TEMPORAL CHANGES IN CUTANEOUS SENSITIVITY DURING PROLONGED VISUAL DEPRIVATION

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ABSTRACT

TEMPORAL CHANGES IN CUTANEOUS SENSITIVITY DURING PROLONGED VISUAL DEPRIVATION

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A series of studies recently performed at the University of Manitoba have demonstrated that subjects who were visually deprived for a week, but otherwise exposed to a normal and varied sensory environment, showed a significant increase in pain sensitivity and in tactual acuity (two-point threshold and tactual fusion) at the end of the experimental period. However, since no attempt was made in these studies to investigate the changes in cutaneous sensitivity <u>during</u> the experimental condition, the measures being confined to the pre- and post-period, two experiments were conducted whose purpose was to determine the temporal course of development of this cutaneous facilitatory phenomenon.

In Experiment I, 16 male subjects were exposed to a week of visual deprivation. Apart from constant darkness, their sensory environment was normal. Measures of pain sensitivity (thermal pain) and absolute pressure sensitivity (von Frey hairs) were taken on the volar surface of the forearm, before as well as at intervals of 1/2, 1, 2, 3, 5, and 7 days after the beginning of deprivation. Thirty male control subjects were tested at the same time intervals but under a condition of normal visual stimulation. The results showed that the visual deprivation group

exhibited a trend toward increased sensitivity, relative to the controls, on both pain and pressure, particularly after the third day. On neither measure, however, were the results statistically significant.

In Experiment II, a new group of 16 subjects was exposed to one week of visual deprivation. Two measures of tactual acuity (two-point threshold and tactual fusion) were administered at the same time intervals as in Experiment I. In this experiment, a differential pattern of results was observed. The visual deprivation subjects showed no consistent pattern of changes in tactual acuity as determined by the two-point threshold technique. In contrast to this negative finding, the tactual fusion measure revealed that the visually deprived subjects showed, relative to the controls, a progressive increase in sensitivity with increasing durations of deprivation. This change was statistically significant.

The apparent inconsistency in these results and the failure to obtain a significant improvement on all four cutaneous measures can probably be accounted for by the confounding effect of interpolated testing, the differential stimulus characteristics of the individual measures, and by the differential action of various types of sensory stimuli on the reticular activating system.

Although the results of these two experiments have been only partially successful in answering the questions posed, they have, nevertheless, raised a number of important problems and issues which previously have not been considered in the deprivation literature. These findings are also of considerable theoretical importance since they provide some experimental support for the sensoristatic model of the nervous system recently formulated by Schultz (1965) viz., "when stimulus variation is restricted central regulation of threshold sensitivity will function to lower sensory thresholds." However, to fully account for the differential effects which have been obtained, a slight modification of this model is required - consideration must be given to the nature of the sensory tasks being employed.

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CHAPTER I

THE PROBLEM AND INTRODUCTION

Statement of the Problem

Various investigators have reported that subjects who are deprived of visual, auditory, kinesthetic, and social stimulation, for periods ranging from several days to a week, show a significant increase in tactual acuity and pain sensitivity. Recently, however, a series of studies at the University of Manitoba have demonstrated that a similar facilitatory effect can occur after visual deprivation alone and that an overall reduction in sensory stimulation from several modalities is not essential for its occurrence. The subjects who were visually deprived for a week, but otherwise were exposed to a normal and varied sensory environment, showed a significant increase in pain sensitivity and in tactual acuity (two-point threshold and tactual fusion) at the end of the experimental period. Furthermore, this effect was uniform with all, or almost all, of the experimental subjects showing this phenomenon. These results are of considerable theoretical importance since they provide experimental support for the sensoristatic model of the nervous system recently formulated by Schultz (1965) viz., "when stimulus variation is restricted central regulation of threshold sensitivity will function to lower sensory thresholds."

Although the Manitoba studies have clearly demonstrated an increase in cutaneous sensitivity after prolonged visual deprivation, no attempt was made to investigate the temporal course of development of this facilitatory phenomenon. In view of this, it is proposed to administer various measures of cutaneous sensitivity at periodic intervals during a week of visual deprivation. This experimental design should provide some answers to three important questions. First, what is the <u>approximate</u> minimum duration of deprivation required to produce these facilitatory effects? Second, is there a critical period for optimal effects at approximately two days, as some of the multi-modality deprivation studies appear to suggest, or does the critical period occur at some other duration? Third, if optimal effects do occur early in the one-week period, does the magnitude of these phenomena subsequently diminish with time as the result of a possible adaptation of the subject to the impoverished visual environment or is their temporal course characterized by some other type of functional relationship? Unfortunately, no answers to these questions are provided in Schultz's sensoristatic theory.

Introduction

The first experimental work on sensory restriction was initiated at McGill University in the early 1950's (Bexton, Heron, & Scott, 1954). Since this pioneer research, considerable interest has been shown by investigators from various disciplines in the behavioral and physiological effects of a reduction in the level and variability of sensory stimulation. Furthermore, many different procedures have been employed to reduce sensory input. These procedures are customarily divided into two main categories: sensory deprivation and perceptual deprivation, a two-fold classification first advocated by Kubzansky (1961).

In sensory deprivation, an attempt is made to reduce the level of sensory input to as low a degree as possible, this condition being achieved by requiring the subjects to lie or sit quietly in a dark and silent environment. Perceptual deprivation, on the other hand, involves a reduction in the patterning and meaningfulness of sensory stimulation while maintaining the level of input near normal. This is accomplished by providing a constant masking sound (white noise or hum of a fan), covering the eyes with translucent goggles or a white mask which permits diffuse light but eliminates pattern vision, and requiring a minimum of movement from the subject. In the studies employing these two general approaches, the duration of sensory restriction has ranged from 5 minutes to 14 days, the most common periods being either 8 hours or 1, 3, and 7 days.

Since the early McGill studies, research on the effects of sensory and perceptual deprivation has involved the measurement of a wide range of physiological and behavioral processes (see reviews of Schultz, 1965; Zubek, 1964b; Zubek, 1969a).

The physiological studies have included measures of EEG activity, skin resistance, muscle potentials, respiration, blood pressure, basal metabolic rate, and urinary excretion of adrenaline and noradrenaline. The results have indicated a progressive slowing of EEG activity and a decrease in skin resistance (greater arousal) with increasing durations of sensory restriction. In contrast to these positive findings, none of the other physiological measures appear to be affected.

In the study of behavioral changes, a variety of cognitive abilities have been appraised. The measurements largely involve subtests of standard I.Q. tests or tests of primary mental abilities. These have yielded a differential pattern of results e.g., space relations, number facility, and abstract reasoning are impaired whereas digit span, rote learning, recall, and verbal reasoning are unaffected by sensory restriction. An even more complex pattern of results has been revealed in studies employing measures of various sensory and perceptual-motor processes. These investigations have shown that such performance tasks as depth perception, the constancies, brightness discrimination, and c.f.f. are unaffected by deprivation while motor coordination, color perception, different types of illusions, and visual reaction time are considerably impaired. Certain other measures, surprisingly, have shown a facilitatory effect or improvement after prolonged periods of sensory restriction e.g., tactual acuity, pain sensitivity, taste sensitivity, and auditory vigilance.

Although no satisfactory explanation of these perplexing sensory facilitatory phenomena is available, it has been suggested that an essential condition for their appearance is a severe reduction in sensory stimulation from several modalities. Recently, however, a series of studies from the University of Manitoba, employing a one-week duration, have demonstrated that similar facilitatory effects can be produced by visual deprivation alone. Since no attempt was made to study the changes in sensitivity during the experimental period, the measures being confined to the pre- and post-period, further research appears to be warranted.

In view of this, two experiments will be conducted to investigate the temporal pattern of change in cutaneous sensitivity at intervals of 1/2, 1, 2, 3, 5, and 7 days of visual deprivation.

CHAPTER II

HISTORICAL BACKGROUND

Since a voluminous literature (see Zubek, 1969a) exists on the behavioral and physiological effects of sensory restriction, this historical review will be restricted to studies involving the measurement of cutaneous sensitivity. For organization purposes, the review will be presented in two sections. The first, multi-modality deprivation, will be concerned with an appraisal of the cutaneous changes resulting from an overall reduction in stimulation from several modalities. The second section will describe the more recent research on single modality deprivation i.e., visual deprivation. No review, however, will be presented of the extensive literature on the blind. In describing the various experiments, a differentiation will be made between sensory and perceptual deprivation as defined in the introduction.

Multi-modality Deprivation Studies

The earliest demonstration of an increase in tactual acuity was reported in one of the McGill experiments (Doane, Mahatoo, Heron, & Scott, 1959) in which two-point threshold determinations were taken from five subjects before and at intervals of two and three days of perceptual deprivation. A group of 20 controls was used for comparative purposes. The results revealed an increase in tactual acuity of the forehead and upper arm at both time intervals, an effect which was considerably greater after two than after three days. No significant changes in acuity were seen on the finger and forearm. The latter skin area, however, did show a definite trend toward increased tactual acuity. Although these two negative results might be attributed to the smallness of the experimental sample, another possibility at least for the finger, is that the two-point threshold technique does not have sufficient resolution to demonstrate increased sensitivity in an area of the skin which normally is highly sensitive.

Despite these differential results, it is significant that a greater increase in tactual acuity of both the forehead and upper arm was observed after two than after three days, suggesting the presence of a critical period for optimal effects at two days or below. Furthermore, beyond this duration the effects appear to diminish, presumably as a result of the adaptation of the subject to the impoverished sensory environment. A similar temporal pattern, it is important to note, has also been observed in two other studies. In the first, Weinstein, Richlin, Weisinger, and Fisher (1967), measuring the difference threshold for pressure of the palm, found a greater improvement in accuracy in subjects quitting prior to three days of sensory deprivation than in those completing the three-day prescribed period. In the second study, Doane et al. (1959) reported a much greater change in tactual form discrimination after two than after three days of perceptual deprivation. Both of these experiments, therefore, provide additional evidence for the possible existence of a critical period for optimal effects on certain tactual tasks prior to the third day.

Although no significant change in tactual acuity of the finger and forearm was observed in the McGill study, Zubek (1964a), using a more sensitive measure (tactual fusion), reported a significant increase in tactual acuity in both of these skin areas after a week of perceptual deprivation. All 12 experimental subjects showed increased forearm acuity, and 11 of the 12 subjects an increased finger acuity on the second threshold determination. Similar results also have been demonstrated at a Japanese laboratory after two days of perceptual deprivation. Nagatsuka and Maruyama (1963) reported a significant increase in the tactual acuity of the back of the hand (two-point threshold). It is interesting to note that 8 of the 9 experimental subjects showed the effect. A further verification of this phenomenon was provided in a subsequent replication, also employing a two-day duration (Nagatsuka & Suzuki, 1964).

The available evidence seems to indicate that this increase in tactual acuity does not occur with deprivation durations of eight hours or less. Pollard, Uhr, and Jackson (1963) reported no changes in the two-point threshold of the forearm after eight hours of perceptual deprivation. Cohen, Silverman, and Shmavonian (1962), and Culver, Cohen, Silverman, and Shmavonian (1964) also observed no significant effects on measures of two-point threshold (palm and back of hand), identification of letters traced on the forehead and back of hand, and tactile localization (palm), administered before and after two hours of sensory deprivation. Finally, Reitman and Cleveland (1964) reported no significant changes in two-point threshold or absolute pressure sensitivity (von Frey hairs) of the finger and wrist in a group of non-psychotic patients exposed to four hours of perceptual deprivation. Surprisingly, however, a group of schizophrenic subjects did show a significant improvement on both measures relative to schizophrenic controls. The reason for this differential effect in these two types of patients must await further research.

