthermore, since central mechanisms are believed to be involved, it would be predicted that a homologous area of the contralateral arm should also increase in sensitivity. These predictions were recently borne out in an unpublished study by Heron and Morrison. These investigators reported a significant increase in tactual sensitivity (von Frey hairs) after four days of occlusion of a small area on the forearm. They also found a slight increase in sensitivity in the homologous area of the contralateral arm. A non-homologous skin area showed no change. These results offer further experimental support for the importance of central mechanisms. Heron and Morrison also reported that their subjects experienced "wierd" sensations, which they found hard to verbalize, when the occluded area was stimulated with the hairs after the experimental period. Other subjects indicated the presence of sensations of pain, heat or itch and diffuseness when the arm was stimulated.

It is clear from the above review of the literature that only one experiment, that of Heron and Morrison, is directly relevant to the thesis topic. This study is, however, deficient in a number of respects. For example, no provision was made in the design of the experiment to control for such things as the bandage and the pressure exerted by the occluding apparatus on the circumference of the experimental skin area. The changes in sensitivity may, therefore, be partly due to these factors. Also, the modified von Frey technique which was employed to measure skin sensitivity does not appear to be very reliable in view of its large intra-subject variance. Finally, considerable emphasis is placed on qualitative reports from the subjects but these were not obtained in any systematic manner such as through the use of a structured questionnaire. The results, therefore, were not amenable to statistical treatment.

The present study differs from the Heron and Morrison experiment in a number of important respects. First, a condition of constant tactual stimulation is employed in addition to one involving no tactual stimulation. This condition approximates the perceptual deprivation situation used in the visual and auditory studies in that it provides constant amorphous stimulation to the skin. Second, a control group, wearing an open plastic ring, has been added in order to control for the presence of bandages and pressure in the periphery of the experimental skin area. Third, the duration of the experiment has been increased to seven days in keeping with current auditory and visual deprivation studies at this laboratory. Finally, this study is different in that three measures of cutaneous sensitivity rather than one are taken, namely tactual acuity, temperature and pain sensitivity. The last two measures were taken since it is now known that many skin receptors are sensitive to both pressure and temperature (Melzack & Wall, 1962). Interaction effects are, therefore, possible. A structured questionnaire is also employed.

