RESPONSES TO REPEATED TACTILE STIMULATION IN THE PLANARIAN: DUGESIA TIGRINA

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ABSTRACT

RESPONSES TO REPEATED TACTILE STIMULATION IN THE PLANARIAN: *DUGESIA TIGRINA*

by John M. VanDeventer

Habituation, which may be operationally defined as the repeated application of an unconditioned stimulus, has, in the past, received little attention. In view of its importance in connection with a number of other behavior processes, there exists an urgent necessity to subject habituation to systematic scrutiny. The present paper represents an effort to do this. Its aims are (1) to assess the effects of this process for the planarian, *Dugesia tigrina*, (2) to determine whether this species lends itself to further study of the process and (3) to identify some of the variables which may indicate the nature of the process.

Definitions of habituation were examined; it was found that the majority of investigators define habituation in terms of response characteristics rather than in terms of procedure. For purposes of the present study, habituation was described as the repeated application of an unconditioned stimulus, regardless of the type of response produced. It was then visualized that changes other than a response decrement might occur.

A pilot study and four additional studies suggested by the pilot study are described. In the pilot study,

the effects of repeated presentation of light, electric current and tactile stimulation were examined. It was decided that the use of tactile stimulation might lead to the most fruitful results. In addition, the results of the pilot study indicated that changes in response topography may accompany the decline in responsiveness, an observation which earlier definitions of habituation would have made difficult.

In Study I the effects of repeated posterior tactile stimulation were studied. A decline in responsiveness (tail contractions) was observed, but the change in response topography suggested by the pilot study did not occur. Dishabituation with light indicated that the effects observed were not due to "fatigue" nor to receptor adaptation. Dishabituation trials were significantly correlated with habituation trials establishing some degree of reliability of the procedure. It was decided that the change in response topography observed in the pilot study may have been due to difficulty in applying the stimulus to the same area on each trial (this was corrected by a stimulus modification in Study I and subsequent studies). In Study II anterior and medial application of the tactile stimulus was compared to the posterior application of Study I. It was found that (1) anterior stimulation produced only tail contractions and turns and that posterior stimulation produced only tail contractions whereas medial

stimulation produced both, (2) in the case of medial application tail contractions declined while head responses appeared to first increase and then decrease and (3) with anterior application, turns away declined while turns toward the stimulus increased and then declined. These results indicate that a change in response topography takes place with medial and anterior stimulation.

Study III was designed to observe the retention of the effects of medial tactile stimulation. These effects were retained for more than 24 hours but less than 96 hours. A low correlation between training and retraining trials suggest that the data was unreliable. Possible sources of unreliability are discussed. It was concluded, among other things, that posterior stimulation would be a better procedure in the study of the retention of the effects of habituation than medial stimulation.

Finally, in Study IV, the effects of concurrent stimulation upon the course of habituation were studied. Habituation to a posterior tactile stimulus under conditions of low illumination was compared to habituation under conditions of a high level of illumination. The latter required significantly fewer trials to criterion (three responses in ten consecutive trials) than was the case during the former condition.

It was concluded that both a decline in responsiveness as well as a change in response topography under some conditions as a result of repeated tactile stimulation occurs in the planarian, *D. tigrina*; and that the species may be profitably studied in this respect providing that additional studies be undertaken to identify possible sources of "noise" in the procedure.

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INTRODUCTION

The field of study generally subsumed under the term "Habituation" has rarely occasioned any systematic study. This seems singularly strange insofar as some type of "acclimitization" procedure - which, among other phenomena, includes habituation - precedes the laboratory investigation of other processes in nearly all vertebrate phyla. This kind of procedure seems to be less evident in invertebrate studies but this lack may reflect more the relative paucity of investigations of these organisms rather than the inappropriateness of such a procedure.

Those studies of infrahuman organisms which have been conducted in the past have been largely defined by interests and problems stimulated by practical human Psychology rather than a general Psychology which ignores phylogenetic boundaries. It is probably for this reason that habituation has been passed over lightly. While it may constitute a major mode of response modification in the invertebrates, its role in human behavior has been obscured for multiple reasons. First, human behavioral complexity and a variety of people creates a situation where habituation is less readily observable and somewhat less interesting. Second, the majority of psychological investigations have been undertaken with adult subjects, that is to say, with subjects that may be to a considerable extent already habituated to a variety of stimuli. Third, the theorists of the thirties deemphasized instinct theory and therefore the analysis of the unconditioned response was deemphasized.

In the last few decades, however, the importance of habituation as a factor in human behavior has become clearer. Its relationship to learning has been emphasized (Maltzman and Raskin, 1965). A greater concern with problem areas other than learning where habituation is more readily seen has also lead to a greater interest in response decrement as, for example, the study of vigilance (Bakan, Belton and Toth, 1963) or as an explanation of the inability of the feebleminded to learn (Denny, 1964).

Zoologists have possessed a greater interest in the phenomenon of habituation than Psychologists have and, as a result of this greater interest, nearly all of the earlier research studies of the process have been under their leadership. Nevertheless, their inquisitiveness has been directed more to the demonstration of its existence in some one species rather than to the systematic inquiry after its properties and nature.

The present study was conceived in the spirit of establishing a rude beginning of a systematic investigation.

Definition of the Area of Investigation. The relative sparsity of systematic research dealing with habituation demands that the definition of the phenomenon be subjected to careful scrutiny. A recent concern with operational definitions in the experimental literature begs clarification of one point at the onset of this discussion, viz.,whereas most writers appear to set up rigid specifications of a phenomenon (presumably following the lead of the natural scientists), such definitions are not in fact altogether warranted in the absence of precise theoretical formulations relating the variables in the domain of experience concerned (Frank, 1957). Furthermore, even granted a formal theory, the general notion of an event need not be as rigidly specified as would be necessary in the case of a concrete problem deriving from the theory (Nagel, 1957). Thus, the most desirable course to follow would be to admit of as broad and neutral a definition as is possible and reserve the more precise formulations for the level of a particular experiment. In cases where we know little about a phenomenon even the latter suggestion should be relaxed to some degree.