The results of these long-term and short-term deprivation studies, taken together, appear to suggest that a significant increase in tactual acuity first occurs somewhere between eight hours and two days. Although the specific duration required to produce this facilitatory phenomenon still remains to be determined, the present study on temporal changes, although restricted to visual deprivation alone, may throw some light on this problem.

Contrary to the results on tactual acuity, a prolonged period of deprivation does not appear to produce an increase in absolute pressure sensitivity of the skin. Using a von Frey hair technique, Weinstein et al. (1967) observed a significant <u>decrease</u> in pressure sensitivity on the palm of the non-preferred hand after 72 hours of sensory deprivation while durations shorter than 72 hours had no effect. In interpreting these results, the investigators suggest that it is possible that a "U-shaped function exists in this area, with fairly short (< 72 hrs.) or sufficiently long (> 72 hrs.) periods of deprivation improving sensitivity, while a 72-hour period leads to impairment" (p. 67). This hypothesis is highly questionable, particularly since Weinstein et al. reported no change in absolute pressure sensitivity at durations below 72 hours, a finding contrary to their U-shaped hypothesis. An alternative explanation proposed by these investigators viz., that the decrement in sensitivity of the palm may be related to the severity of sensory restriction, appears to be more plausible. Since the subjects were exposed not only to darkness and silence, but also wore a special glove so constructed as to eliminate all tactual stimulation of the palm, Weinstein et al. suggest that total sensory deprivation (visual, auditory, and tactual) may impair pressure sensitivity while partial deprivation, involving only one or two sense modalities, may improve it. Some support for this alternative hypothesis has been provided in a series of studies on partial deprivation in which it has been shown that a prolonged period of visual deprivation alone (Phelps & Zubek, 1969) or tactual deprivation alone (Heron & Morrison, unpublished paper; Weinstein et al., 1967) produce a significant increase in absolute pressure sensitivity as measured by the von Frey technique. It still remains to be determined, however, whether a deprivation of two or more sense modalities will produce the opposite effect.

An increased sensitivity to pain can also occur but apparently only under conditions of sensory deprivation. Vernon and McGill (1961), measuring the absolute threshold of electrical pain of the earlobe, reported a 42 per cent increase in pain sensitivity after four days of sensory deprivation in contrast to an increase of only 5 per cent in a group of controls. Of the nine experimental subjects, all but one showed this change. In discussing these results in a subsequent publication, Vernon (1963) raised two intriguing questions. First, since a

42 per cent increase was obtained after four days, would one day yield a 10 per cent change? Second, would longer periods lead to an even greater increase in sensitivity? Although a linear increase in pain sensitivity may occur with increasing durations, a more likely possibility is that the greatest increase will occur early in the deprivation period and subsequently diminish with time. Some support for this hypothesis has been offered by both Doane et al. (1959), who observed a greater change on two different cutaneous measures after two than after three days of sensory restriction, and by Weinstein et al. (1967) who reported a greater improvement on the discrimination of pressure in the "below three-day group" than in those completing a full three-day period.

In a second relevant study (Weinstein et al., 1967), a modified cold pressor method was employed to determine the pain sensitivity of the preferred and non-preferred hand before and after three days of sensory deprivation. Two measures were obtained from this method, viz., pain threshold (time in seconds from immersion of the hand in ice cold water until S reported pain) and pain tolerance (time in seconds from immersion of the hand until S reported that the pain was intolerable). Although the results were not statistically significant, probably because of large individual differences, a definite trend toward increased sensitivity was observed on both measures and on both hands. Furthermore, on the pain tolerance measure a greater change was seen in the "below three-day group" than in the three-day group, a finding similar to that reported for discrimination of pressure. One possible explanation for the lack of significant results may be the inaccuracy of the cold pressor method. Since it produces a vague rather than a clearly discriminable sensation of pricking pain, as obtained by either the electrical or radiant heat method, the subjects may have experienced considerable difficulty in making accurate pain judgments, a fact suggested by the presence of unusually large intra- and inter-subject variability scores. Another possible explanation may be the severity of their experimental condition; not only visual and auditory deprivation but also tactual deprivation of the hand was employed.

Although the evidence indicates that prolonged sensory deprivation can produce an increase in pain sensitivity, contrary results were reported by Zubek, Aftanas, Hasek, Sansom, Schludermann, Wilgosh, and Winocur (1962), who, using a one-week period of perceptual deprivation (unpatterned light and white noise) and a radiant heat technique for eliciting pricking pain, reported a significant decrease in sensitivity. Although this discrepancy might be attributed to the use of a seven-day rather than Weinstein and Vernon's shorter deprivation period (3 and 4 days), this appears unlikely since in two subsequent studies at the Manitoba laboratory, using seven days of visual deprivation alone, a significant increase in pain sensitivity was observed (Zubek, Flye, & Aftanas, 1964; Zubek, Flye, & Willows, 1964). A more likely possibility is that this decrease, occurring after perceptual deprivation, resulted from the constant exposure to white noise. Both Gardner and Licklider (1959) and Carlin, Ward, Gershorn, and Ingraham (1962) have reported that white noise has certain analgesic properties. Furthermore, Licklider (1961) has stated that "Mountcastle has found cells, both in the posterior group nuclei and in the cerebral cortex, which responded to nociceptive stimulation and whose responses are suppressed by acoustic stimulation" (p. 70). It would appear, therefore, that the presence or absence of white noise may be the critical factor in accounting for the apparently contradictory results produced by sensory and perceptual deprivation.

Finally, in the only short-term study, Glazer and Zenhausern (1966) reported a significant increase in thermal pain sensitivity (absolute threshold for pricking pain) after only five minutes of sensory deprivation. These results, however, are highly questionable since no control group was used for comparative purposes. Furthermore, it is known that control subjects frequently show an increase in pain sensitivity on a retest session (Vernon & McGill, 1961; Weinstein et al., 1967).

Single-modality Deprivation Studies

A brief review will now be given of a series of three experiments, conducted at the University of Manitoba, which have indicated that sensory facilitatory effects, similar to those described earlier, can result from visual deprivation alone; an overall reduction in sensory stimulation from several modalities is not essential for their occurrence. Unfortunately, in these Manitoba studies no attempt was made to investigate the temporal pattern of changes in cutaneous sensitivity. The measurements were confined exclusively to the pre- and post-deprivation periods.

In the first study, (Zubek, Flye, & Aftanas, 1964) 16 male subjects were placed, in groups of two, in total darkness for a prescribed period of one week. Apart from the exposure to constant darkness, their environment was normal i.e., no gloves were worn and no restrictions were placed on their motor activity or on talking. A radio was available in the room at all times. Measures of tactual acuity were taken from the index finger, palm, and forearm before and immediately after the week of darkness, and subsequently at follow-up intervals of 1, 2, 3, 5, and 7 days. The measures consisted of the two-point threshold and tactual fusion (interrupted bursts of air whose frequency can be increased until a constant sensation of pressure is reported). In addition to these measures, heat and pain thresholds of the forearm were taken by means of the Hardy, Wolff, and Goodell dolorimeter. A group of control subjects received the same tests and at the same time intervals as the experimentals. The results showed a significant increase in cutaneous sensitivity relative to the control subjects. This increase was shown on all measures, on all skin areas tested, and by all 16 experimental subjects. Furthermore, this increase in sensitivity was still present several days after the termination of darkness.

The purpose of the second experiment (Zubek, Flye, & Willows, 1964) was to determine whether effects, similar to those resulting from darkness, will result from prolonged exposure to non-varying homogeneous illumination. The previous procedure, therefore, was repeated with a new group of subjects, but instead of being exposed to darkness, each subject wore a pair of translucent goggles which permitted diffuse light but eliminated all pattern vision. The results revealed an essentially similar picture: an increase in pain and heat sensitivity and in tactual acuity as measured by the tactual fusion method, with the after-effects persisting from 1 to 2 days. Surprisingly, no significant change in the two-point threshold of the palm was observed. However, a definite trend toward increased acuity was present. These results appear to suggest that it is the absence of pattern vision or of changes in visual input rather than an absence of visual stimulation per se which is responsible for the increased cutaneous sensitivity.

In the third study (Phelps & Zubek, 1969) on visual deprivation (darkness), two other cutaneous measures were employed viz., point localization on the forearm and absolute pressure sensitivity (von Frey hair technique) of the finger, palm, forearm, neck, and leg. The results revealed an increase in pressure sensitivity on all skin areas. Furthermore, all of the increases were statistically significant except for the palm. The results on point localization, however, revealed no significant change, a finding which the investigator attributed to the importance of learning in this performance measure.

Finally, only one short-term study has been concerned with changes in cutaneous sensitivity after visual deprivation alone. Using a two-point threshold technique, the Soviet investigator Kamchatnov (1962) reported that the tactual acuity of the index finger, thumb, and forearm of a group of women working for four hours in the dark was much poorer than that of a group of women working for a similar duration in the light. This conclusion, however, is questionable since there was a sizeable difference in tactual acuity of the two groups of subjects <u>prior</u> to the experiment. In view of this, a statistical treatment involving a "difference of differences" analysis would undoubtedly have yielded negative results.

In summary, this review of the literature has indicated (a) that durations of sensory restriction, ranging from two days to a week, can produce a significant improvement on various measures of cutaneous sensitivity, (b) that durations of several days sometimes produce greater changes than longer deprivation periods and finally, (c) that no attempt has been made to investigate, systematically, the temporal pattern of changes in cutaneous sensitivity during prolonged sensory restriction.

CHAPTER III

EXPERIMENTAL METHOD AND RESULTS

EXPERIMENT I

The purpose of the first experiment was to investigate the temporal changes in absolute pressure and pain sensitivity of the forearm at various intervals during a one-week period of visual deprivation.

Method

Subjects

Sixteen male university students (mean age = 20.3 years), each wearing a black mask, were placed in groups of two in an air-conditioned windowless room (15 ft. x 10 ft.) for a prescribed period of one week. Apart from the exposure to constant darkness, their environment was normal i.e., no gloves were worn and no restrictions were placed on their motor activity or on conversation with one another. A radio was available in the room at all times. The subjects were confined to the room for the entire week, except for periodic visits to the washroom. At these times they were accompanied by the experimenter. A diet of sandwiches, juice, and coffee or tea was served according to a fixed schedule. For comparative purposes, a group of 30 male students (mean age = 22.3 years) were used as ambulatory control subjects.

Neither the experimental nor the control subjects were permitted any medication (particularly analgesics) either during the one-week period or for two days prior to it. Both groups of subjects were paid for their services: $125 for the experimentals and $35 for the controls.

Test Procedure

Two measures of cutaneous sensitivity viz., absolute pressure sensitivity and pain sensitivity, were taken from the volar surface of the forearm before and at intervals of 1/2, 1, 2, 3, 5, and 7 days of visual deprivation. The measures were always taken at approximately 9:00 A.M. except at the 1/2 day period, when they were administered at approximately 9:00 P.M. The black mask was worn by the experimental subjects during all test sessions, with the exception of the pre-test.

Sensitivity to pressure was determined by the Semmes-Weinstein pressure aesthesiometer which consists of a series of 20 nylon monofilaments, 38 mm. in length and ranging in diameter from .06 to 1.14 mm. This series of filaments has been calibrated by pressing the tip of each filament on a chemical balance and determining the logarithm of the force (in mg.) required to bend it maximally. The procedure used was similar to that employed by Semmes, Weinstein, Ghent, and Teuber (1960). Using a method of limits, two ascending and two descending trials (ADAD and DADA) were administered to the volar surface of each forearm, approximately 8 cm. below the elbow. Half of the subjects were tested on the left arm first and the other half on the right arm. A record was made of the first filament perceived in each ascending determination, and of the last filament perceived in each descending determination. Each filament was applied for approximately 1 second with intervals of 3 to 8 seconds between individual applications (see Appendix A for test instructions).