CHAPTER II

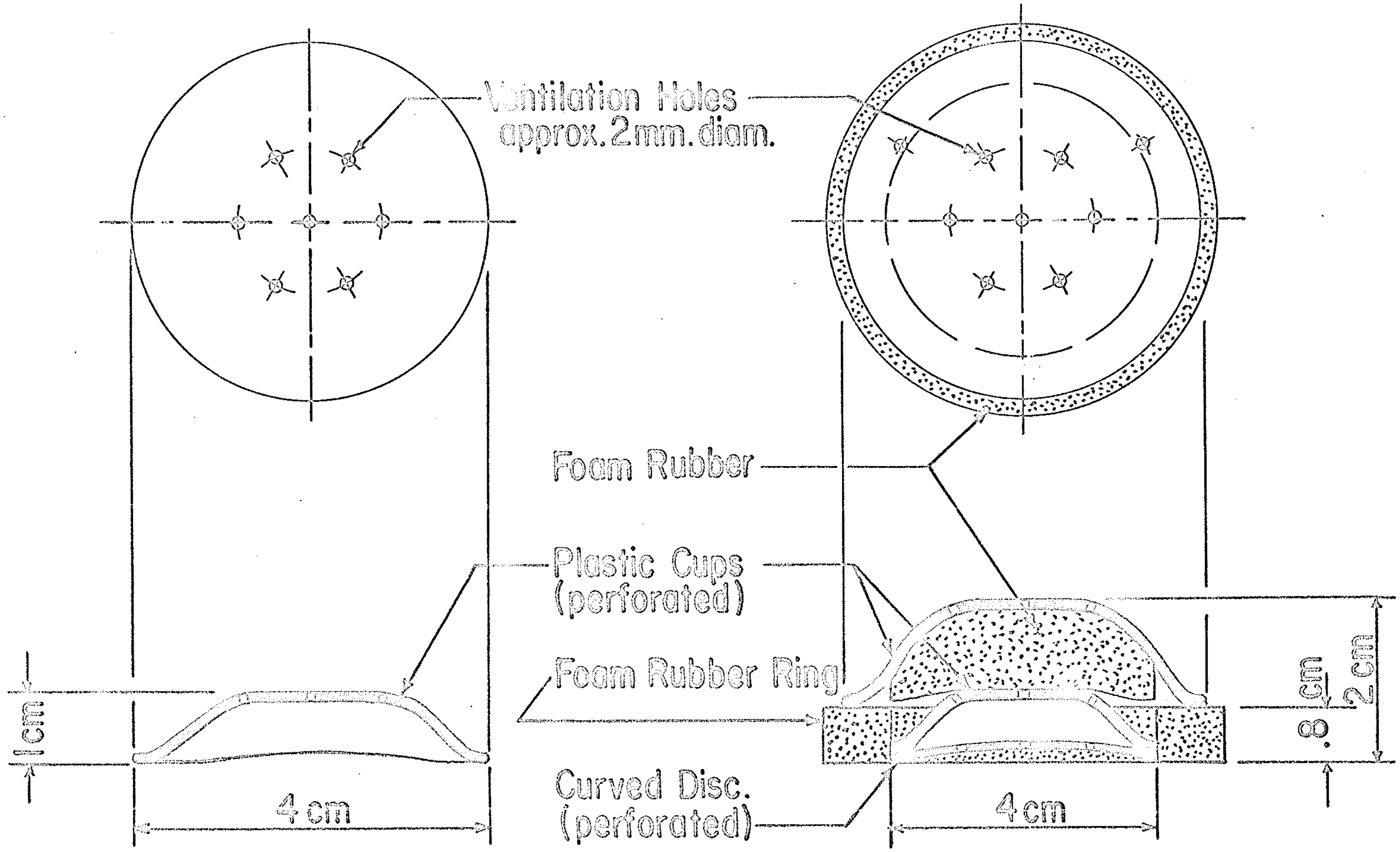
EXPERIMENTAL METHOD

I. THE PROBLEM

The preceding chapter has revealed an almost total lack of studies involving an experimental interference with the level of tactual stimulation in a manner analogous to that already performed in the field of visual and auditory deprivation. What little work has been done is concerned with the effects of an absence of tactual stimulation on sensitivity to light pressure. No data, however, are available for other measures of skin sensitivity such as temperature and pain. Furthermore, no attempt has been made to investigate the effects of constant tactual stimulation. The purpose of the present experiment is to determine (a) the behavioural effects of a 7 day period of no tactual stimulation of a circumscribed area of the forearm, and (b) whether these effects are similar to those resulting from a 7 day application of constant pressure to the same skin area. Measures of tactual acuity and temperature and pain sensitivity will be taken.

II. PROCEDURE

A group of 36 university students were used, with twelve in each of three conditions. The first condition involved an absence of tactual stimulation. This was achieved by placing a perforated plastic cup, 1 cm. in height and 4 cm. in diameter (see Fig. 1) on the volar surface of the non-preferred arm at a distance of 8 cms. from the elbow. The cup was attached to the arm with porous Elastoplast bandage. The perforations and the porous bandage were used in an effort to provide adequate ventilation for the underlying skin. The second condition consisted of the application of constant light pressure to the same region. This was achieved by placing a slightly curved, perforated disc, 4 cms. in diameter, on the skin and covering it with two perforated plastic cups, one inside the other (see Fig. 2). The inner plastic cup applied a pressure to the disc, and hence to the skin of approximately 20 grams/cm^2. The outer cup served as a protective device to prevent the disc from being subjected to undue variations in pressure from the external environment. In the third condition, an open ring was attached to the experimental skin area. The main purpose of this condition was to control for the possible effects of the bandage and the pressure exerted by the cups on the circumference of the occluded area of the skin. Each condition lasted seven days.



(a)

Figure 1. No Stimulation Apparatus.

(b)

Figure 2. Constant Stimulation Apparatus.

Three measures of skin sensitivity namely, tactual discriminatory ability or acuity and heat and pain sensitivity were taken from the experimental skin area before and immediately after each of the three conditions. Follow-up measures were also taken a day and two days later.

Tactual acuity was determined by means of a "flicker" technique described in detail in a report by Shewchuck and Zubek (1960a). Using this apparatus, they (1960b) have shown that the rank order of body area sensitivity agrees with that found by the classical two-point threshold method. This "flicker" technique involves the production of an interrupted stream of air at a specified pressure whose frequency can be systematically increased. This interrupted stream of air is presented to the skin area and systematically increased until the subject reports a constant sensation of pressure. The frequency of air bursts at which the constant sensation occurs is referred to as the critical frequency of percussion (c.f.p.).

In determining a subject's tactual acuity, his arm was immobilized so as to maintain the skin surface at a constant distance of 0.50 cm. from the air nozzle. A thin layer of petrolatum was spread on the test area to protect it from the drying action of the bursts of air. The subjects were prevented from making discriminations through other sense modalities by shielding the arm from their view, and by providing N.R.C. type earmuffs through which a low level of "white noise" was generated. Four measurements separated by ten second intervals were obtained at 30 lbs./sq.in. tank pressure. The threshold measurements were established by a modified method of limits, ascending series only.