It will be argued that the majority of previous workers have become more and more specific in their definitions of habituation and as a result of this rigidity may have directed attention away from investigational strategies which might lead to the determination of the nature of the phenomenon. Harris (1943) probably represents the earliest attempt to review the scattered studies of habituation. He defines the process as follows (evidently establishing the precedent for future workers):

> (By habituation) . . . what is referred to are all those instances of decrement in magnitude of unlearned responses (1) which occur centrally in the intact organism, (2) which are due to repetitive stimulation activation, and which may . . . be distinguished from the types of response decrement occurring as a result of, for example, receptor adaptation, loss of the effector's ability to respond, or any of the various types of inhibition. (p. 385)

Later, Thorpe (1961), apparently in an effort to revive interest in habituation, offers a similar definition:

> Used in its widest sense, habituation is a simple learning not to respond to stimuli which tend to be without significance in the life of the animal; and stimuli without significance obviously cannot release consumatory acts. Habituation thus implies a tendency merely to drop out responses, not to incorporate new ones or complicate those already present. In this respect it is certainly the simplest kind of learning. ... (p. 21)

Thorpe's otherwise excellent review (1961), in search of precise formulation of habituation, commits a major error: explanation of a poorly understood process in terms of another poorly understood (<u>albeit</u>, not quite as) process, <u>viz</u>., learning. Were there any relationship between the two, habituation is most analogous to extinction and the explanation of extinction as learning not to respond is certainly not above question (Kimble, 1961). It would be more prudent to maintain an independence from learning in the study of habituation until the evidence shows, more vividly, the relationship (this evidence, indeed, would probably be in the form of the identification of the physiological substrates of the two processes).

A more recent paper was even more specific: Thompson and Spencer (1966) suggest that habituation acts in the following manner:

> Given that a particular stimulus elicits a response, repeated applications of the stimulus result in decreased responses (habituation). The decrease is usually a negative exponential function of the number of stimulus presentations. (p. 18)

In addition, they maintain that the phenomenon has the following properties: (1) spontaneous recovery, (2) more rapid habituation after a series of habituation trials and spontaneous recoveries, (3) the more rapid the frequency the more rapid the habituation, (4) the weaker the stimulus, the more rapid the habituation, (5) strong stimuli may yield no habituation, (6) stimulus generalization occurs, (7) dishabituation occurs with another strong stimulus, (8) and finally, the dishabituating stimuli tend to habituate as well. Thompson and Spencer (1966) further assert that the extent to which any observed response decrement fits these properties will determine whether there has beenj habituation. It seems grossly premature to specify the properties of a process which has not yet been adequately surveyed. For example, the almost total lack of any systematic study of invertebrate species leaves us without a frame of reference against which to view the more extensive vertebrate studies. This neglect of invertebrates leaves Psychology in a position which would be analogous to the investigation of hormone chemistry in ignorance of inorganic chemistry. When psychology looks to the natural sciences it usually cannot see the strategy because of the instruments. Habituation in vertebrate species may (1) be an entirely different process than the analogous type of behavior in invertebrates, (2) or, as we go "up" the phylogenetic scale, a particular simple process may more reflect the influence of other behavioral processes than it does its own individual properties, (3) or finally, what is called habituation in vertebrates may be a complex of processes which do not occur in that combination in "lower" species. Only additional research, unfettered by such heavy definitional chains can delineate the nature of the process. Of paramount importance is a thorough study of invertebrates.

All of the above cited reviewers (as well as persons conducting specific investigations) tend to identify the site of effect when the effects of repeated stimulation are being considered. Generally speaking, most investigators make some attempt to distinguish whether the effects observed are taking place centrally or peripherally and, if the latter, whether in the receptor or the effector side of the "reflex arc." The procedure usually applied is termed "dishabituation." This procedure may take several courses; the site of stimulation may be changed and if, as a result, the response rate increases, then "fatigue"may be ruled out--but not receptor adaptation; but receptor adaptation and fatigue may be ruled out by applying a second stimulus concurrent with the habituation stimulus after it has been established that the second stimulus does not elicit the response in question; receptor adaptation--but not fatigue--may be ruled out if a different response can still be elicited with the same stimulus. Still another procedure may be used: if the retention of the effect is relatively long, then both receptor adaptation and fatigue, the effects of which are of brief duration, may be ruled out. If the effect is not transient, it may be argued that is central in locus. This is, at best, questionable since unwarranted assumptions are being made about central events. Failure to dishabituate or failure of retention may not necessarily vitiate the interpretation of habituation.

In a discipline noted for its disagreements, the definers of habituation stand out with their essential agreement. With the manner in which they have agreed to define habituation (as a form of learning and with the exact specification of the response) they have led us away from the major research problem associated with habituation. By specifying the response side of the process, any theoretical formulations would undoubtedly explain why habituation occurs but not why it does not occur. The same problem seems to have arisen in the area of learning; interest in the behavior change has caused failures to change to become largely ignored. Thus current learning theories, while they enable us to explain why learning will occur, do not enable us to easily *predict* when it will not occur (that is due to impossibility rather than poor procedure) even though the usual learning paradigm is applied. It is evident that this state of affairs has been brought about by a study of the learning process as defined by responses rather than a study of the learning paradigm. Only a theory which explains why something did not occur is adequate.

The purpose of the present discussion is to draw attention to the possibility that a response decrement is one of several possible response outcomes which may result when the habituation paradigm is applied. This suggestion has recently been tendered in a review of Annelid learning by Ratner (1967). If the term "habituation" refers to a type of response outcome, *viz*., a decrement, then the past reviewers have shirked their responsibility in failing to study the broader problem, *i.e.*, the effects of repeated unconditioned stimulus presentation.

Viewing the problem in this fashion now makes possible some preliminary comments about habituation. First, at least methodologically, habituation is not the same thing as learning when the latter is viewed as repeated presentation of two stimuli rather than just one. Second, it is methodologically different from extinction in that while both result from the repeated presentation of a single stimulus, the complete definition of extinction requires the inclusion of the previous learning paradigm. Indeed, we might suspect that insofar as learning is defined by research with "higher" vertebrates, the term may well include a variety of processes (one of which may be habituation). To state now that habituation is a simple form of learning seems at best confusing and nothing is lost by eliminating any mention of learning from a definition of habituation.