Pain sensitivity was measured by the Hardy, Wolff, and Goodell dolorimeter connected to a timer. This apparatus consists of an incandescent lamp whose rays can be focused onto a blackened area of the skin. The basal setting of the dolorimeter was 100 mcal./cm.^{2}/sec. and the method of limits was used. Four trials, ascending series only, were given on the volar surface of each forearm (the aperture of the dolorimeter being placed several inches away from the test area for pressure, 2-4 mm. above the skin), alternating arms every trial in order to allow for dissipation of heat in the test area. An inter-trial interval of 1 minute was employed. A timer was used to determine the threshold by measuring the latency, in seconds, from the onset of radiant heat to the first indication of pricking pain. Since the periodic application of radiant heat might affect the sensitivity of the adjacent test area for pressure, via skin conductance, the pain measure was always taken _after_ the completion of the absolute pressure determinations.

In order to familiarize the subjects with the test procedure, a practice session on the two cutaneous measures was given one day prior to visual deprivation. Furthermore, the same standard set of instructions was read to the subjects prior to the practice session and at all subsequent test sessions (see Appendix A for test instructions).

A group of 30 ambulatory control subjects were given the same cutaneous measures and at the same time intervals as the experimentals. In order to avoid even a short duration of visual deprivation, no black mask was worn by the control subjects during the test administration sessions. Their view of the forearm, however, was occluded by means of a large screen placed over the elbow. A similar screen was applied to the visually deprived group but only during the pre-experimental test sessions.

Results

For purposes of statistical analysis, the pre-deprivation scores of the 16 experimental subjects were matched with the initial scores of 16 of the 30 control subjects. The subjects were separately matched for pressure and pain sensitivity, and the same control subjects were not necessarily used for both measures. An analysis of variance for repeated measures, both factors, (Myers, 1966) was used to compare the cutaneous sensitivity of the two groups of subjects at various intervals during the one-week duration.

Figure 1 summarizes the results on pain sensitivity. It can be seen that relative to the controls, the experimental subjects show an increase in pain sensitivity at virtually all temporal periods with the greatest difference in sensitivity being present after the third day. An analysis of variance, unfortunately (see Table 1), indicated that the difference in performance of the two groups was not statistically significant ($F < 1$). However, since a significant difference in performance may have occurred after the third day but conceivably was masked in the overall F ratio by the small difference in the early days, two t-tests for matched groups were applied to the results of day 5 and day 7. No significant difference was again observed. Although the F ratio for the

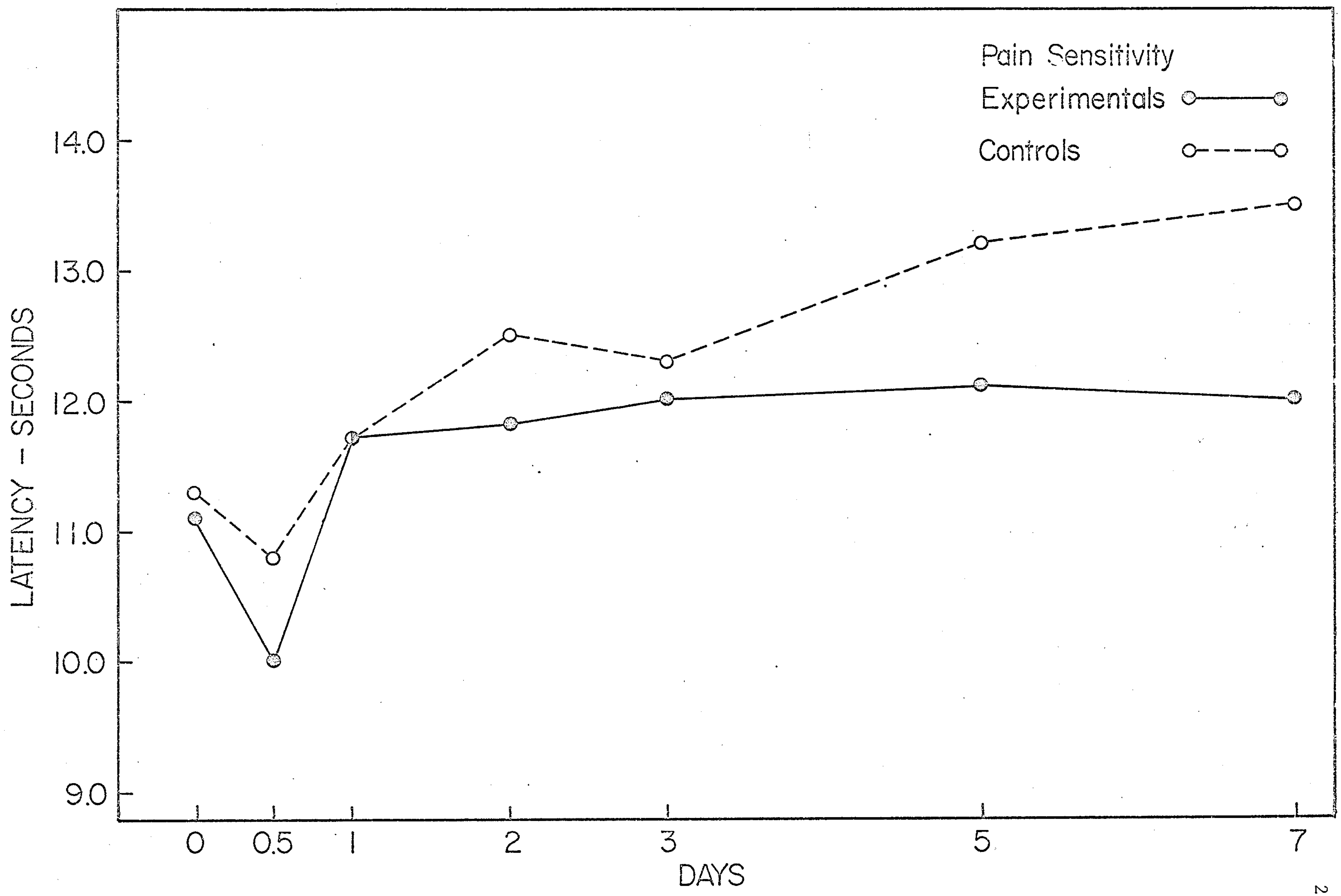

Fig. 1 Changes in pain sensitivity of the forearm in two groups of subjects before and during a week of visual deprivation or of a control condition

between groups effect was not significant, the between days effect was ($F = 14.73$). Also the interaction was not significant ($F < 1$).

TABLE I

ANALYSIS OF VARIANCE FOR THE RESULTS ON PAIN SENSITIVITY

Source	SS	DF	MS	F
A (Between Groups)	29.290	1	29.290	< 1
B (Between Days)	128.991	6	21.498	14.73*
S	1440.135	15	96.009	
AB	11.991	6	1.998	< 1
AS	345.494	15	23.033	
BS	131.578	90	1.462	
ERROR	209.705	90	2.330	
TOTAL	2297.186	223		

*Significant at the .001 level.

Figure 2 summarizes the results on pressure sensitivity. It can be seen that relative to the controls, the experimentals show a trend toward increased sensitivity after the third day. Although no trend is obvious, prior to this period the visually deprived group is more sensitive than the controls at most intervals. The analysis of variance, however, again indicates that the difference in performance of the two groups was not statistically significant ($F < 1$, see Table 2).

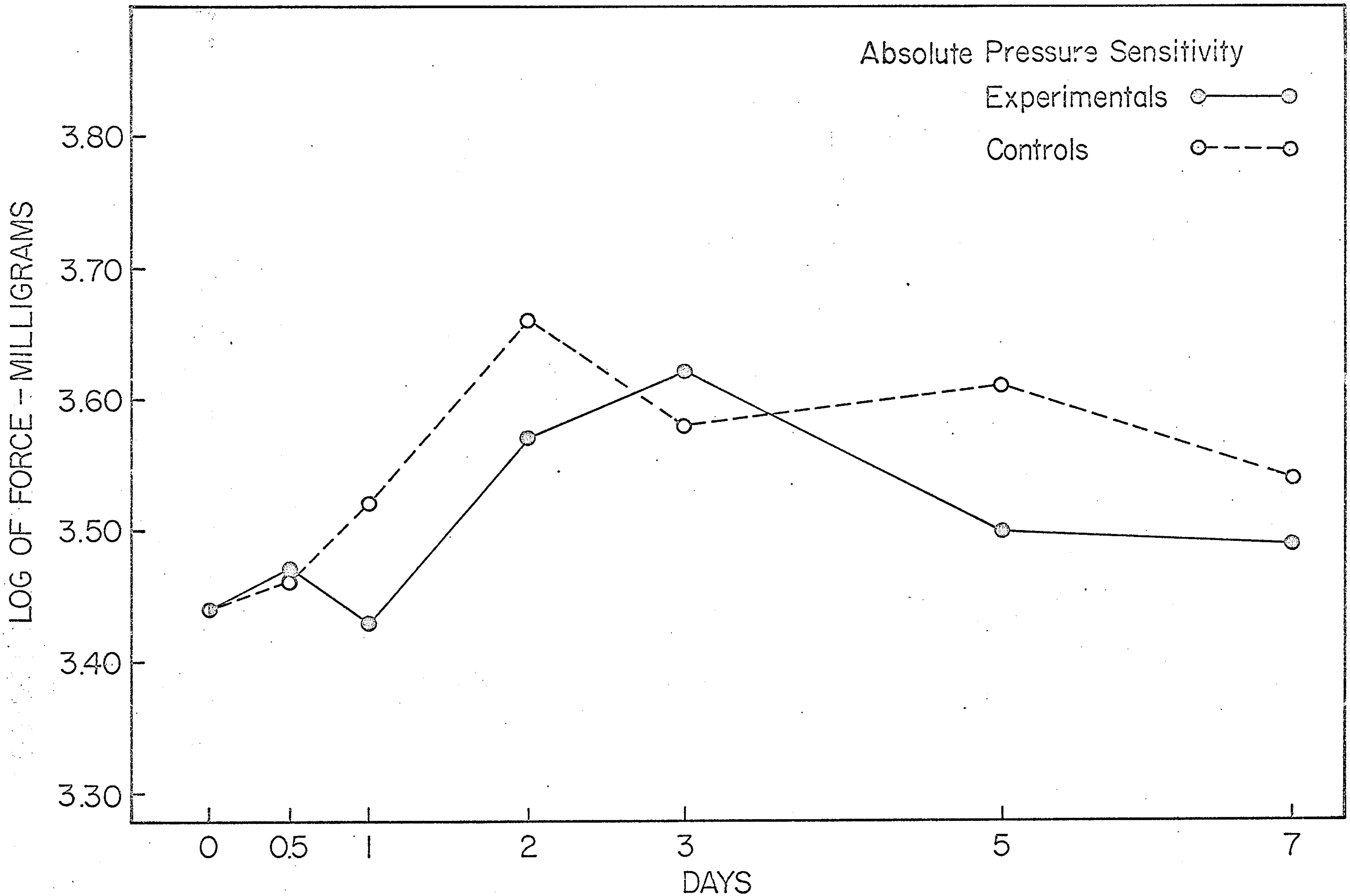

Fig.2 Changes in absolute pressure sensitivity of the forearm in two groups of subjects before and during a week of visual deprivation or of a control condition

In addition, neither the between days effect nor the interaction were significant ($F < 1$).