The subjects were instructed as follows: "The purpose of this test is to determine the resolving power of the skin. Puffs of air will be directed at your skin in such a way that at first you will perceive them as discrete and separate. The frequency of these bursts will then be gradually increased until at some point you will no longer feel them as separate but as a continuous sensation of pressure. Indicate by saying 'now' as soon as you first feel that the air bursts are continuous".

Heat and pain thresholds were measured by the Hardy, Wolff and Goodell dolorimeter (model ER 2-ES 2, Williamson Development Co.). Construction details, including circuit diagrams, may be found in its _Instruction Manual_. This apparatus consists of an incandescent lamp whose rays are focused, with the aid of a system of mirrors and lenses, onto a blackened area of the skin. Regulation of the radiant heat output is made possible by a heat setting dial on the control box. The dial is calibrated from 50 to 500 m. cal./cm.^{2}/sec. in units of 10 millicalories. The heat and pain thresholds were measured by the time method; that is, in terms of the minimum exposure time required to produce heat and then pain, keeping the heat level constant. The latency for heat thresholds was measured by a Hunter Klockounter, and for pain by a Standard high speed timer. Accurate latency readings are possible for both instruments to at least 0.10 second. Both the Klockounter and the timer were initiated by the onset of the radiant heat stimulus.

The determination of heat and pain thresholds followed the c.f.p. measurements. The skin surface was first sponged with rubbing alcohol to remove the petrolatum and any perspiration from the test area. The area was then blackened uniformly with dolorimeter ink; a mixture of poster black, rubbing alcohol, and glycerine. Testing was begun only after the dolorimeter ink was completely dry. Four heat and pain measurements separated by one minute intervals were obtained. The basal setting for the radiant heat dolorimeter was 100 m.cal./cm.^{2}/sec. for a skin temperature of 34°C. A correction of $H_s = 100 + 20\ (34°C. - T_s)$ (where H_s is the final dolorimeter setting and T_s is the skin temperature) was applied to the basal setting in cases of variation from the normal skin temperature. The actual skin temperature was determined with a clinical thermometer prior to testing.

The subject was instructed that the purpose of the test was to determine his ability to perceive the first trace of warmth and then pain. He was told that when the radiation was turned on he would, at first, feel nothing and then he would experience warmth. As soon as he felt this warmth he was to depress a microswitch which would stop a Hunter Klockounter. The subject was instructed further, that the stimulus would then continue until he felt a slight burning or pricking pain sensation. When he felt the first indication of pricking pain he was to say 'now' quickly, so that both the stimulus and the Standard high speed timer would be stopped.

In addition to the three measures of cutaneous sensitivity, all of the subjects were given a questionnaire. They were asked to read it prior to the removal of the arm apparatus and to complete it immediately following the test session. This "4-part" questionnaire is shown in Appendix 1. Part A of the questionnaire consists of six 5-point rating scales in which the subject is asked to compare the felt experience of the intermittent tactile stimulus on the non-homologous practice area with that of the experimental area. These scales represent such experiential continua as central-diffuse, sharper-duller, warmer-colder etc. If there were no differences in the felt experience for the different arms, the subject would report this experiential equality by marking the number three on the continuum. Since experience similarity is represented by the central position, differences could be recorded in terms of direction and degree. An interval scale was used so that representations would be amenable to statistical procedures. Part B of the questionnaire is similar to that of Part A except that the subjects have to rate the temperature and pain stimulus rather than the intermittent tactile stimulus. Finally, Parts C and D consisted of a series of questions, e.g. "Did the air bursts induce a tickling sensation", which the subjects answered as true, false, or undecided. In each case the questions were directed toward determining differences in felt experience between the experimental and non-homologous practice areas. The subjects were also encouraged to report on any experiences that were not covered in the questionnaire.

The sample consisted of 36 male students registered at the University of Manitoba. Only male subjects were selected in an attempt to decrease the variance in the threshold measurements. The experimental test area for all subjects was on the volar surface of the non-preferred forearm 8 cms. from the elbow. A non-homologous area on the preferred arm was used for practice purposes prior to each test session. Tactual acuity measurements were always taken before the heat and pain thresholds. The volunteers were tested twenty-four hours prior to application of the experimental apparatus to acquaint them with the test procedure and to determine the reliability of their thresholds. Subjects whose thresholds were not stable or whose scores deviated too much from previously determined norms were excluded from the study. These measurements were taken to insure at least equal preliminary threshold deviation in the groups. The remainder of the subjects were randomly assigned to the three groups. In order to control for possible environmental changes, the subjects were always tested in multiples of three, with at least one subject for each condition.