The present study, then, is conceived as a study of the effects of repeated presentation of an unconditioned stimulus, whatever the outcome of such a paradigm. Within this framework, it is now possible to ask what different outcomes may be expected when an organism is repeatedly exposed to a stimulus. Such a course could produce no change, a response increment, a response decrement, a change in response topography, or some combination of these outcomes. On the basis of actual research have any of these outcomes been observed? Rushforth (1965) reports that while a response decrement was found to occur with repeated mechanical stimulation in *Hydra pirardi*, no change was observed with respect to light in spite of 200 presentations of the latter. Response increments commonly occur and are generally subsumed under the term "sensitization." Here complex changes have been observed to occur; for example, Gardner (1966) describes the habituation of *Lumbricus terrestris* to vibration as involving two types of responses, one of which drops out before the other. Wendt (1951) has reported that during the habituation of nystagmus not only does the movement decline but may go in the direction opposite of the original (secondary nystagmus). It is a general known fact that for vertebrates, the response to a strange stimulus may first involve an immobility response, then a withdrawal response which decrements to a state of "alertness" which is replaced by incrementing approach responses which may in turn tend to decrement.

Habituation Research with Planaria. In the course of the study of habituation, planarian species seem to have been virtually ignored. Harris in his review (1943), cites only one study, Pearl (1903). The latter investigator found a response decrement to mechanical stimulation applied to the anterior end. Conditions under which the study was made are not described. Harris, however, seems to have missed two other studies: Walter (1908) reported a response decrement to rotation of the subjects' bowl as well as a decline in responsiveness to the crossing of a light-dark boundary; Dilk (1937) reports a response decrement for _Dugesis gonocephala_ when vibration was presented for one minute or longer with inter-trial intervals of not more than 10-15 seconds. These three poorly described studies appear to be the only ones, barring brief asides in the studies of other processes, _i.e._, Thompson and McConnell (1955) in their study of classical conditioning in the planarian _D_. _dorotocephala_ note that their light control group showed a slight decline in responsiveness to light, until a report by Best and Rubenstein (1962) that planaria delay feeding in an environment with which they are not familiar. This study, however, suffers from the failure to include a handling control group and to include data on the size of the food which in large concentrations may act as an aversive stimulus. This is particularly important in view of the fact that the species used (_Cura foremanii_) by Best and Rubenstein (1962) is very sensitive to contamination (VanDeventer, 1963). Best's and Rubenstein's paper was followed by a report by Westerman (1963). In this study a response decrement to light was retained over several days. This study is difficult to place in proper perspective with other of habituation insofar as "practice" was given throughout the retention interval, i.e., the method of distributive practice, commonly associated with learning, was used.

In summary, habituation in planarian species is certainly indicated but has not been clearly established. Variables which affect the habituation of responses have not been reported. The restrictive definition of habituation as a response decrement has guided these previous studies.

Planaria as an Object of Study. Planaria have been selected for study in the present investigation for a variety of reasons. First, my previous research has dealt largely with this particular group (VanDeventer, 1960; VanDeventer, 1963); VanDeventer and Ratner, 1964; Ratner and VanDeventer, 1965). Second, it is my bias that there exists an urgent necessity to study and understand the behavior of the "lower" invertebrates. Third, planaria have become increasingly popular as objects of investigation in Psychology. This popularity has centered primarily around learning and thus there is a necessity for studies of less glamorous topics in order to place the learning research in proper perspective. Other, more mundane reasons such as the ready availability of subjects and materials for their care, have, of course, in the past, played some role in the choice of this animal for research.

To recapitulate, the aim of the present study is severalfold: (1) to conduct a study of habituation free from the strictures of the earlier investigations, (2) to determine the effects of repeated stimulation on planaria, (3) to determine whether or not such effects may be easily studied in this particular group of animals, (4) and finally to consider a few variables which might affect the nature and direction of the effects. This investigation, then, is essentially exploratory and descriptive in nature.

RESULTS OF THE PILOT STUDIES

In consideration of the lack of research dealing with the effects of reported stimulation on planaria several pilot studies were conducted in order to determine the most appropriate beginning to the undertaking of the present study. Three primary objectives might be realized by such preliminary studies: (1) which particular stimulus would be the most appropriate to study; (2) identification of possible response changes other than a decrement in responding; (3) and determination of difficulties which might arise with regard to questions of technique, measurement, *etc*.

Planaria are sensitive to a wide variety of energy form such as light (Parker and Burnett, 1901), temperature (Mast, 1903), gravitational forces (Olmsted, 1917), chemical gradients (Wulzen, 1916), electric current (Shafer and Corman, 1963), tactile stimulation (Walter, 1907) and water current (Beauchamp, 1937). Temperature changes, chemical change and changes in water current were ruled out at the onset due to obvious difficulties inherent in controlling these forms of stimulation in studies of brief, intermittant stimulus presentation. Whereas gravitational changes might be produced readily and rapidly, such changes would be easily confounded with changes in water current and alterations of chemical gradients; thus this form of stimulation was also ruled out. It was decided to consider the relative advantages of light, electric current, and tactile stimulation.

Study One: Light. Brief pulses of light (one second) with a short inter-trial interval (three seconds) were presented to two groups of *Dugesia tigrina*. One group was light adapted, the other, dark adapted. A third group was observed for the random response frequency. As Halas, James, and Stone (1961) have previously noted, there were two types of responses to light: anterior turns and contractions. The former predominated whereas the latter rarely occurred. Inspection of Appendix Figure 1:1 for the light adapted group reveals a distinct response decrement with regard to turns as a function of trials. The same trend appears to occur with the contractions but the incidence seems to be too low to be subjected to analysis. Inspection of Appendix Figure 1:2 for the dark-adapted group reveals that dark adapted subjects do not habituate appreciably to light over the same interval used with group 1. These subjects also show no contraction responses in contrast to the light adapted group.

Study Two: Electric Current. One group of *D. trigina* was treated in the same way as in Study One except that electric current was used rather than light. As in the case of a previous study (Shafer and Corman, 1963) two types of responses to electric current were observed: anterior turns and longitudinal contractions (usually anterior). Whereas Shafer and Corman interpret their study in such a way as to suggest that the type of response is a function of head orientation with regard to the polarity of the electrodes, such an explanation seems untenable here insofar as 60 cycle alternating current was used rather than direct current as was the case in the Shafer and Corman investigation (1963). Appendix Figure 1:3 shows slight habituation of the contractions and no apparent habituation of the turns. It is of some interest to note that the turn frequency shows a possible increment after repeated stimulation.