TABLE II

ANALYSIS OF VARIANCE FOR THE RESULTS ON PRESSURE SENSITIVITY

Source	SS	DF	MS	F
A (Between Groups)	0.121	1	0.121	< 1
B (Between Days)	0.933	6	0.155	< 1
S	29.264	15	1.950	
AB	0.196	6	0.033	< 1
AS	2.224	15	0.148	
BS	7.761	90	0.086	
ERROR	4.608	90	0.051	
TOTAL	45.107	223		

EXPERIMENT II

The purpose of the second experiment was to study the temporal changes in tactual acuity (two-point threshold and tactual fusion) at various intervals during one week of visual deprivation.

Method

Subjects

The same number of subjects, 16 experimentals (Mean age = 20.8 years) and 30 controls (mean age = 19.6 years) and the same deprivation procedure, as in the preceding experiment, was employed.

Test Procedure

Two measures of tactual acuity viz., two-point threshold and tactual fusion were taken from the volar surface of the forearm, approximately 8 cm. below the elbow, before and at intervals of 1/2, 1, 2, 3, 5, and 7 days of visual deprivation.

The two-point threshold was obtained by placing the aesthesiometer along the proximo-distal axis of the arm. The method of limits was used with two ascending and two descending series (ADAD and DADA) applied to each forearm. An approximate threshold was first determined by a bracketing procedure at the beginning of the practice session. This bracketed threshold became the basis of the starting point for the practice trials. The ascending series was begun at a separation 10-25 mm. below and the descending series 10-25 mm. above the threshold determined by the bracketing procedure. The increments or decrements were in intervals of 2 mm. In all subsequent sessions the threshold determined during the practice session was the basis of the starting point. The criterion for the two-point threshold for the ascending series was a report of pressure at two points on the skin on two consecutive trials and for the descending series, was a report of pressure at one point on the skin on two consecutive trials. In order to increase the reliability of the data and to control for guessing, the subjects were told that sometimes they would be touched with two points and sometimes with only one.

The tactual fusion threshold was determined by means of a "flicker" technique developed by Shewchuk and Zubek (1960). This method utilizes an interrupted jet of air at a specified pressure whose frequency can be systematically increased until the subject reports a constant sensation of pressure on the skin. The frequency at which this sensation occurs is referred to as the critical frequency of percussion or CFP. Four trials were given on each forearm, the test area being covered with vaseline to minimize drying of the skin. All stimuli were presented in an ascending order and at a tank pressure of 30 lbs. The tip of the air nozzle was placed a 1/2 cm. from the skin. In administering both the tactual fusion and two-point threshold measures, half the subjects were tested on the left arm first and the other half on the right arm.

In contrast to Experiment I, the same test area on the forearm was employed for both tactual acuity measures. Furthermore, since the repeated application of an aesthesiometer is known to produce a slight reddending of the skin, the two-point threshold measure was always taken _after_ the completion of the tactual fusion determinations. Practice trials on each of the two types of acuity measures were given a day prior to the experimental session. The same standard set of instructions was read to the subjects prior to the practice session and on all subsequent test sessions (see Appendix A).

Two important considerations were involved in employing only two cutaneous measures in each of the experiments. The first was to keep the total testing time to approximately 15 or 20 minutes, thus minimizing the possible operation of fatigue and attentional factors. The second consideration pertains to possible future research in this area. If a period of only half a day should produce a significant change on any of the measures of cutaneous sensitivity, very short durations of several hours or less may have to be employed in order to determine the minimum period of visual deprivation required to produce the facilitatory effects. In such an event, a brief test session is essential particularly if the results of this future research are to be directly comparable to those of the present long-duration experiments.

Results

For purposes of statistical analysis, the pre-deprivation scores of the 16 experimental subjects were matched with the initial scores of 16 of the 30 control subjects. The subjects were separately matched for two-point threshold and tactual fusion and the same control subjects were not necessarily used for both measures. An analysis of variance for repeated measures, both factors (Myers, 1966) was again employed to compare the tactual acuity of the two groups of subjects at various intervals during the one-week duration.

A summary of the results on the two-point threshold determinations is shown in Figure 3. It can be seen that the experimental subjects show no constant pattern of changes in tactual acuity, relative to the controls, at the various temporal periods. An apparently random pattern of changes in acuity appears to be present. In view of these results, it is not surprising that no significant differences in performance between the two

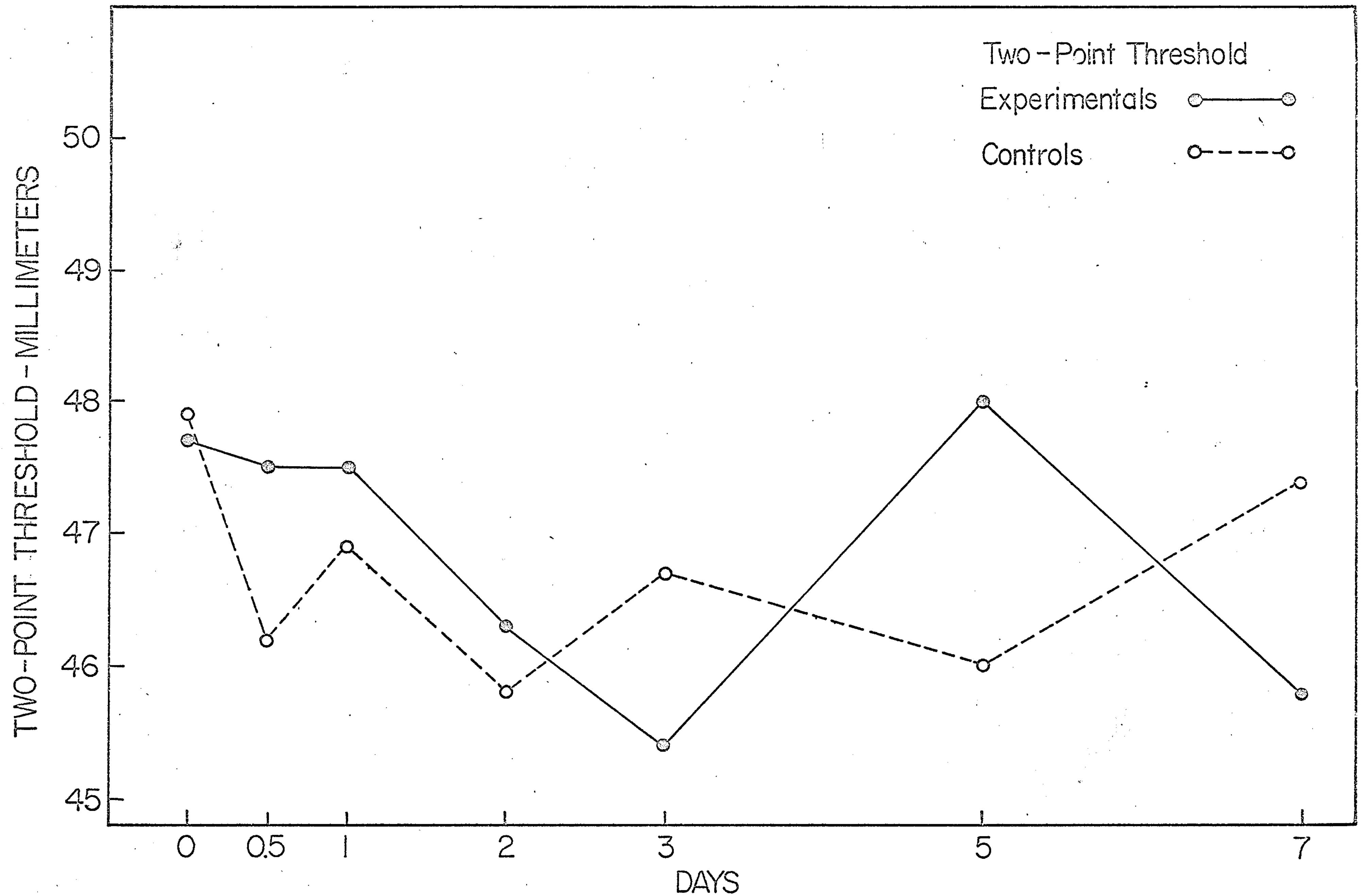

Fig. 3 Changes in tactual acuity of the forearm, as measured by a two-point threshold technique, in two groups of subjects before and during a week of visual deprivation or of a control condition

groups of subjects should have been obtained (see Table 3).

Figure 4 summarizes the results on tactual fusion. In contrast to the negative finding on the two-point threshold, this particular measure of tactual acuity reveals that the visually deprived subjects show, relative to the controls, a progressive increase in sensitivity with increasing durations of deprivation. Furthermore, an examination of the individual scores (see Appendix B) indicates that by the end of the 7-day period virtually all of the experimental subjects (15 out of 16) exhibit an increase in tactual acuity in contrast to only 5 of the 16 control subjects.

TABLE III

ANALYSIS OF VARIANCE FOR THE RESULTS ON THE TWO-POINT THRESHOLD

Source	SS	DF	MS	F
A (Between Groups)	2.362	1	2.362	< 1
B (Between Days)	76.740	6	12.790	< 1
S	17824.539	15	1188.302	
AB	77.295	6	12.882	< 1
AS	5902.265	15	393.484	
BS	3204.376	90	35.604	
ERROR	3111.252	90	34.569	
TOTAL	30198.836	223		