CHAPTER III

EXPERIMENTAL FINDINGS AND DISCUSSION OF RESULTS

I. THE RESULTS

Figure 3 indicates the performance on the tactual acuity test before and after a week. It can be seen that the no stimulation condition is followed by an increase in acuity, while the constant stimulation condition produces a decrease in acuity. Only a slight change is evident in the control group. Since the three groups were not homogeneous with respect to within-groups variance, a non-parametric test, the Kruskal-Wallis one-way analysis of variance by ranks (Siegel, 1956), was employed for statistical comparison. The data were analyzed in terms of difference scores. An individual's initial mean threshold score was subtracted from his mean threshold after the 7 day period ("pre-post" scores), and again from his mean score twenty-four hours ("pre-post day 1") and forty-eight hours ("pre-post day 2") after removal of the experimental apparatus. The analysis of variance revealed that the "pre-post" differences among the three conditions were statistically reliable ($\chi^2 = 21.4$, $p < .001$). Further analysis revealed that both the no stimulation and the constant stimulation groups differed reliably from the control condition ($\chi^2 = 7.36$, $p < .01$; $\chi^2 = 10.45$, $p < .01$, respectively).

The changes in acuity, as Figure 3 indicates, still seem to be present two days after the termination of the experimental conditions. The analyses of variance indicated that both the "pre-post day 1" and the "pre-post day 2" differences among conditions were reliably different ($\chi^2 = 10.85$, $p < .01$; $\chi^2 = 14.74$, $p < .001$ respectively). Furthermore, both the no stimulation and the constant stimulation groups continue to differ reliably from the control group on the "pre-post day 1" measures ($\chi^2 = 4.94$, $p < .05$; $\chi^2 = 4.94$, $p < .05$, respectively) and on the "pre-post day 2" measures ($\chi^2 = 6.15$, $p < .02$; $\chi^2 = 4.08$, $p < .05$, respectively).

An examination of the performance of individual subjects revealed a tendency for individuals with a higher initial tactual acuity to manifest a greater increase in acuity after the no stimulation condition than subjects with lower initial thresholds. No such individual difference trends were evident in the constant stimulation group. It would be interesting to determine whether the suggested trend toward greater increases in acuity for individuals with higher initial sensitivity would continue