Study Three: Tactile Stimulation. One group of *D. tigrina* was touched briefly on the posterior and with a human hair; the inter-trial interval was five seconds. With this group a criterion of habituation was used (only three responses out of ten consecutive trials) and when the criterion had been reached, dishabituation trials were given. These consisted of turning on an overhead light and immediately following this with tactile stimulation. The responses to tactile stimulation were (in order of decreasing frequency) posterior contractions, single anterior turns, anterior contractions, head waving, momentary cessation of locomotion. The latter two responses occurred very rarely. Each type of response occasionally would occur in combination with any of the others. Appendix Figure

1:4 depicts posterior responses (contractions) and anterior responses (Largely turns and contractions but head waving and stopping are also included) as a function of trials as well as the results of the dishabituation trials. Whereas a decrement in the posterior responses is definitely indicated, the anterior responses suggest an interesting course, *viz.*, an increment in response which is followed by a decrement. The dishabituation trials rule out both "fatigue" and sensory adaptation (as only posterior contractions are shown and Study One found no such responses to light, therefore, those contractions must be to the tactile stimulation). The subjects of this study were dark-adapted and were tested in the dark. An additional two subjects were tactilly stimulated in the presence of continuous light from a 100 watt bulb suspended 8 inches above the test chamber. These subjects appeared to habituate to the tactile stimulus in remarkably few trials.

Discussion of the Pilot Study Results. In general, the results of the pilot study were encouraging. The results seemed to be the most primising in the case of tactile stimulation. This seemed definitely to be an exception to the usual definition of habituation. Dishabituation to tactile stimulation produced a majority of posterior contractions when light was used as a dishabituating stimulus. Neither light nor shock produced any tail contractions whereas tactile stimu-

lation elicited a majority of posterior contractions as well as a number of anterior turns. While fatigue could be ruled out with any of the above stimuli with a dishabituation procedure, sensory adaptation could not be so easily excluded if either light or shock were used, insofar as anterior turns could be attributed to the dishabituation stimulus whether it were light, electric current or a tactile stimulus. On the other hand, if tactile stimulation were used to habituate, then either light or shock could be used in the dishabituation procedure since neither of these appeared to elicit tail contractions. It was thus decided to continue the study with tactile stimulation even though this form of stimulation is more difficult to control than either electric current or light.

The pilot studies suggested the following investigations: A more carefully controlled study of the course of responses to repeated tactile stimulation in _D. tigrina_, the effects of background stimulation upon the phenomenon in question and the retention of the effects of repeated stimulation. The use of the hair created undue problems of control so that the tactile stimulus was altered for the ensuing investigations.

EXPERIMENT ONE: THE EFFECTS OF REPEATED TACTILE STIMULATION; POSTERIOR APPLICATION

METHOD

Subjects. 20 D. tigrina were arbitrarily selected and divided into two groups. The colony of planaria had been collected from the Fox River beneath the spillway of the dam across the river at Burlington, Wisconsin. They were maintained in boiled tap water--approximately 50 per quart--which was changed after each feeding of raw beef liver. They were fed once a week and were kept in total darkness. Subjects were tested 3-5 days after feeding and members of one group were tested alternately with members of the other group. The Ss were 7-10 mm. long. No testing was attempted until the colony had been in the laboratory for at least a month. The laboratory temperature was 70° F.

Apparatus and procedure. One S at a time was transferred by means of a medicine dropper pipette (with an enlarged hole) from its home container to the test chamber which was a round milk glass cereal bowl and was allowed to swim for one minute prior to testing. Testing was accomplished in a dark room with a 7½ watt red darkroom buib suspended 10 inches above the test chamber. The test stimulus was modified from the one used in the pilot study. An enameled copper wire was affixed to a match stick with paraffin wax. The tip of the wire was then heated in a flame until a ball was formed at the end of the wire. Measurements of the ball and wire diameters were taken with the aid of a microscope micrometer eyepiece. The diameter of the ball was approximately 0.4 mm. and the wire diameter was 0.1 mm. The ball on the tip permitted contact without fear of puncture and enabled E to more easily apply the test stimulus to the same area and, in addition, produced approximately the same amount of contact from trial to trial. For the experimental group (I) a trial consisted of momentarily touching the posterior tip of S with the test stimulus. The ITI was 4 seconds. Responses which were expected to occur were posterior contractions, anterior turns, anterior contractions, head waving and momentary cessation of locomotion. All responses which occurred one second after the onset of stimulation were recorded. Testing of an S was discontinued when S failed to respond 7 out of 10 consecutive trials. When S had met this criterion, dishabituation was given. This consisted of turning on a 100 watt bulb for one second. The bulb was suspended 8 inches above the test chamber. Immediately following the onset of the light, S was touched on the posterior. The same ITI and same procedure for recording responses during habituation was used during dishabituation trials. Ten dishabituation trials were administered. For the control group (II), a random response group, the same procedure was followed except that the test stimulus was not applied and S's behavior was observed every 4 seconds for a period of one second during which time all responses were recorded. All Ss in group II received 70 trials and no dishabituation test was administered.

RESULTS

The results of this study, depicted in Figure 1, indicate that a response decrement occurred as a result of repeated stimulation with respect to posterior contractions. Comparison of the anterior responses of group I with those of group II (the random response group) indicate that anterior responses to tactile stimulation do not appear to differ significantly for the two groups in contrast to the results which had been obtained in the pilot study.

In the case of posterior contractions, on the other hand, a large number of responses were elicited. Group II (random response group) exhibited no posterior contractions. An analysis of variance (Appendix Table II:1) revealed a significant effect ($F=5.85$, $p< .01$) of trials on posterior contractions. Means, standard deviations and differences between means are provided in Table 1. The latter were analyzed with Duncan's range test,the results of which are also indicated in Table 1. Toward the end of the curve in Figure 1, the function flattens out slightly and then drops; this is probably an artifact of the loss of over half the subjects after trial block V. The mean dishabituation score does not differ significantly from the first two trial blocks