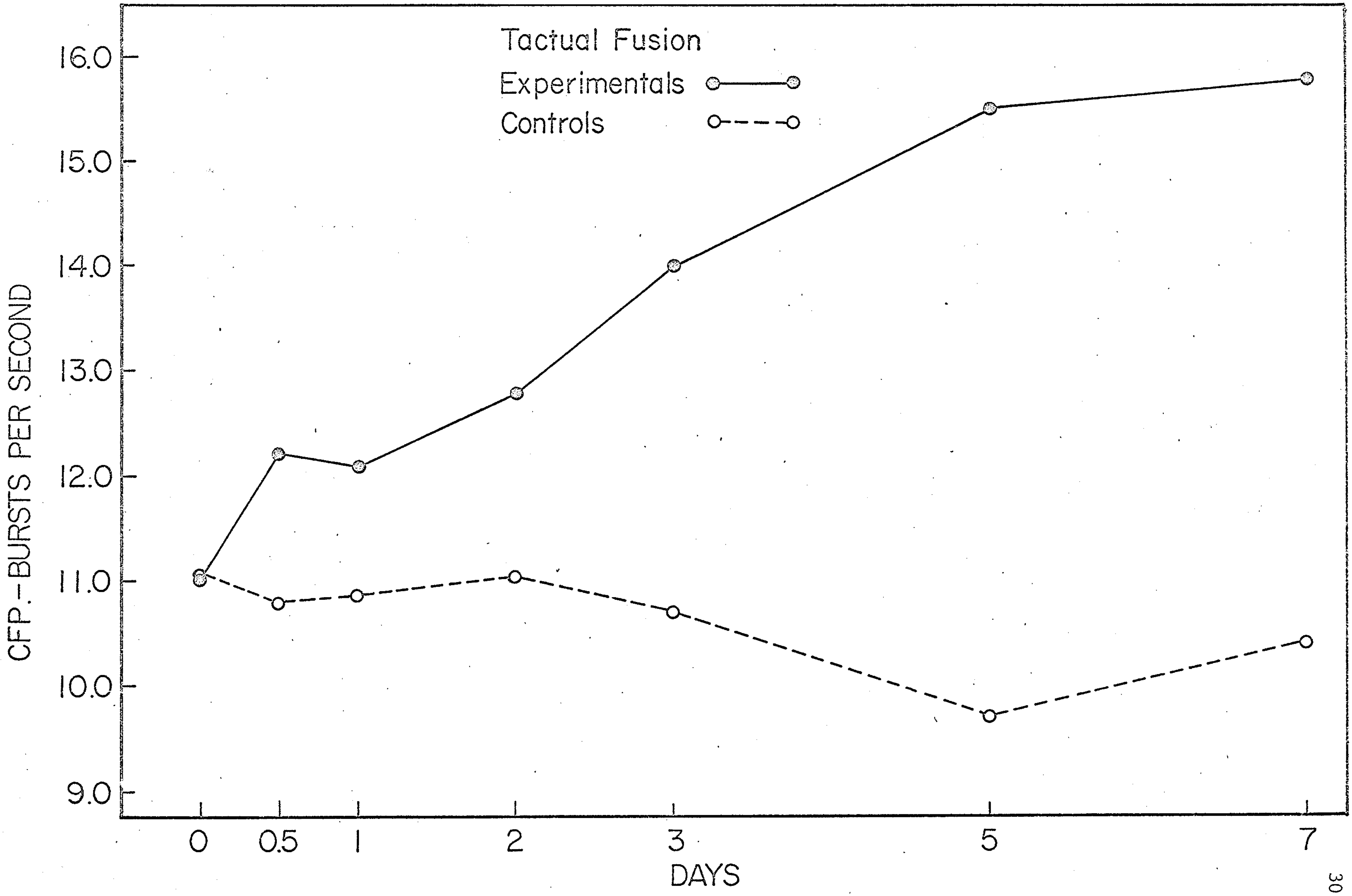

Fig. 4 Changes in tactual acuity of the forearm as measured by a fusion technique, in two groups of subjects before and during a week of visual deprivation or a control condition

An analysis of variance performed on the tactual acuity data showed a significant difference between the visually deprived and control groups (A effect), a significant change over days (B effect), as well as a significant interaction effect (AB effect). All three differences viz., between groups, over days, and interaction were significant at the .001 level of significance (see Table 4).

Since Figure 4 indicates that the experimental subjects show a noticeable increase in tactual acuity relative to the controls, after only 12 hours of visual deprivation, a t-test for matched groups was

TABLE IV

ANALYSIS OF VARIANCE FOR THE RESULTS ON TACTUAL FUSION

Source	SS	DF	MS	F
A (Between Groups)	412.571	1	412.571	19.15*
B (Between Days)	98.553	6	16.426	7.24*
S	1424.408	15	94.961	
AB	247.428	6	41.248	18.17*
AS	323.142	15	21.543	
BS	204.588	90	2.273	
ERROR	250.842	90	2.787	
TOTAL	2961.533	223		

*Significant at the .001 level.

performed to determine whether this difference is statistically significant. This analysis revealed a significant effect ($p < .05$). A further analysis of the data indicated that 14 of the 16 experimental subjects showed an increase in tactual acuity at 12 hours compared to only 7 of the 16 controls (see Appendix B).

Since a determination of the shape of the tactual fusion curve as a function of duration of deprivation is of some importance, the best fitting polynomial was determined. A weighted least square solution was used in computing the regression equation for the polynomials best fitting the tactual fusion scores of the experimental group (see Halasz, 1968). Attention was paid to the reliability of the data at each time period by weighting the mean score for each time period by the reciprocal of the variance. In addition to giving the evaluated points (points on the curve) for each test duration, an interpolated point was given between each experimental or actual data point. Both polynomials and the root mean square (RMS) error were obtained for orders 1 through 10 with the order polynomial having the smallest root mean square error being accepted as the best representation of the data.

This analysis indicated that the fourth order polynomial was the curve of best fit (RMS = .034), closely approximating the actual data points (see Figure 5). Figure 5 also shows that the polynomial is a straight line between the first and fifth days. Furthermore, a comparison of the RMS and evaluated points for the first order (linear) and fourth order polynomials, indicated that their RMS errors are very close (4th order = .034; 1st order = .055). A graphical plot of the two

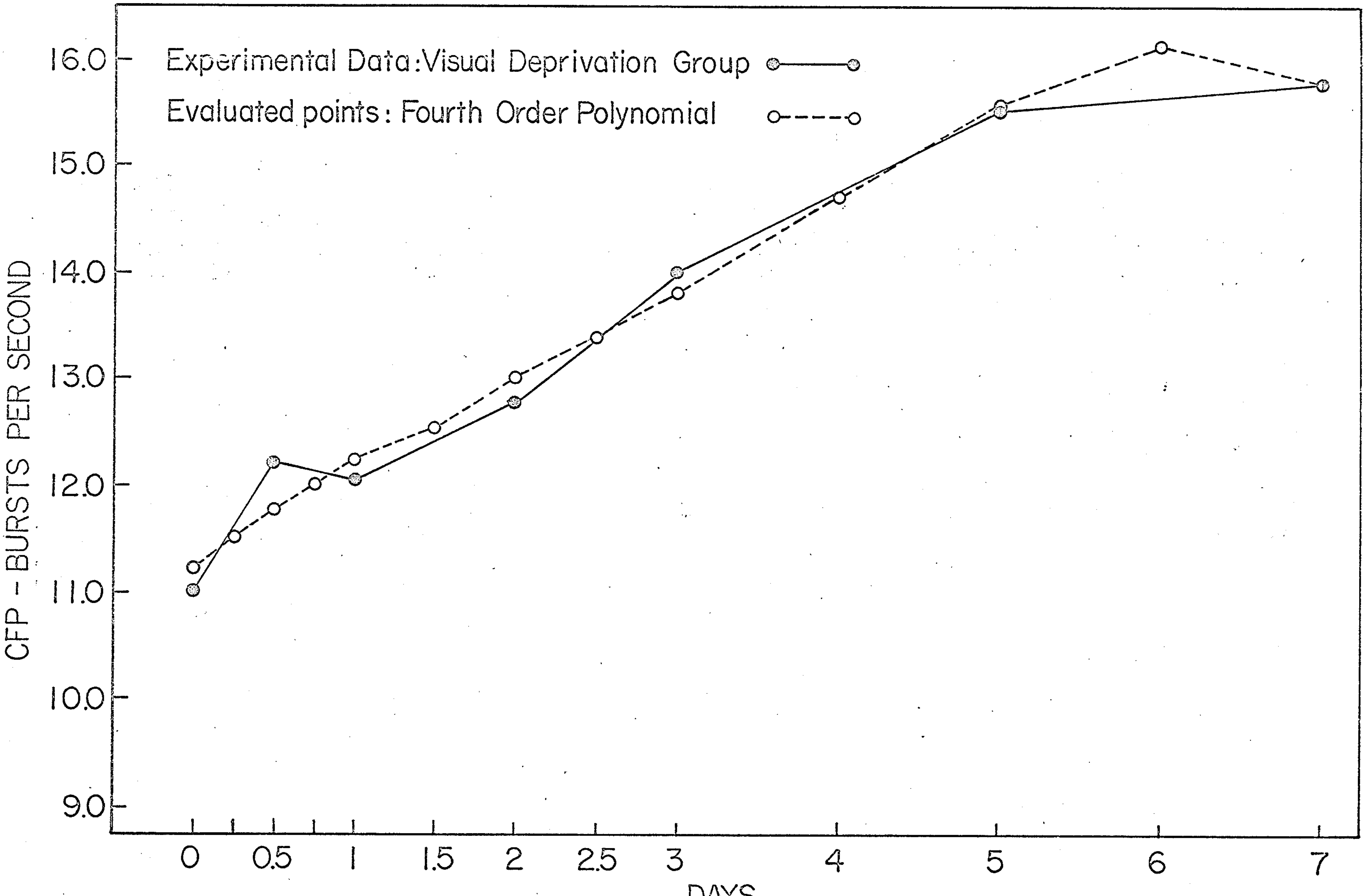

Fig. 5 A comparison of the experimentally obtained tactual fusion data of the visually deprived group with the evaluated points of the fourth order polynomial at various temporal periods

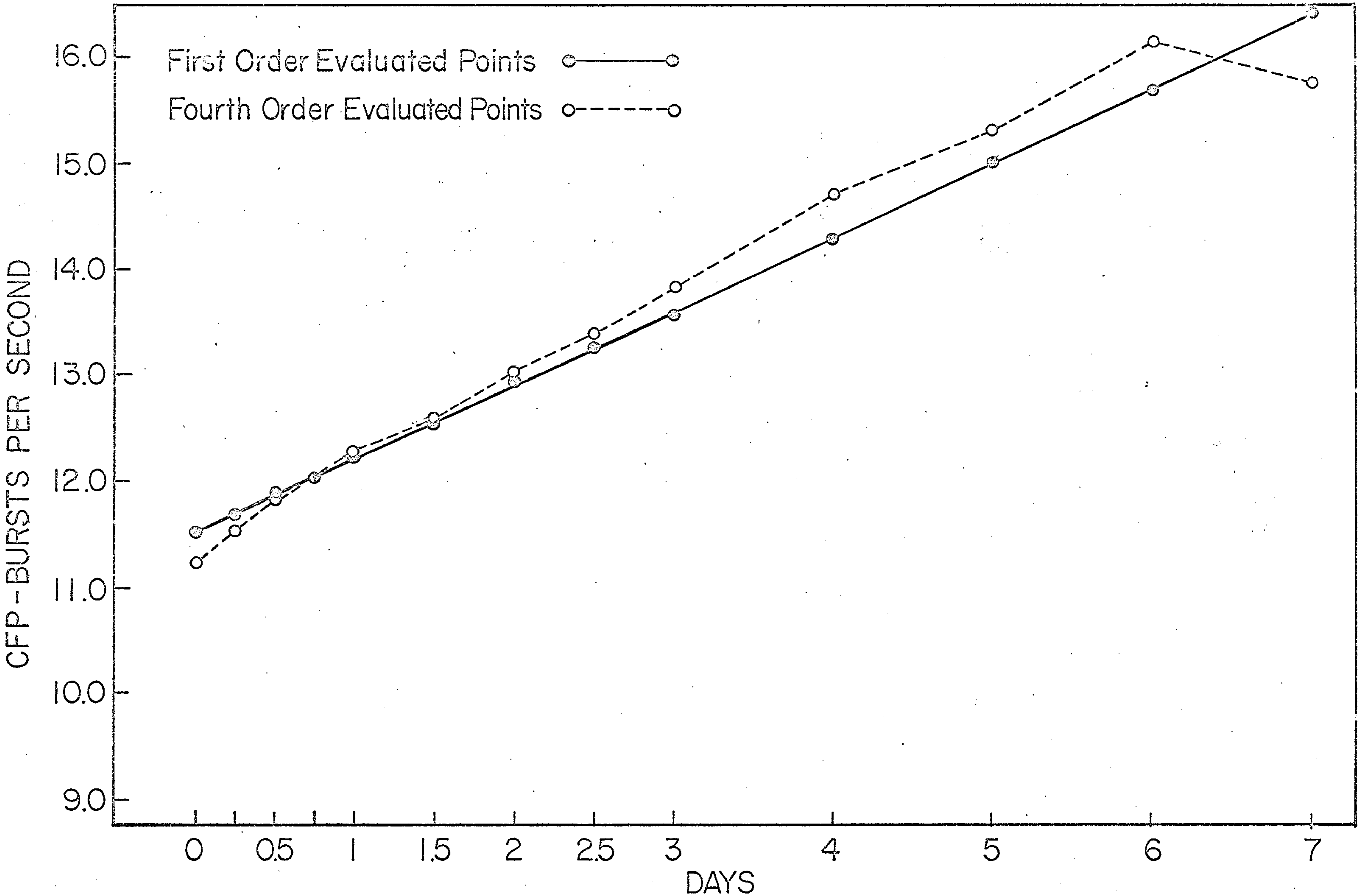

Fig. 6 A comparison of the first order (linear) and fourth order polynomial-evaluated points of the experimental group of subjects at various temporal periods.

sets of evaluated points is shown in Figure 6. It can be seen that the two curves closely approximate each other.