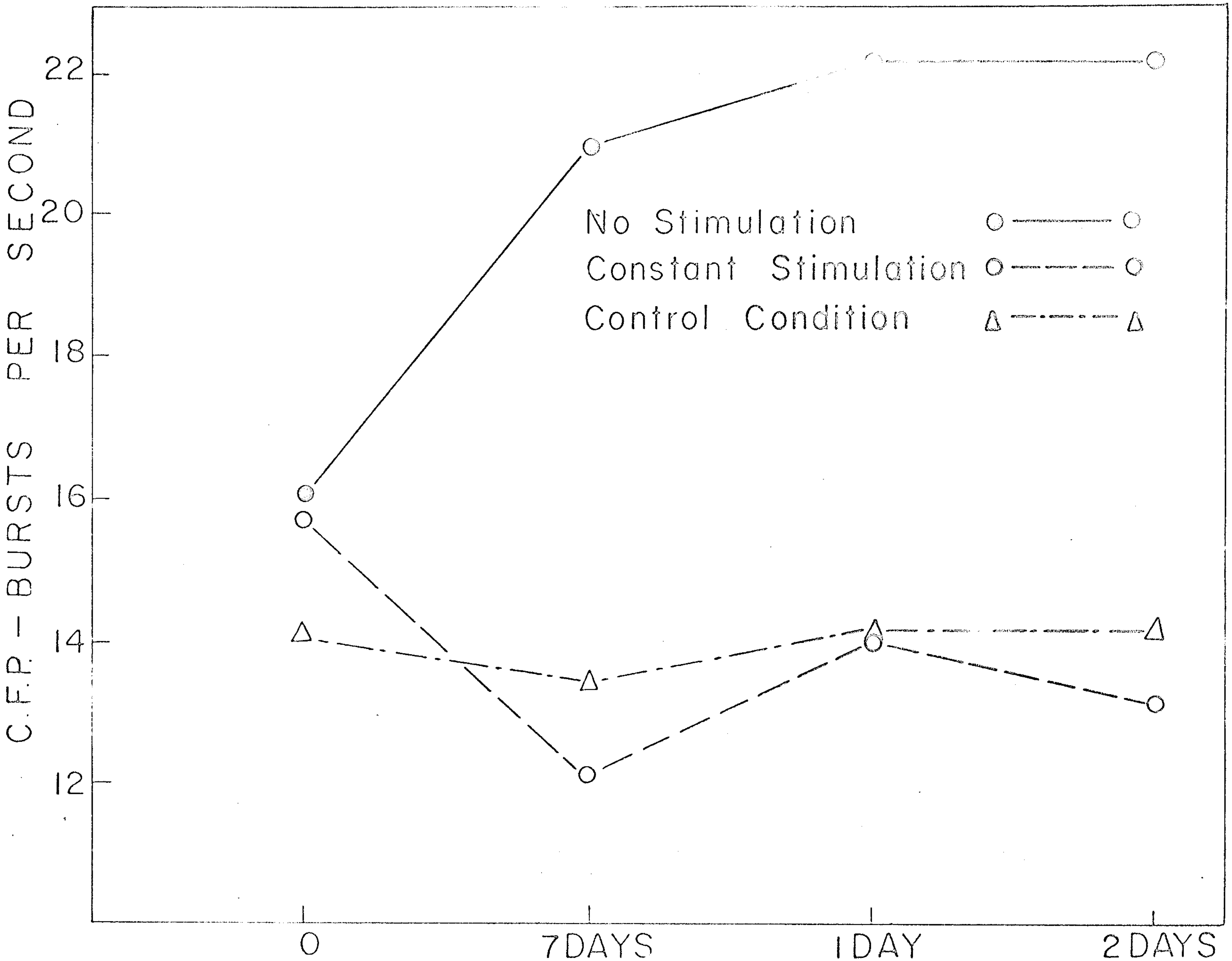


Figure 3. Tactual Acuity of the Control and Two Experimental Groups Before and After 7 Days, and 1 and 2 Days Later.

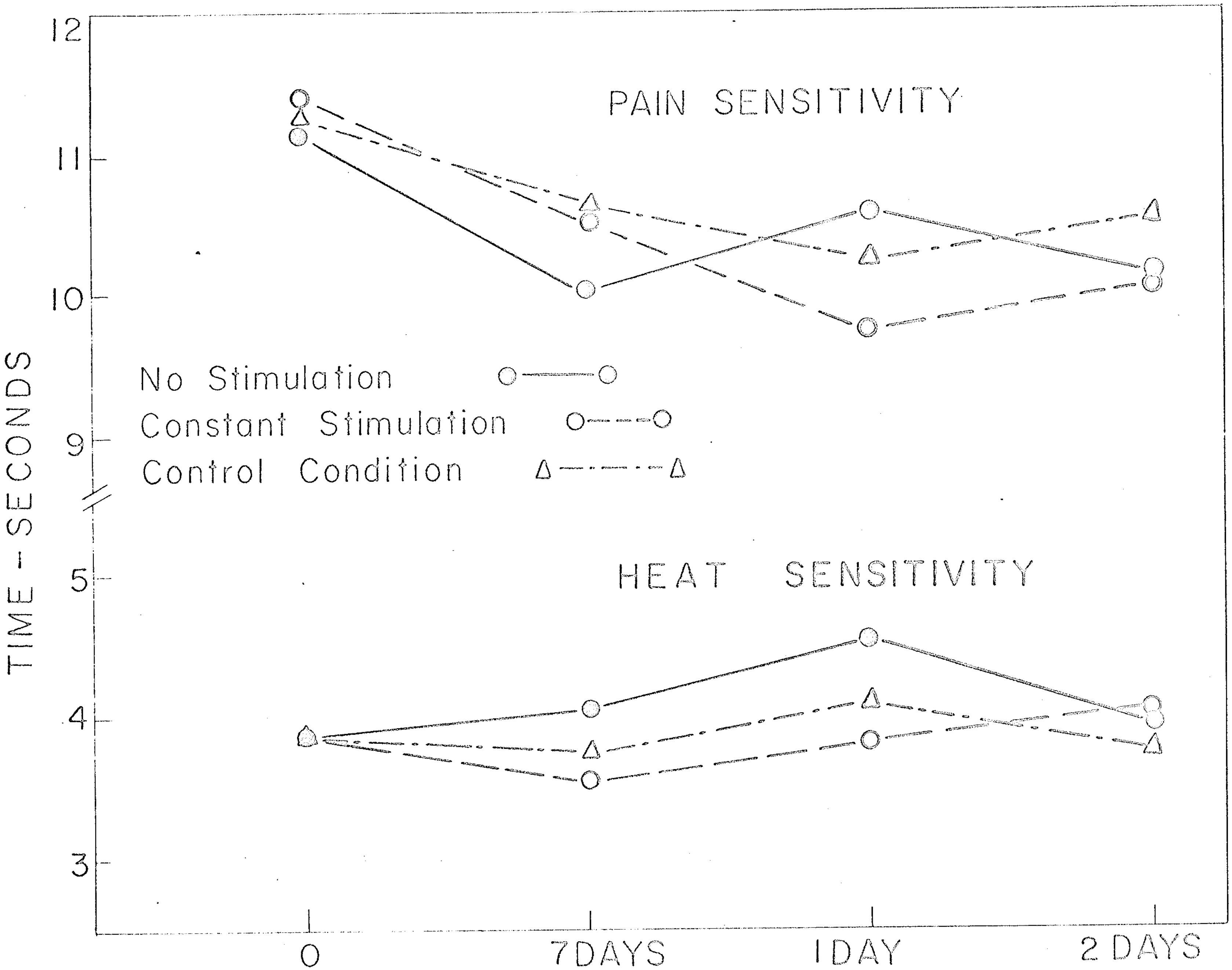


Figure 4. Heat and Pain Sensitivity of the Control and Two Experimental Groups Before and After 7 Days, and 1 and 2 Days Later.

in a larger sample of such subjects. Such a finding could have important implications insofar as the role of the somato-sensory cortex in differential body area sensitivity is concerned. Further work is necessary, however, before any definite conclusions can be drawn.