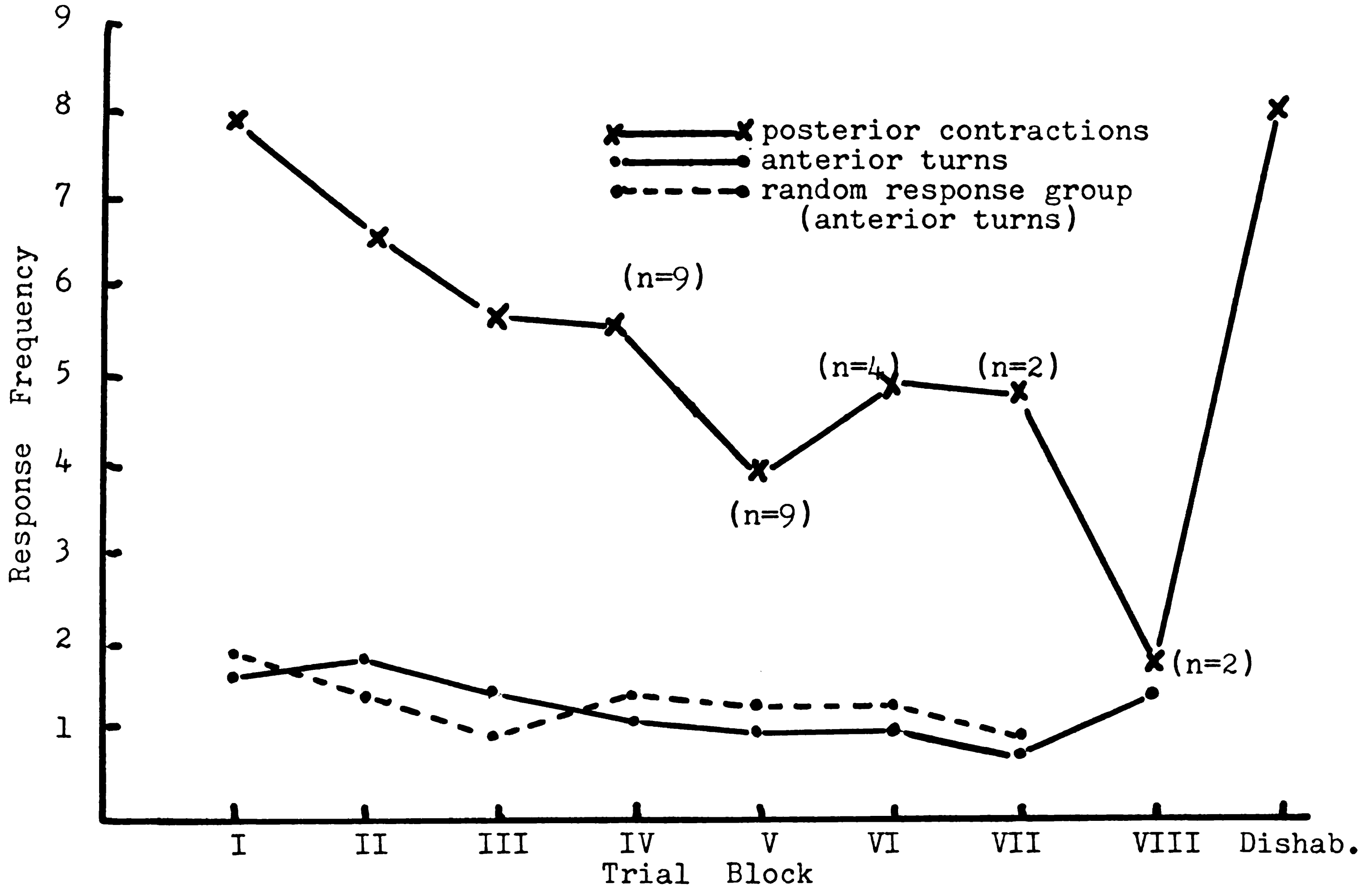

Figure 1.--Response frequency asva function of blocks of ten trials for the posterior stimulation and random response groups of Experiment 1. Figures in parentheses indicate the number of Ss remaining in the sample, i.e., the number not meeting criterion. When not indicated, n is 10.

Table 1. Means, standard deviations, and differences between means for posterior contractions to the stimulus in Experiment 1. for each block of trials.

Trial Block	I	II	III	IV	V	VI	Dishab.
Mean	8.0	6.8	5.9	5.9	4.0	5.0	8.3
S. D.	1.73	1.89	2.11	1.23	1.58	1.73	1.90
N	10	10	10	9	9	4	10

Trial Block							
I	8.0						
II	6.8	1.8					
III	5.9	2.1*	.9				
IV	5.9	2.1*	.9	0.0			
V	4.0	4.0*	2.8*	1.9	1.9		
VI	5.0	3.0*	1.8	.9	.9	1.0	
Dishab.	8.3	0.3	1.5	2.4*	2.4*	4.3*	3.3

*$p < .05$

Table 2. Means and standard deviations of frequency of anterior responses to the stimulus in Experiment 1 for each block of trials.

Trial Block	I	II	III	IV	V	VI
Mean	1.6	1.7	1.6	1.2	1.0	1.0
S. D.	1.11	.84	1.28	1.29	1.05	.71
N	10	10	10	9	9	4

Table 3. Means and standard deviations of frequency of anterior responses made by the random group in Experiment 1 for each block of trials.

Trial Block	I	II	III	IV	V	VI	VII
Mean	1.7	1.4	0.8	1.0	0.9	1.3	0.9
S. D.	1.00	1.20	.60	1.00	0.83	1.11	1.22
N	10	10	10	10	10	10	10

but does differ significantly from the remaining trial blocks. While blocks after block VI are shown in the figure, they are not included in the analysis due to the small N involved. The mean trials to criterion for the group was 44.9 trials.

DISCUSSION

The results of Experiment One clearly indicate that repeated posterior stimulation results in a decrement of posterior contractions with no apparent changes in response topography. This is contrary to the expectations generated by the pilot study in which it appeared that there were a significant number of anterior turns the habituation of which took a different form than the habituation of the posterior contractions. The dishabituation procedure clearly restored the frequency of posterior contractions to its original level and thus ruling out fatigue. That these posterior contractions were not responses to the dishabituation stimulus (light) is indicated by the results of the pilot study where no such responses were elicited by light; adaptation of tactile receptors is thus ruled out as an explanation of the decrement observed. The failure to replicate the results of the pilot study will be discussed in the next experiment which was conceived in part as a result of this failure.

The validity of the interpretation that dishabituation restored the responsiveness to normal was checked by doing a product moment correlation between the first block of habituation trials and the 10 dishabituation trials. The correlation obtained was $r=.75$; a t-test performed on this correlation indicated that it was significantly different from zero ($t=3.21$; d.f.$=8$; $p < .01$).