On the basis of this analysis one can conclude that there is a linear improvement in tactual acuity as a function of increasing duration of visual deprivation. This facilitatory effect is present at 12 hours and progressively increases thereafter.

CHAPTER IV

DISCUSSION AND CONCLUSIONS

Although an extensive body of literature has demonstrated the presence of sensory facilitatory effects following either sensory deprivation or visual deprivation alone, virtually no research has been directed toward identifying the pattern of temporal changes. Because of the hesitation of investigators to intrude upon the deprivation condition for fear that it might raise the level of sensory stimulation, these facilitatory phenomena have been studied by the use of a pre-post design and procedure. The present study, on the other hand, represents the first serious attempt to investigate the temporal pattern of development of one of these phenomena viz., increased cutaneous sensitivity, at periodic intervals during a prolonged period of visual deprivation. Although the results of this experiment have been only partially successful in answering the questions posed, and in fulfilling the purpose of the study, they have, nevertheless, raised a number of important problems and issues which previously have not been considered in the deprivation literature. These problems will be dealt with in appropriate places in this discussion.

The results of Experiment I indicated that no specific duration within the one-week period of visual deprivation produced a significant change in either pain or absolute pressure sensitivity. Although no statistically significant effects were obtained, it is important to note that a definite trend toward increased pain sensitivity in the experimental relative to the control group was present at virtually all test durations, a trend particularly noticeable after the third day. A similar trend toward increased pressure sensitivity, although not as pronounced as for pain, was also observed.

The absence of a significant increase in pain and pressure sensitivity, especially at the end of the one-week period, is puzzling in the light of two earlier experiments from the Manitoba laboratory (Phelps & Zubek, 1969; Zubek, Flye, & Aftanas, 1964). Using the same visual deprivation procedure, duration, and test measures as in the present study, but a pre-post design, a significant increase in pain and pressure sensitivity of the forearm was observed at the end of the one-week period of deprivation. Since the main procedural difference was the introduction of interpolated testing in the present study, it is possible that the repeated testing during the deprivation period may have dampened the magnitude of the true facilitatory effect that would have occurred in its absence. Such a dampening or "habituation" effect could result from the persistence of the after-effects of one test session into the next, particularly since the same cutaneous area was stimulated at periodic intervals. Furthermore, it is reasonable to assume that the greater the interval is between two test sessions the smaller would be the intrusion of the first after-effect into the next test session.

Some support for this interpretation of the results is provided by the experimental data. It is interesting to note that the largest difference between the experimental and control groups on both cutaneous measures was observed after the third day when the inter-test intervals were two days rather than one day. This appears to suggest that if the test session on the fifth day had been omitted and thus a four day inter-test interval had been employed, it is possible that a statistically significant increase in pain and pressure sensitivity may have been obtained on the seventh day, a finding consistent with that reported in the two earlier Manitoba experiments.

This interpretation or hypothesis also possesses the merit of being able to throw some new light on a set of perplexing results obtained at McGill University. Doane et al. (1959) in the only other longitudinal study concerned with the temporal changes in cutaneous sensitivity, reports a considerable improvement in tactual acuity of the arm (two-point threshold) at the end of two days of perceptual deprivation but little effect at the end of three days. This latter effect, it would now appear, may be related to the use of a prior test period at two days. Furthermore, this raises the question as to whether a facilitatory effect would have occurred at two days if some prior test periods had been inserted, for example, at 1/2, and 1 days, a procedure similar to that employed in the present study. Further speculations can also be made. For example, would Vernon and McGill (1961) have obtained a significant increase in pain sensitivity after four days of sensory deprivation if one or more measures had been interpolated during this prescribed period? A similar question could be raised with regard to all previous deprivation studies in which an exclusively pre-post design has been employed.

Finally, a brief reference will be made to some physiological data which indicates that the after-effects of one stimulus session may persist into the next, producing a habituation effect. According to Deutsch and Deutsch (1966), the repetition of the same stimulus results in a gradual failure to elicit EEG arousal. Furthermore, Sharpless and Jasper (1956) have demonstrated that this habituation of the arousal response can develop even when many hours intervene between successive presentations of the same stimulus and may persist for hours or even days.

Since the evidence appears to suggest that the use of periodic testing during deprivation may be a confounding variable, at least on certain sensory measures, any successful attempt to determine the relationship between deprivation duration and pain and pressure sensitivity will probably require the use of a cross-sectional approach in which a number of experimental groups are employed, each being visually deprived for a different duration e.g., 1, 3, 5, and 7 days with the test measures restricted to the pre- and post-period. However, even with this approach it may be difficult to determine the minimum duration required to produce a facilitatory effect if the pre- and post-deprivation test sessions are too close in time to each other.

Another implication resulting from this evidence is that any future research which may be concerned with the temporal pattern of development of various non-cutaneous facilitatory phenomena (e.g., the increase in olfactory and gustatory sensitivity reported by Schutte and Zubek, 1967) should also seriously consider the use of a cross-sectional method. Furthermore, it might prove fruitful to compare the results derived from a cross-sectional approach and a longitudinal approach employing interpolated tests at various durations. Such research might indicate whether the confounding role of periodic tests during deprivation is restricted to certain cutaneous measures or whether the effect is more general in nature.

Turning to Experiment II we observe a differential set of results. The first measure of tactual acuity, the two-point threshold, indicated that visual deprivation produced no significant effect relative to the control condition at any temporal period. Furthermore, no suggestion of a trend toward an improvement in tactual acuity was observed. These negative results are probably due, in part, to the problem encountered in Experiment I, i.e., the confounding role of interpolated testing. In addition, they may also be related to the large variability of the inter- and intra-subject scores obtained on the two-point threshold measure at the various temporal periods (see Figure 3), a phenomenon frequently noted in other studies employing the two-point threshold as a measure of tactual acuity. It was the unreliability of this technique which was largely responsible for the development of the tactual fusion method by Shewchuk and Zubek (1960).

In contrast to this negative finding on the two-point threshold, the results on tactual acuity, as determined by the fusion method, indicated a significant improvement in performance in the experimental relative to the control group at all test durations. Furthermore, this improvement in tactual acuity increased in magnitude, as a function of duration, in a linear fashion with some indication of a levelling off of the phenomenon on the seventh day. Since the facilitatory effect was already present, to a statistically significant degree, at the first test period i.e., 12 hours, further research is required to determine the minimum duration of visual deprivation necessary to produce this effect. A follow-up study, currently in progress at the Manitoba laboratory, suggests that the duration will probably fall somewhere between 4 and 12 hours.

If the hypothesis is advanced that the presence of interpolated testing is somehow responsible for the negative results on two-point threshold and pain and pressure sensitivity, the question arises as to why a significant increase in tactual fusion should have occurred under the same periodic testing conditions. In attempting to answer this question attention must be given to two factors: (a) the stimulus characteristics of the measures and (b) the differential action of various stimuli on the reticular system, which is believed to be involved in mediating some of the intersensory facilitatory effects (e.g., Schultz, 1965; Zubek, 1969b).

A close examination of the four measures of cutaneous sensitivity employed in this study reveals that their stimulus characteristics are dissimilar. While the measures of two-point threshold and pain and pressure sensitivity are primarily spatial in nature, the tactual fusion measure, on the other hand, largely involves temporal discrimination or resolution. Since different perceptual processes (and possibly different neural processes) are undoubtedly involved in the performance of temporal and non-temporal tasks it is likely that these two types of measures may interact differentially with visual deprivation. Some support for the importance of this distinction has been provided by Duda and Zubek (1965) who, in attempting to account for some differential auditory results occurring after a week of visual deprivation viz., an improved performance on an auditory flutter fusion task but no change in the absolute threshold of hearing for pure tones, reported that the "facilitatory effects following prolonged visual deprivation may apply only to sensory tests involving a temporal discrimination." Boynton, Sturr, and Ikeda (1961) further reinforce this distinction between temporal and non-temporal test stimuli by stating that a flicker stimulus has different effects on visual response processes as compared to a steady visual stimulus of the same average luminance. Finally, Sharpless and Jasper (1956) have demonstrated that stimulus characteristics are a factor in influencing the speed of habituation. While habituation to a click stimulus needs only six trials, habituation to a modulated tone changing continuously in pitch requires sixty trials. Possibly habituation to stimuli with spatial characteristics occurs more rapidly and lasts longer than does habituation to stimuli with temporal characteristics.

If, as has been hypothesized, the temporal discriminatory nature of the tactual fusion task is an important factor in accounting for the facilitatory effect on this particular cutaneous measure, one might expect a similar improvement in performance on other types of tasks, also involving temporal resolutions e.g., on auditory flutter fusion which has been shown to increase significantly after a week of visual deprivation (Duda & Zubek, 1965). Such an experiment might indicate, for example, whether the performance on auditory flutter fusion, like tactual fusion, would also increase in a linear fashion with increasing duration of visual deprivation if interpolated tests were administered at 1/2, 1, 2, 3, 5, and 7 days.

Although the temporal versus non-temporal distinction appears to be important in accounting for the present set of results, a second factor which may also be involved is the differential action of various types of sensory stimuli on the reticular activating system. Hernandez-Peon and Hogbarth (1955) have demonstrated that the brain stem reticular formation acts in a heterogeneous, rather than in a unitary fashion, in response to stimuli. In discussing this neural system they report that the type of stimulus employed is a variable to consider when discussing reticular responsiveness. Reticular units, unresponsive to stimuli presented singly, will frequently respond when applied repetitively, a condition characterizing the tactual fusion procedure. Moreover, the individual units will respond with different patterns and latencies of firing, depending on the nature of the sensory stimulation.

According to Lindsley (1961), not only the brain stem but also the thalamic portion of the reticular system responds in a heterogenous rather than in a unitary fashion. For example, two adjacent reticular units may react differently to a microinjection of the same pharmacological agent.

Finally, since a significant improvement in tactual acuity has been observed during visual deprivation, some reference will be made to the possible physiological mechanism or mechanisms which may underly this and the other intersensory facilitatory effects reported in the deprivation literature. Several lines of evidence indicate that these effects are probably mediated by the reticular activating system (RAS). First, the RAS receives afferent impulses from various sensory sources via collaterals of ascending tract fibers and transmits these impulses diffusely to various regions of the cerebral cortex, including the primary sensory areas. Therefore, a mechanism for intersensory effects exists. Second, an improvement in sensory discrimination may occur following electrical stimulation of the RAS. For example, Fuster (1958) showed that stimulation of the brain stem reticular formation of monkeys, while they were engaged in the performance of visual discrimination tasks, increased their speed of reaction and improved the accuracy of their perception. In addition, Lindsley (1961) has reported improved resolving power in the visual cortex to two brief flashes of light as a result of reticular stimulation. The third line of evidence is the work of Chang (1952, 1959). He has demonstrated an enhancement of the cortical response to electrical stimulation of the auditory system (medial geniculate body) of cats during continuous retinal illumination (Chang, 1952). Since excision of the visual cortex only partially reduced this phenomena, Chang (1959) concluded that the RAS was the logical mediator for this intersensory effect.