Figure 4 shows the changes in heat and pain sensitivity for the three groups of subjects. No clear cut trends seem to be indicated. Both sets of data were analyzed in two separate Type 1 mixed designs (Lindquist, 1953). For neither cutaneous measure were the differences among conditions significant. However, the Type 1 analysis for the pain data did reveal a significant "day-tested" effect ($F=6.01$, $p<.001$). This significant "day-tested" effect could be interpreted as indicating that some factor present in the three different conditions, such as the presence of the bandaging material or the plastic ring, might account for the similar changes in pain sensitivity.

Table I summarizes the analyses of responses to Part A of the questionnaire for the different groups. The analyses of variance (Lindquist, 1953) applied to the tactual fusion data indicated significant differences among the three conditions for the "central-diffuse" continuum ($F=3.41$, $p<.05$) and the "deeper-shallower"

TABLE I. Mean scores of the three groups of subjects on Part A of questionnaire (Intermittent Tactile Stimulus)

Qualitative Continuum	No Stimulation	Constant Stimulation	Control	F	p value
warmer-colder	3.42	3.33	3.25	1.21	N.S.
sharper-duller	2.25	3.00	3.25	1.29	N.S.
central-diffuse	2.75	3.58	3.50	3.41	$<.05$
faint-pronounced	3.33	3.66	2.75	2.39	N.S.
rougher-smoother	3.25	2.83	3.42	1.44	N.S.
deeper-shallower	2.42	3.00	3.42	5.03	$<.05$

continuum ($F= 5.03$, $p<.05$). Analyses of the differences between the groups for the "central-diffuse" continuum revealed a reliable difference between the no stimulation and control groups ($t=2.20$, $p<.05$), and between the no stimulation and constant stimulation groups ($t = 2.44$, $p<.05$). These results indicate that to the no stimulation group the tactile stimulus felt more localized while to the constant stimulation and control groups it appeared more diffuse. For the "deeper-shallower" continuum only the no stimulation and control reactions were reliably different ($t=3.12$, $p<.01$) i.e. the tactile stimulus felt "deeper" to the no stimulation group. It is apparent from inspection of Table I that although the perceived experiential differences between the practice and experimental arms are pronounced for the other continua, these experiences are not significantly different for the three groups.

Table II shows the mean scores of the three groups of subjects to questionnaire items dealing with temperature and pain stimuli. No significant differences among the groups were indicated in the analyses of these data. The percentage of "True" responses for Parts C and D of the questionnaire are given in Tables III and IV. The largest observed percentage difference was found not to be significant when the χ^2 test for two independent samples (Siegel, 1956) was applied. Inspection of Tables III and IV again indicates that differences were observed between the practice and experimental arms, but that the observations were not reliably different for the three groups.

TABLE II. Mean scores of the three groups of subjects on Part B of questionnaire (Heat and Pain Stimuli)

Qualitative Continuum	No Stimulation	Constant Stimulation	Control	F	p value
sharper-duller	2.42	3.08	2.67	2.14	N.S.
faint-pronounced	3.75	3.16	3.08	1.89	N.S.
central-diffuse	2.58	3.08	2.75	-	N.S.
deeper-shallower	2.17	2.67	2.33	-	N.S.

TABLE III. Percentage of true answers given by the three groups of subjects on Part C of questionnaire (Intermittent Tactile Stimulus)

Question	No Stimulation	Constant Stimulation	Control
1	67	50	41
2	50	50	33
3	33	50	16
4	16	41	25
5	25	25	25
6	67	75	58
7	16	16	8
8	25	33	8
9	0	8	8
10	25	41	8
11	16	33	8
12	8	41	8

TABLE IV. Percentage of true answers given by the three groups of subjects on Part D of questionnaire (Heat and Pain Stimuli)

Question	No Stimulation	Constant Stimulation	Control
1	58	66	41
2	58	66	33
3	83	75	66
4	83	91	91
5	33	58	41
6	0	8	16
7	8	25	0