EXPERIMENT TWO: THE EFFECTS OF REPEATED STIMULATION ANTERIOR AND MEDIAL APPLICATION

At the time that the pilot study was completed, one explanation for the change in response topography due to repeated stimulation which was considered, was that the posterior contractions represented withdrawal responses whereas the anterior responses might be interpreted as approach responses. Some of the anterior turns which the subjects made were nearly 180°; it seemed as if, on these occasions that the subjects were attempting to reach the test stimulus. Such an interpretation is further supported by Pearl's observation (1903) that planaria tend to stop in the corners of their containers, as well as by the results of VanDeventer and Ratner (1964) which suggest that responsiveness to light may be reduced by increased body contact with a surface. Insofar as Pearl (1902) has made the generalization that planaria tend to react to weak stimuli with a positive reaction and to strong stimuli with a negative reaction, we might have predicted the pilot study results, _i_._e_., a decrement of posterior contractions accompanied by an increment of anterior turns; with repeated application, a strong stimulus becomes functionally a weak one. The present study was thus projected to examine this hypothesis and add support to the interpretation of anterior turns during tactile stimulation as approach responses. In view of the outcome of Experiment 1, this latter interpretation appeared less tenable. However, a few casual observations suggested that the study might still be worth the effort, as it might be possible to explain the differences between the results of the pilot study and Experiment 1. In the pilot study the test stimulus consisted of a hair which was applied to the side of the subject _near_ the posterior, whereas the test stimulus of Experiment 1 was applied to the posterior tip of the subject. A few tests revealed that if the test stimulus were applied to the anterior of the subject, all the responses seemed to be turns. One might therefore predict that if the test stimulus were applied to the medial area of the subject, both posterior and anterior responses would result and thus the differences between the results of Experiment 1 and the pilot study could be explained.

Experiment 2 was thus designated to examine two considerations: (1) the hypothesis that anterior responses would increase as the stimulation locus is moved toward the anterior, and (2) to examine the course of habituation to a tactile stimulus applied to the anterior; more specifically, to see if turns away would decline and turns toward the test stimulus would increase.

Method

Subjects. 20 naive _D_. _tigrina_ as described in

Experiment 1 were divided into two groups: a medial stimulation group and an anterior stimulation group. Data from Experiment 1 was used for the posterior stimulation group. Experiment 2 was conducted at the same time as Experiment 1, being broken up in this fashion for expository purposes.

Apparatus and Procedure. The procedure was the same as that utilized for Experiment 1, except Ss in Group III were touched with the test stimulus on the anterior just posterior to the auricles and Group IV was touched on the side at the midline (referred to as medial stimulation). All responses described in Experiment 1 were recorded. For Group III, the direction of an anterior turn with respect to the stimulus was recorded as "toward" or "away" (only anterior turns were elicited by the test stimulus when applied to the anterior. All Ss received 50 trials.

Results

The frequency of anterior turns for 50 trials for various loci of stimulation are depicted in Figure 2. Also presented are the frequencies of all responses (all posterior plus all anterior) for each group as well as the frequency of such responses for the random response group from Experiment 1. An analysis of variance performed on the groups indicates that the site of stimulation significantly ($p < .01$) affects the frequency of anterior turns (summary of the analysis of variance

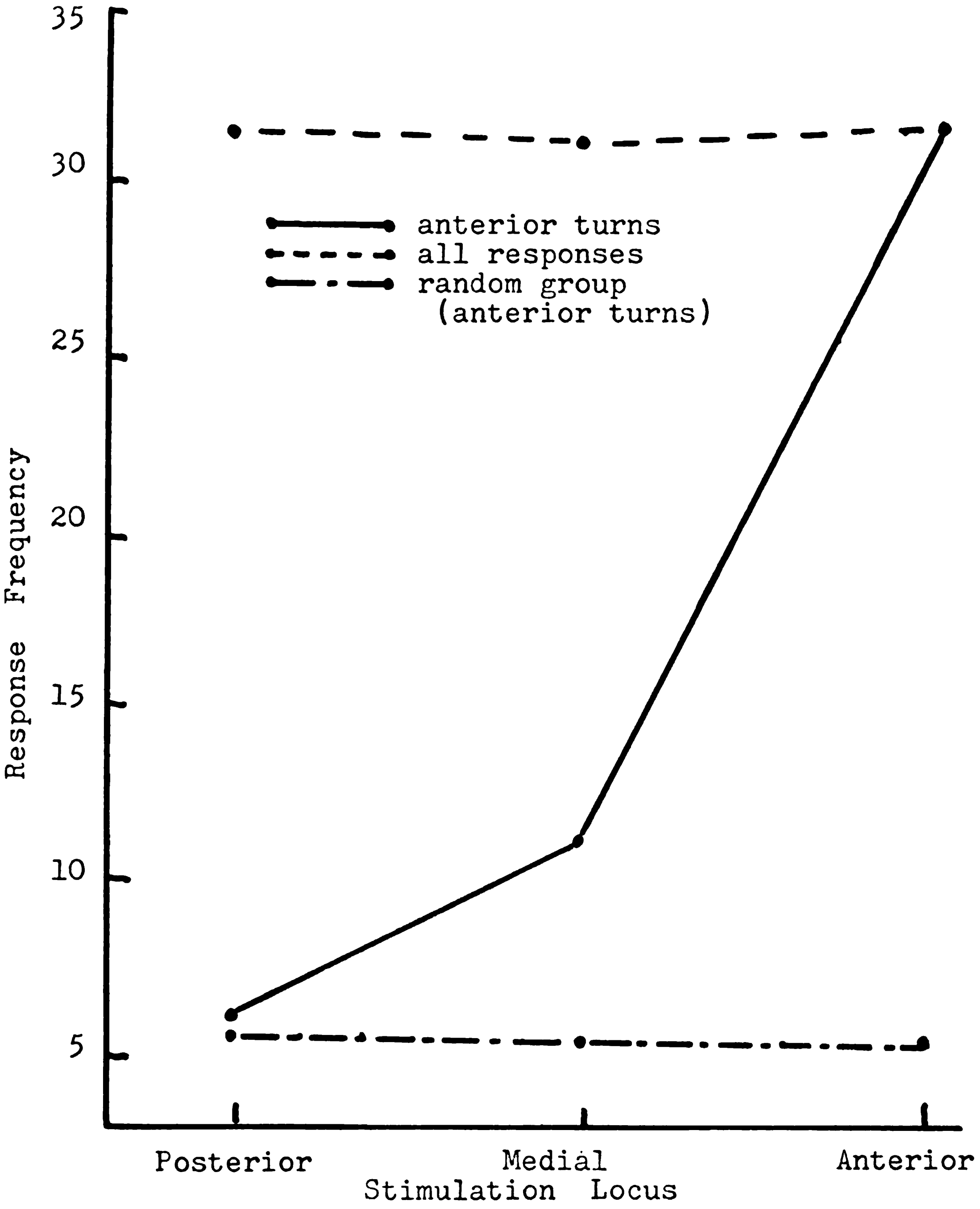

Figure 2.--Frequency of anterior turns as a function of locus of stimulation with responses of the random group (Experiment 1) shown as means of all types of responses for the three loci of stimulation groups. The data for the posterior stimulation group is from Experiment 1.