Recently, Schultz (1965) has incorporated much of the RAS research into a "sensoristatic" theory of the nervous system. According to Schultz, sensoristasis is a condition in which the organism strives to maintain an optimal range of sensory variation. The monitor serving to maintain the sensoristatic balance is the RAS which Lindsley (1961) considers to be a "homeostat" or regulator, adjusting "input-output" relations. One of the predictions which Schultz derives from his model is that "when stimulus variation is restricted, central regulation of threshold sensitivity will function to lower sensory thresholds. Thus, the organism becomes increasingly sensitized to a stimulation in an attempt to restore the balance" (p. 32).

Although Schultz's theoretical model is capable of accounting for the earlier facilitatory effects reported from the Manitoba laboratory (improvement in various measures of cutaneous, auditory, olfactory, and gustatory sensitivity after visual deprivation) which were obtained from a pre-post test procedure, it is too general in its present form to account for the present set of results. These new results, however, can be dealt with by a slight modification of the model if we consider the nature of the sensory tasks being employed. If the task requires a temporal discrimination e.g., tactual fusion, the present model applies. However, if the sensory task is of a largely spatial nature, a facilitatory effect will only occur if the inter-test interval is sufficiently large to prevent the after-effects of one test period from intruding into the next test period.

This modification of Schultz's model is able to account, quite satisfactorily, for both the past and present results on deprivation. Furthermore, it possesses the virtue of being able to generate various hypotheses for future research. For example, one would predict that auditory deprivation alone should produce a significant improvement in performance on various measures of cutaneous, visual, olfactory, and gustatory sensitivity if an exclusively pre-post design was to be employed. If, on the other hand, interpolated tests were used one would expect a significant improvement only in sensory measures requiring a temporal discrimination. Such a line of future investigation would be helpful not only in furthering our understanding of the present perplexing results but also in throwing some new light on the nature of intersensory effects in general.

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APPENDIX A - TEST INSTRUCTIONS

PHONE CALL TO EXPERIMENTAL SUBJECTS TO ARRANGE FOR PARTICIPATION

This is (name of caller) from the Department of Psychology at the University of Manitoba. We are calling about the one week darkness experiment you volunteered to participate in. We would like you to begin your participation on (date and time). At this time you and another student will begin living together for one week under a condition of constant darkness. No restrictions will be placed on talking or moving about the room and a radio will be available at all times. You will receive $125 for your participation. Since we will want to give you several behavioral tests prior to your participation, it is necessary that you come into the laboratory for approximately half an hour on (date and time). Please come to room 308 Isbister.

It is important that you take no medication of any kind e.g., analgesics from now until the end of the experiment.

PHONE CALL TO CONTROL SUBJECTS TO ARRANGE FOR PARTICIPATION

This is (name of caller) calling from the Department of Psychology, at the University of Manitoba. We are calling about the experiment you volunteered to participate in. For this experiment you will be required to come to our laboratory 8 times over an 8 day period. Each session will take 1/2 hour or less. For your help you will receive $35.

We would like you to come on (date and time). At that time you will receive a schedule as to when you are to be at the laboratory.

Please come to room 308 Isbister.

It is important that you take no medication of any kind e.g., analgesics, from now until the end of the experiment.

INSTRUCTIONS READ TO EXPERIMENTAL SUBJECTS ON ARRIVAL FOR PRACTICE SESSION

This is an experiment on the effect of living in constant darkness for one week. There is no danger involved. You will be at liberty to lie down, sit up, and walk around the room. You are also free to talk or listen to the radio during the day and evening. During the course of the week you will periodically receive behavioral tests like those you are about to receive today.

Tomorrow when you report to the laboratory you are to bring a blanket, pillow, tooth brush, tooth paste, and change of clothes. However, it is not necessary to bring a razor as you will not be able to use it. If you smoke, bring enough cigarettes for the entire week as you will be allowed to smoke after each meal and at your coffee break (but not at other times). A well balanced diet is provided but you may wish to order in food, so it is advisable to bring a small amount of money.

It is important that you take no medication of any kind e.g., analgesics, from now until the end of the experiment.

Do you have any questions?

INSTRUCTIONS READ TO CONTROL SUBJECTS ON ARRIVAL FOR PRACTICE SESSION

In this experiment we are interested in determining your skin sensitivity over a period of eight days. Here is your test schedule. It is important that you be here exactly at the time period on the schedule. If you are late, you may be dismissed from the experiment with no payment.

Are there any questions?

INSTRUCTIONS READ TO EXPERIMENTAL SUBJECTS PRIOR TO BEGINNING OF EXPERIMENT

This is an experiment on the effect of living in constant darkness for one week. There is no danger involved. You are at liberty to lie down, sit up and walk around the room. You also are free to talk to each other and listen to the radio. However, the radio will be disconnected late in the evening so that you may get a good nights sleep. During the course of the week you will periodically receive behavioral tests like those you received this morning.

During the experiment you will be asked to follow a schedule. You will be awakened in the morning and receive your meals on schedule. Periodically you will be given behavioral tests. If you wish to visit the washroom you are to signal the experimenter with the buzzer on the wall and he will escort you there. Smoking is only permitted at meal times and coffee time. If you have any problems, contact the experimenter.

Under no circumstances, and at no time, are you to remove your mask during the experiment. If the mask comes loose you are to close your eyes immediately and buzz for the experimenter.

VIOLATION OF ANY OF THESE RULES WILL RESULT IN DISMISSAL FROM THE EXPERIMENT WITH NO PAYMENT.

An experimenter is on duty at all times. However, if no one answers your buzz wait a few minutes and buzz again; he is probably next door.

Are there any questions?

ABSOLUTE PRESSURE SENSITIVITY - INSTRUCTIONS

"This box contains a series of hairs varying in diameter. You will be touched with some of them in order to determine the lightest pressure you can feel. Say "touch" whenever you feel anything on your forearm. Only say "touch" when the pressure is clearly discernable. If there is any doubt as to whether or not you felt pressure, do not say anything."

PAIN SENSITIVITY - INSTRUCTIONS

"I am going to apply a circle of light to your forearm. At first you will feel nothing, then a slight feeling of warmth, and finally a slight burning or sensation of pricking pain. I want you to say "now" at the first indication of pricking pain. Remember, we do not wish to determine how much pain you can endure. Our interest is in knowing when you experience the first indication of pricking pain. Try not to confuse it with the sensation of warmth which will be experienced first."

Pay attention and try your best. You will be given 8 trials, 4 on each arm. Remember, when you feel the first sensation of pain say "now".

TWO-POINT THRESHOLD - INSTRUCTIONS

"This instrument, called an aesthesiometer, will be applied to your forearm - sometimes with two points and sometimes with only one. Tell me whether you feel pressure at one or two points on the skin."

TACTUAL FUSION - INSTRUCTIONS

"The purpose of this test is to determine the resolving power of the skin. Puffs of air will be directed on your forearm in such a way that at first you will perceive them as separate and discrete. The frequency of the 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.

Are there any questions?

Remember, we are interested in determining the resolving power of the skin. Not the ear. To help you in this task we are going to mask the sound of the air by having you listen to a noise through these earphones. I am going to put the earphones on you and turn up the loudness of the sound. Say "now" when you no longer hear the bursts of air."

Remember, this is a very difficult task. So concentrate hard on what you are doing and follow the instructions exactly."

<u>NB:</u> For controls and for VD-practice and pre-trials add: "Keep your eyes open during the test."

APPENDIX B - RAW DATA

EXPERIMENT I

INDIVIDUAL MEAN SCORES OF THE VISUAL DEPRIVATION GROUP:

PAIN SENSITIVITY

Subject	Pre	1/2	1	2	3	5	7
1	11.2	8.1	9.2	8.7	8.8	9.1	8.5
2	9.9	9.9	9.1	12.0	11.0	10.6	13.1
3	16.2	13.2	15.5	15.4	16.1	15.7	11.2
4	10.7	9.3	11.9	14.2	13.8	13.4	12.4
5	11.1	12.6	11.8	12.6	13.6	14.8	16.9
6	12.7	12.9	13.8	14.6	14.7	16.0	16.5
7	13.8	9.7	14.0	11.9	10.1	11.8	13.5
8	7.8	5.1	8.7	6.5	7.8	7.4	7.1
9	12.2	11.0	13.1	13.8	14.3	13.6	13.7
10	12.8	8.7	10.9	11.9	13.6	10.9	11.3
11	9.7	8.5	10.4	11.5	9.9	11.8	10.8
12	10.6	11.0	14.2	15.0	14.2	15.2	14.4
13	8.3	8.7	11.7	10.9	11.8	12.9	10.3
14	7.6	9.1	9.6	8.7	8.1	7.2	7.8
15	8.7	8.4	9.1	9.2	11.2	8.8	8.2
16	14.6	13.9	13.8	11.8	13.1	14.4	15.9

EXPERIMENT II

INDIVIDUAL MEAN SCORES OF THE AMBULATORY CONTROL GROUP:

PAIN SENSITIVITY

Subject	Pre	1/2	1	2	3	5	7
1	13.1	10.6	11.6	11.5	11.9	13.9	16.4
2	4.6	7.0	10.8	10.1	11.4	12.0	13.3
3*	7.7	3.4	3.0	4.9	6.0	5.3	7.2
4*	11.4	10.4	13.7	13.4	14.4	13.5	14.9
5	9.4	9.8	7.9	9.5	10.9	9.6	9.8
6*	11.4	8.1	10.0	12.2	12.1	11.0	11.8
7*	14.5	13.0	15.2	14.1	14.7	14.1	16.9
8	9.2	7.7	10.0	10.7	9.5	14.0	10.5
9*	12.2	10.9	12.1	13.5	10.7	14.3	13.6
10*	12.2	13.6	14.3	14.7	15.3	12.9	13.4
11	7.9	7.6	7.6	9.4	9.0	9.0	9.4
12	11.8	9.9	11.1	13.8	13.1	13.5	14.5
13*	8.4	9.7	10.9	11.2	11.0	12.8	12.3
14*	12.6	10.2	11.2	13.0	12.9	13.7	11.4
15	22.5	22.2	20.7	22.5	21.9	23.3	26.2
16*	11.4	11.1	11.7	11.1	10.9	14.3	11.5
17*	10.8	12.4	11.5	13.4	14.1	13.3	15.7
18*	8.1	10.1	11.9	14.0	11.1	12.3	13.9
19	13.4	12.7	15.4	15.9	17.1	17.5	16.3
20	12.3	12.3	13.5	12.7	12.9	14.6	12.5
21	11.8	6.8	10.6	11.0	13.2	14.2	12.5
22	13.1	12.4	13.1	13.6	13.0	13.1	14.0
23*	9.8	8.8	8.9	7.2	7.4	7.9	6.9
24*	14.0	11.4	13.1	14.4	14.5	15.4	14.7
25	40.1	42.8	35.8	35.2	36.3	31.5	34.5
26	5.6	6.2	5.4	4.8	4.5	6.7	7.5
27*	8.6	8.5	10.6	12.3	11.8	11.9	13.0
28*	9.5	9.7	10.1	10.7	10.4	11.2	12.0
29	12.3	10.0	13.7	12.9	14.0	13.9	13.3
30*	17.5	21.2	19.3	19.1	20.2	26.3	27.9

*Subjects employed for matching purposes are identified by an asterisk.