II. DISCUSSION OF RESULTS

The results of this study have demonstrated that an absence of tactual stimulation and constant tactual stimulation are not equivalent behaviourally, with the former condition producing an increase in tactual acuity and the latter a decrease. These results are consistent with some of the results obtained for other sense modalities. For example, it has been shown that the behavioural effects of prolonged darkness and silence are both quantitatively and qualitatively different from those occurring after exposure to constant light and white noise (Zubek, Sansom & Prysiazniuk, 1961; Vernon & McGill, 1961; Zubek et al., 1962). Furthermore, these two types of sensory conditions differ in their effects on the electrical activity of the brain (Zubek & Welch, 1963). Perhaps the most surprising feature of the present results is the magnitude of the changes found after isolation of such a small portion of the total skin surface. There is, however, some experimental evidence to substantiate this finding. Heron and Morrison, in an unpublished report, found a significant increase in tactual sensitivity (von Frey hairs) after a four day period of no stimulation even with large intra-subject variance. The change was not as pronounced as in this experiment but this may be due to their shorter period of isolation and to the use of a measure which was not too reliable. They also reported an increase in sensitivity in the homologous area of the contralateral arm. This finding would suggest that central rather than peripheral factors are responsible for these changes. They offer no data on the effect of constant pressure.

The finding that tactual acuity is increased following the no stimulation condition is also supported by a series of studies on unilateral amputee subjects, who may be viewed as possessing a limited degree of sensory deprivation (Haber, 1955; Tueber, Krieger & Bender, 1949; Wilson, Wilson & Swinyard, 1962). These studies have all demonstrated increased sensitivity to touch on the stump arm as compared to the homologous area of the contralateral arm. There is also evidence that the sensitivity of the intact arm of the amputees is greater than that of the most sensitive arm of normals (Wilson, Wilson & Swinyard, 1962). This would suggest the importance of central factors in accounting for the increased cutaneous sensitivity. Possibly the second somatic area of the cortex, which mediates cutaneous sensitivity of both halves of the body (Morgan & Stellar, 1950) is involved in these effects.

In contrast to the clear cut results for tactual acuity, temperature and pain sensitivity were not significantly affected by the experimental conditions. These negative results may be due to the fact that these two sense modalities are, biologically, of considerable importance in survival. Perhaps only a very extended period of occlusion of the skin will affect their function. However, a more likely explanation of these negative results is that the experimental cups and discs, in actual practice, do little to produce significant changes in the level of temperature and pain stimulation. Instances of painful stimulation, for example, occur so rarely in normal life that very little protection is provided by the cups or discs. However, an increase or decrease in sensitivity to heat and pain stimuli might be expected if the induced change in light pressure sensitivity interacted with heat and pain sensitivity. Such an interaction would be predicted if the evidence put forward by Malzack and Wall (1962) is substantiated. They have presented some evidence suggesting that certain peripheral receptor fibres are sensitive to both tactual and thermal stimuli. The present data indicate, however, that the relationship might well be a complex one, and further work with longer periods of deprivation would be needed before any discernible trend would become evident.

An analysis of the questionnaire data revealed only two significant differences in subjective experiences among the three groups. Both of these pertained to the clarity of the intermittent stimulation. Significantly more of the no stimulation group reported that the tactile stimulus felt more localized and deeper. Other types of cutaneous sensations were not elicited by any of the stimuli to a statistically reliable degree. These results are at variance with those of an exploratory study reported by Heron (1961), who noted that some of his subjects felt sensations of pain, heat or itch in the occluded area in response to von Frey hairs. This discrepancy may be due to differences in the nature of the tactual stimulus employed, or to the type of questions asked of the subjects. None of the subjects in this study spontaneously reported any unusual experiences that were not related to the clarity of the stimulus.

The findings of this study could perhaps be best explained by a slight modification of the "differential input hypothesis" postulated by Wilson, Wilson and Swinyard (1962) to account for the increased skin sensitivity of amputees. According to this differential input theory, neural impulses arising from the skin after isolation enter the somaesthetic cortex against a reduced background level of nervous activity as compared with the normal level prior to isolation. Because of this reduced background level of activity, an intermittent tactile stimulus applied to the isolated area will be more readily discriminated than when it was applied to the same area prior to isolation. The tactile threshold will, therefore, be represented as a higher c.f.p. value after the isolation condition. The converse situation would exist under conditions of constant stimulation. The prolonged constant stimulation results in decreased acuity since the tactile stimulus is presented against a background of heightened nervous activity as compared with that existing prior to the application of constant pressure. Furthermore, since the aftereffects persist for some time it would appear that the changes brought about in the somaesthetic cortex must be of such a magnitude that they are still present two days later. There is supporting experimental evidence that changes in central neural activity can persist for some time. For example, Zubek, Welch and Saunders (1963) have shown that prolonged visual and auditory deprivation produces changes in occipital alpha activity which are still present a week later. Sharpless and Jasper (1956) have also reported a habituation of the

EEG arousal reaction to successive presentations of the same auditory stimulus which "persists for days". It would appear, therefore, that a change in cortical activity, if it does occur, is not immediately overcome by the return to normal sensory activity.