Table 4. Means, standard deviations, and differences between means for various loci of stimulation in Experiment II. All Ss received 50 trials, posterior and random data from Experiment 1. A Fartley F-max test indicates that the variances (F=31) are significantly different. A Kruskal-Wallis test (H=35.2) indicates that the effect of loci of stimulation on responses is significant. The analysis of variance data is retained to be consistent with the rest of the paper.

Group	random response	post. stim.	med stim.	ant. stim.
Mean	5.6	5.9	11.4	33.0
S. D.	1.91	1.76	2.94	9.74
N	10	10	10	10

Group				
random	5.6			
posterior	5.9	0.3		
medial	11.4	5.8*	5.5*	
anterior	33.0	27.4*	27.1*	21.6*

*Significant, $p < .05$

may be found in Appendix Table II:2). Means, standard deviations, and differences between means are provided in Table 4. A Duncan's range test was performed (significant differences are indicated in Table 4) on the data. The results of this test indicated that all three groups differed significantly from one another with respect to anterior turn frequency, and that the random response group did ;not differ significantly from the posterior stimulation group, whereas it did from the other two site of stimulation groups.

The type of turns (away or toward) made by the anterior stimulation group for each block of trials is shown in Figure 3. An analysis of variance (summaries are in Appendix Tables II:3 and II:4) was performed on turns away and on turns toward. Both analyses showed significant effects ($p < .01$ for both types of responses) of trial blocks on turn frequency. Means, standard deviations and differences between means are presented in Tables 5 and 6. Duncan's range tests (significant differences are indicated in Tables 5 and 6) indicate that the difference between the high frequency of turns for the first block and the low frequency of turns for the last block for turns away are significantly different. In contrast, this is not the case for turns toward, rather, for turns toward, the frequency of turns in the first block of trials is significantly lower than the remaining

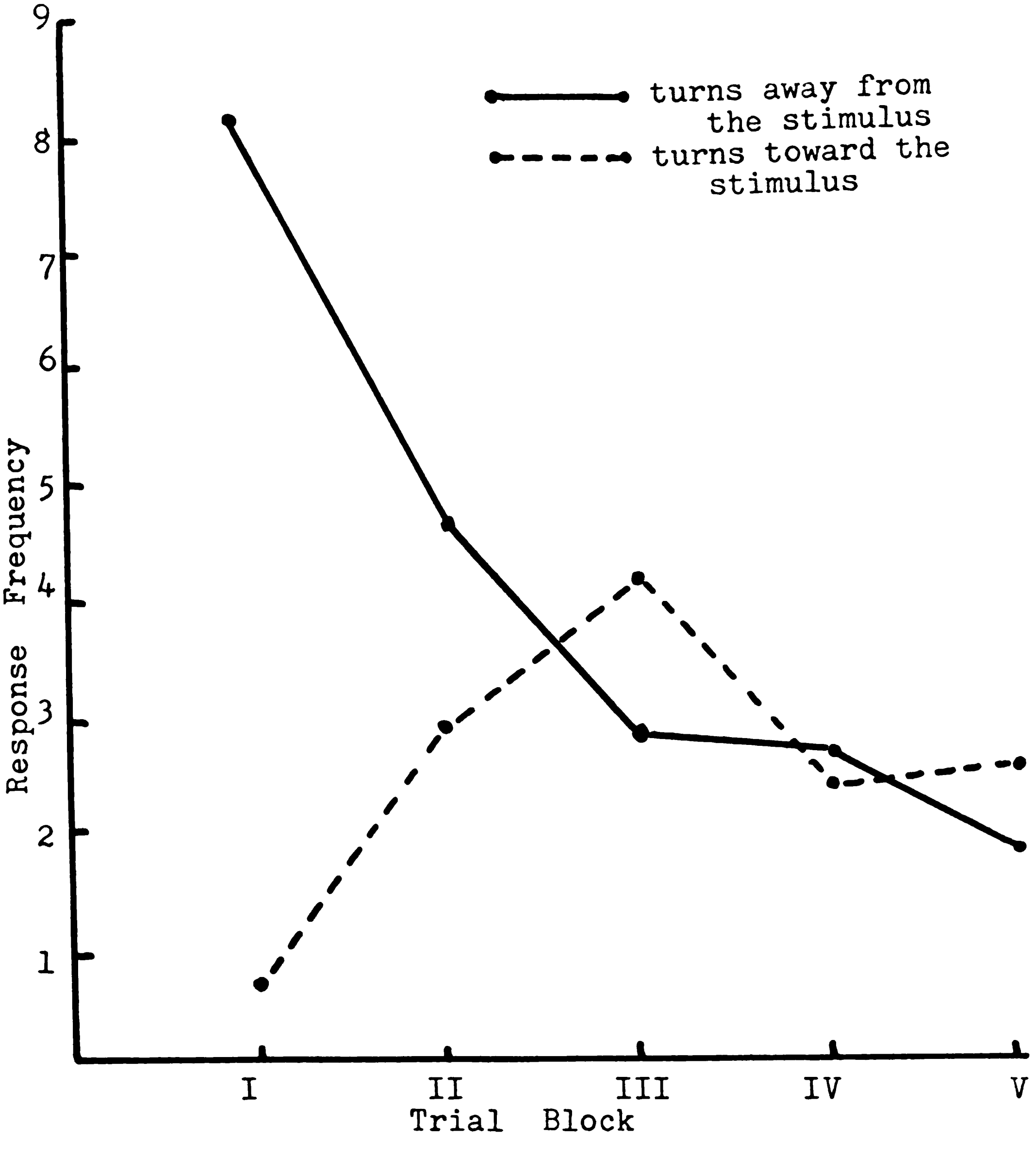

Figure 3.--Turns toward and turns away from an anteriorly applied test stimulus (Experiment 2) as a function of blocks of ten trials.