EXPERIMENT I

INDIVIDUAL MEAN SCORES OF THE VISUAL DEPRIVATION GROUP:

PRESSURE SENSITIVITY

Subject	Pre	1/2	1	2	3	5	7
1	3.56	3.99	3.60	3.79	3.84	3.94	4.05
2	2.80	3.38	2.81	2.98	2.99	2.90	3.08
3	2.91	3.00	2.58	2.87	3.36	2.38	2.67
4	3.43	3.51	3.29	3.41	3.43	3.29	2.99
5	2.68	2.92	2.57	3.05	3.43	3.22	2.81
6	3.09	2.81	3.14	2.91	3.09	2.83	3.38
7	3.08	2.91	3.10	3.36	3.14	3.47	3.70
8	3.79	3.53	4.17	4.02	4.15	4.14	4.10
9	4.07	4.00	4.33	4.14	4.03	4.12	3.90
10	3.76	3.46	3.22	3.93	3.75	3.41	3.81
11	3.92	3.67	3.88	3.98	3.74	3.87	3.41
12	3.98	3.88	4.10	3.98	4.04	3.78	3.81
13	3.52	3.53	3.50	3.53	3.51	3.29	3.37
14	3.13	3.46	3.42	3.32	3.29	3.53	2.62
15	3.93	4.03	3.75	4.28	4.31	4.07	3.98
16	3.36	3.41	3.45	3.62	3.81	3.88	4.08

EXPERIMENT I

INDIVIDUAL MEAN SCORES OF THE AMBULATORY CONTROL GROUP:

PRESSURE SENSITIVITY

Subject	Pre	1/2	1	2	3	5	7
1	4.03	3.87	3.83	3.77	3.81	3.64	3.51
2	3.44	3.15	2.68	3.15	3.23	3.38	3.03
3*	3.94	3.57	3.88	3.99	3.91	4.01	4.00
4*	3.43	2.66	3.23	3.33	3.46	3.05	2.80
5*	3.64	3.54	3.60	3.86	3.46	3.49	3.74
6*	3.52	3.75	3.78	3.88	3.41	3.78	3.75
7*	4.07	3.84	3.92	3.89	3.93	4.01	3.85
8*	3.67	3.81	3.81	4.15	4.21	4.20	4.47
9	2.60	2.97	3.00	3.23	3.30	3.71	3.48
10*	3.18	3.28	2.58	3.26	3.31	3.25	3.23
11	4.20	3.95	3.85	3.85	3.31	3.59	3.57
12*	2.89	2.65	2.65	3.25	3.25	3.20	3.62
13	2.32	2.70	2.58	2.45	2.37	2.75	3.11
14	2.83	2.84	3.63	3.33	3.15	3.90	3.85
15*	3.54	3.88	3.59	3.60	3.83	3.64	3.71
16*	3.15	3.58	3.20	3.68	3.57	3.41	3.91
17	3.62	3.78	3.78	3.70	3.87	3.94	3.88
18*	3.89	3.40	4.04	3.80	3.61	3.85	3.66
19	3.61	3.51	3.64	3.58	3.91	3.75	4.03
20	3.43	3.73	3.54	3.75	3.75	3.68	3.58
21*	3.28	4.01	3.91	4.17	3.64	4.03	2.89
22*	2.75	2.69	3.56	3.72	2.69	3.43	2.18
23*	2.77	3.36	3.35	3.25	3.06	3.32	3.59
24*	3.31	2.97	3.40	3.24	3.61	3.40	3.40
25	4.01	4.28	3.58	3.52	3.63	3.15	3.45
26	3.58	3.79	3.40	3.35	3.53	3.69	3.63
27*	4.00	4.42	3.82	3.41	4.30	3.64	3.83
28	3.51	3.78	3.51	2.67	3.29	3.34	3.34
29	3.54	3.79	3.88	3.69	3.87	3.98	3.79
30	3.60	2.38	3.92	3.93	3.50	3.64	3.56

*Subjects employed for matching purposes are identified by an asterisk.

EXPERIMENT II

INDIVIDUAL MEAN SCORES OF THE VISUAL DEPRIVATION GROUP:

TWO-POINT THRESHOLD

Subject	Pre	1/2	1	2	3	5	7
1	44.9	43.6	42.4	37.3	33.3	40.8	43.1
2	60.1	64.1	52.5	44.5	39.6	38.1	37.9
3	43.8	45.9	50.4	54.6	61.6	62.4	61.0
4	54.1	48.7	62.0	57.6	54.4	68.6	59.0
5	49.3	45.8	48.4	42.4	36.0	49.9	47.1
6	53.6	52.4	51.4	59.3	53.9	56.8	53.3
7	52.1	48.8	43.9	52.8	53.3	50.5	49.6
8	56.4	48.4	52.4	46.8	50.8	44.8	37.5
9	39.1	36.9	31.8	39.4	35.8	32.6	34.3
10	50.8	48.5	52.8	47.8	49.1	50.1	45.8
11	41.6	52.3	54.4	61.3	55.3	61.3	62.0
12	46.8	51.1	42.5	40.9	38.5	35.3	35.4
13	22.5	35.6	31.8	29.8	31.5	36.0	35.5
14	38.0	36.5	34.3	29.3	33.4	34.3	37.6
15	45.1	43.9	46.5	39.6	45.9	46.0	43.5
16	65.3	58.1	56.8	58.1	54.6	60.5	49.4

EXPERIMENT II

INDIVIDUAL MEAN SCORES OF THE AMBULATORY CONTROL GROUP:

TWO-POINT THRESHOLD

Subject	Pre	1/2	1	2	3	5	7
1	36.6	37.8	44.8	48.9	55.6	50.3	43.1
2*	42.5	44.4	42.5	35.0	38.3	29.4	37.1
3*	62.6	73.8	86.0	80.6	85.0	97.8	94.5
4*	44.8	39.8	51.3	41.6	57.4	47.0	45.8
5*	51.9	56.5	58.1	54.3	47.8	47.0	47.5
6*	50.4	51.6	53.1	50.5	41.3	47.4	49.3
7	35.5	30.4	25.6	23.5	32.0	29.3	28.3
8	50.1	55.6	58.6	54.1	55.3	57.9	60.4
9	32.5	37.8	46.1	44.9	47.4	42.0	44.0
10	57.6	51.3	53.6	56.8	61.0	58.1	63.1
11	Subject unable to discriminate stimuli						
12	18.8	22.7	20.0	26.1	25.1	19.0	20.4
13	27.5	20.5	18.9	29.0	24.1	23.3	29.5
14*	60.0	56.4	64.9	57.3	41.3	42.5	53.0
15	31.6	37.4	31.1	33.1	41.8	33.0	37.6
16*	42.1	30.5	27.5	26.8	29.0	36.9	30.6
17	30.3	27.6	25.4	24.4	17.9	23.4	27.5
18	60.5	51.8	50.1	49.6	44.8	44.8	48.8
19*	38.9	30.5	26.5	35.3	33.6	39.3	34.3
20*	45.6	44.1	42.2	44.3	47.0	31.9	43.3
21*	49.9	50.3	63.8	67.3	65.6	62.6	82.0
22	37.8	41.1	31.8	37.0	34.9	33.0	36.8
23	Subject unable to discriminate stimuli						
24*	48.1	47.9	42.0	44.6	53.6	53.9	48.1
25*	58.6	48.3	47.5	53.5	55.1	59.5	59.5
26*	26.4	29.1	29.0	36.6	38.9	37.0	36.0
27	59.3	62.0	58.8	55.4	55.4	53.9	48.3
28*	48.5	49.4	51.0	42.5	52.3	49.4	48.2
29*	56.5	42.9	41.6	34.4	33.3	29.3	30.1
30*	51.8	52.3	54.8	58.9	57.9	54.9	60.4

*Subjects employed for matching purposes are identified by an asterisk.

EXPERIMENT II

INDIVIDUAL MEAN SCORES OF THE VISUAL DEPRIVATION GROUP:

TACTUAL FUSION

Subject	Pre	1/2	1	2	3	5	7
1	11.2	12.4	13.1	15.8	17.2	17.9	14.0
2	8.9	7.3	9.2	8.7	11.7	12.1	12.8
3	8.3	8.9	9.0	11.0	11.2	11.6	12.4
4	7.9	8.2	10.5	9.9	10.3	10.5	13.5
5	10.7	10.8	10.1	11.4	11.5	12.2	13.1
6	10.3	12.9	12.9	11.1	15.7	14.5	12.7
7	11.4	13.2	15.0	12.1	11.1	14.6	14.3
8	10.6	14.3	13.9	15.6	16.4	18.6	21.4
9	9.1	12.6	9.7	13.4	15.4	17.7	18.1
10	10.1	15.6	12.4	13.5	15.3	21.9	20.4
11	10.2	10.8	11.2	10.1	12.8	13.4	12.8
12	20.9	14.9	15.1	15.7	18.3	22.2	17.6
13	14.4	19.3	18.3	18.9	19.6	20.0	25.7
14	9.6	10.3	10.3	10.4	11.0	9.6	12.1
15	14.9	13.9	15.5	18.0	16.2	22.9	20.4
16	7.7	10.0	7.6	9.9	9.9	9.2	11.1

EXPERIMENT II

INDIVIDUAL MEAN SCORES OF THE AMBULATORY CONTROL GROUP:

TACTUAL FUSION

Subject	Pre	1/2	1	2	3	5	7
1*	10.6	11.1	12.0	11.8	9.6	10.6	9.5
2*	8.4	7.9	9.1	8.4	8.0	8.4	7.5
3	7.1	6.6	7.4	7.3	6.8	8.3	8.1
4*	14.8	13.4	9.3	10.6	10.7	4.9	6.1
5*	9.8	9.6	6.4	8.6	8.1	8.3	9.2
6*	8.5	7.4	7.8	6.6	6.6	6.4	5.5
7*	9.0	7.9	9.1	9.5	8.3	9.6	12.1
8	28.7	23.0	27.1	28.4	27.1	35.6	39.3
9	12.6	13.8	15.9	15.4	13.2	14.2	14.0
10	13.1	9.6	9.4	8.2	10.8	9.3	11.0
11*	21.2	18.2	20.3	19.7	16.7	14.8	18.8
12	11.3	12.0	10.6	11.1	11.8	13.8	12.1
13	17.8	13.7	11.1	14.8	13.9	13.1	13.3
14*	10.6	10.9	11.5	11.9	11.8	9.3	12.4
15*	10.3	9.9	10.3	11.9	11.8	10.2	10.3
16*	7.9	9.3	9.5	10.9	9.7	9.3	9.9
17*	11.3	11.2	12.6	12.4	12.9	12.9	12.6
18	13.7	14.5	13.9	14.5	14.0	14.9	12.2
19	8.5	10.4	10.5	10.0	11.0	10.8	13.6
20	11.5	14.0	14.0	12.3	12.1	10.1	11.6
21*	10.9	12.6	10.7	11.9	13.7	10.3	9.3
22*	14.4	14.6	14.7	12.1	13.5	12.4	14.5
23*	9.1	9.5	10.4	10.7	9.0	9.8	9.0
24	13.8	13.6	13.4	11.9	12.8	13.8	11.3
25	Subject was unable to discriminate stimuli						
26*	10.1	8.9	9.0	8.0	9.4	8.4	7.8
27	13.7	15.1	12.9	12.9	12.3	13.2	13.9
28	Subject was unable to discriminate stimuli						
29	12.3	11.1	11.1	10.3	10.1	10.9	8.8
30*	11.3	10.9	12.2	12.9	11.5	9.0	11.2

*Subjects employed for matching purposes are identified by an asterisk.