Although a central explanation of the results is preferred, peripheral factors such as sensory adaptation and possible changes in skin elasticity undoubtedly play some part. This particularly applies to the effects of constant stimulation. Immediately after removal of the flat disc it would be expected that the threshold for pressure discrimination would increase as a result of adaptation of the skin receptors i.e. skin sensitivity would be poor. Whether sensory adaptation or other peripheral factors, however, can account for the persistence of the change two days later is an open question.

CHAPTER IV

SUMMARY AND CONCLUSIONS

This investigation has been concerned with the comparative effects of an absence of cutaneous stimulation and constant stimulation. Some relevant literature for the no stimulation condition (sensory deprivation) is available from work done on amputees, and from an exploratory unpublished report involving a functional decrease in cutaneous stimulation. No comparable data are available for the effect of constant stimulation (perceptual deprivation) on cutaneous sensitivity.

In this study thirty-six male subjects were randomly assigned to three experimental conditions. The first condition provided an absence of tactual stimulation for an area on the volar surface of the non-preferred forearm, while the second involved a continuous stimulation of the same area. In the third condition an open plastic ring was bandaged to the forearm to control for the possible effects of the bandage and for the pressure of the cups on the circumference of the occluded area of the skin. All conditions lasted for seven days. Measurements of tactual acuity and thermal and pain sensitivity were taken before and after the experimental conditions. Two follow-up measurements were taken at 24 hour intervals following removal of the experimental apparatus.

The three conditions differed significantly in their effects upon tactual acuity. Increases in tactual acuity were found following the no stimulation condition while decreased tactual acuity was observed after constant stimulation. The groups continued to differ reliably up to 48 hours after removal of the experimental apparatus. Thermal and pain sensitivity were not affected differentially by the different conditions. A similar increase in sensitivity to pain was, however, evidenced in all groups.

The differential behavioural reactions observed in this study are in keeping with the results of long term visual and auditory studies. The no stimulation data is further substantiated by the amputee studies and by the one study concerned with a functional decrease in cutaneous stimulation. A central neural interpretation of the data has been postulated because it offers a reasonable explanation of all of the data. Peripheral explanations are possible, but it is difficult to employ them to account for the changes which still exist

48 hours later. A crucial test of the relative importance of central and peripheral explanations awaits further experimentation.

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APPENDIX I

QUESTIONNAIRE OF CUTANEOUS RESPONSES

Subjects are asked to report within the framework of this questionnaire, any qualitative differences they may feel in the presentation of stimuli to the different arms. Try to retain a conception of the felt sensation in the experimental arm. The 5 points on the scale represent degree of difference between the felt sensation on the experimental arm as compared with the practice arm. If you think there are no differences in any particular quality, then check number 3 for that quality.

PART A

Tactile Stimulator

Tactile Stimulator	1	2	3	4	5	
warmer	___	___	___	___	___	colder
sharper	___	___	___	___	___	duller
central	___	___	___	___	___	diffuse
faint	___	___	___	___	___	pronounced
rougher	___	___	___	___	___	smoother
deeper	___	___	___	___	___	shallower

PART B

Heat & Pain Threshold Test

	1	2	3	4	5	
sharper	___	___	___	___	___	duller
faint	___	___	___	___	___	pronounced
central	___	___	___	___	___	diffuse
deeper	___	___	___	___	___	shallower

Subjects are required to answer all questions. In all questions which seem not to apply, the question mark should be circled. The questions are directed toward determining differences in felt experience between the control and experimental arms.

PART C

Tactile Stimulator

T ? F 1. Did the sensation appear to be localized to the point of stimulation?

T ? F 2. Was the fusion point harder to determine?

T ? F 3. Was the fusion point easier to determine?

T ? F 4. Did the air stimulus sensation last longer?

T ? F 5. Did the air stimulus sensation disappear more quickly after presentation?

T ? F 6. Did the air stimulus appear to cover a wider area?

T ? F 7. Did the air stimulus appear to cover a smaller area?

T ? F 8. Did the air bursts induce a tickling sensation?

T ? F 9. If so, did the tickling sensation appear at the point of fusion?

Was your experience of tactile stimulation on the experimental arm accompanied by any of the following sensations?

T ? F 1. tingling?

T ? F 2. itching?

T ? F 3. prickling?

PART D

Heat and Pain Threshold Test

T ? F 1. Did the pricking sensation appear more suddenly?

T ? F 2. Did the sensation of heat appear more suddenly?

T ? F 3. Did the heat sensation appear to be localized to the area being stimulated?

T ? F 4. Did the pain sensation appear to be localized to the area being stimulated?

Was your experience of heat and pricking pain on the experimental arm accompanied by any of the following sensations?

T ? F 1. tingling?

T ? F 2. itching?

T ? F 3. tickling?

Use the remaining space to report any experience you felt which was not covered by the questions above.