Table 5. Means, standard deviations, and differences between means for turns away from the stimulus in Experiment II for each block of trials.

Trial block		I	II	III	IV	V
Mean		8.3	4.6	2.9	2.7	1.7
S. D.		1.19	2.69	2.17	2.69	2.59
Trial block						
I	8.3					
II	4.6	3.7				
III	2.9	5.4	1.7			
IV	2.7	5.6	1.9	.2		
V	7.7	6.6	2.9	1.2	1.0	

$*p < .05$

Table 6. Means, standard deviations, and differences between means for turns toward the stimulus in Experiment II for each block of trials.

Trial Block	I	II	III	IV	V
Mean	.7	2.9	4.1	2.4	2.5
S. D.	.64	1.45	2.41	1.50	2.11

Trial Block					
I	.7				
II	2.9	2.2*			
III	4.1	3.4*	1.2		
IV	2.4	1.7*	.5	1.7	
V	2.5	1.8*	.4	1.6+	.1

*$p < .05$
\+ very near $p < .05$

blocks of trials.

Discussion

The results of Experiment 2 have demonstrated that the type of response elicited by tactile stimulation depends upon the site of stimulation. This supports the hypothesis raised at the beginning of Experiment 2 in order to account for the failure of Experiment 1 to replicate the findings of the pilot study; in the pilot study the site of stimulation probably varied from the posterior to the medial section of the subject, giving rise to a higher incidence of turns than was the case for Experiment 1 where only the posterior tip was touched due to the better stimulus control achieved by the modification of the test stimulus for Experiment 1. Experiment 2 also generates a second conclusion: *D. tigrina* is differentially sensitive to the location of tactile stimulation, an observation which does not seem to appear in the literature.

Analysis of the data for the anterior stimulation group suggests that repeated stimulation to the anterior end, in contrast to repeated stimulation to the posterior, produces a more complex response change. A response decrement in turns away occurs, accompanied by an increment in turns toward (had the trials been extended further, from the appearance of the function for turns toward in Figure 3, one would expect to find a decrement in this response). Pearl (1903) has observed that strong stimuli elicit withdrawal responses in planaria whereas weak stimuli elicit approach responses. In line with this generalization, the results of Experiment 2 may be interpreted thusly: Repeated stimulation with a strong stimulus creates conditions whereby the strong stimulus becomes functionally a weak one. This accounts for the change in response topography observed in the anterior stimulation group of Experiment 2. Some modification of Pearl's (1903) generalization, is however, forced by a consideration of the results of Experiment 1. Any turns observed during posterior stimulation may be considered to be random turns so that the only response (if at all) to posterior stimulation is a posterior contraction which is essentially a withdrawal response. If the hypothesis (as a result of repeated stimulation a strong stimulus becomes functionally a weak one) raised above is correct, then one may conclude that a strong posterior tactile stimulus serves the same function as a weak posterior tactile stimulus. Additional research may reveal that _D_. _tigrina_ will give withdrawal responses to both weak and strong stimuli, making Pearl's (1903) generalization less broad. It is not within the scope of the present paper to pursue these matters further.

EXPERIMENT THREE: THE EFFECTS OF REPEATED STIMULATION: RETENTION TESTS

Information regarding the span of the retention of the effects of repeated stimulation has been examined much less often than the occurrence of a response decrement. Rushforth has demonstrated retention in *Hydra pirardi* for four hours; Walter (1908) found that *D. gonocephala* and *D. maculata* recover response (cessation of locomotion) to rotation within one minute; Miller and Mahaffy (1930) have reported recovery from habituation to a shadow within one minute for the Trematode *Cercaria hamata*; and Gardner (1966) has reported retention of habituation to vibration in the earthworm for an interval of 96 hours.

It is tempting to suggest (Gardner, 1966) a phylogenetic trend in the retention period of the effects of repeated stimulation; however, short intervals may not be characteristic of planaria. Whereas Walter (1908) found full recovery in less than a minute for the response to rotation, Westerman (1963) has found some retention of a response decrement to light by planaria for a five day period. Westerman's (1963) procedure, however, utilized a distributed presentation of the light over the five day period; this practice makes it difficult to compare his results with other studies of habituation which ordinarily do not use distributive "practice."

The present experiment was designed to examine the retention interval of the effects of repeated stimulation.

Method

Subjects. 40 D. tigrina as described in Experiment 1 were divided into 4 groups (1 minute, 1 hour, 24 hours, and 96 hours retention interval groups).

Apparatus and Procedure. The procedure was the same as that utilized in the previous experiments except as follows: Ss in this experiment were stimulated medially in the hope of gaining more information about the possible change in topography suggested by the preceding experiment. The Ss from the various retention groups were tested alternately. All responses previously described were recorded. During the retention interval, S was transferred (except for the 5 minute group which were retained individually in the test chamber in which they had been habituated) to a finger bowl until rehabituation trials were begun. Rehabituation was conducted in the same manner as the habituation trials had been conducted. Savings scores were determined by the formula:

$$\%\ \text{Savings} = \frac{H - R}{H}$$

Where H = trials to criterion for original habituation; and R = trials to criterion during rehabituation. When S had failed to respond 7 times out of 10 consecutive trials, habituation (or rehabituation) was discontinued.

Results

Savings scores as a function of retention interval are presented in Figure 4. The shape of the curve resembles that often obtained in studies of retention of learned responses and compares to retention curves generated by other studies of habituation (i.e., Gardner, 1966). A Hartley Fmax.-test indicated that the variances were not significantly different. An analysis of variance (summarized in Appendix Table II:5) indicated a significant effect of retention interval on the savings scores. Means, standard deviations and differences between means are presented in Table 7. A Duncan's range test was performed on the data (significant differences are indicated in Table 7). All groups were significantly different from the 96 hour group but not from each other (although the difference between the 5 minute and 24 hour groups was in the expected direction and nearly significant - see Table 7). Pearson Product Moment correlations between habituation trials to criterion and rehabituation trials to criterion were determined. The correlation coefficients are presented in Table 8. None differ significantly from zero.

The course of habituation for medial stimulation for various responses (posterior contractions, all anterior responses, anterior turns and anterior contractions) is shown in Figures 5 and 6. An analysis of

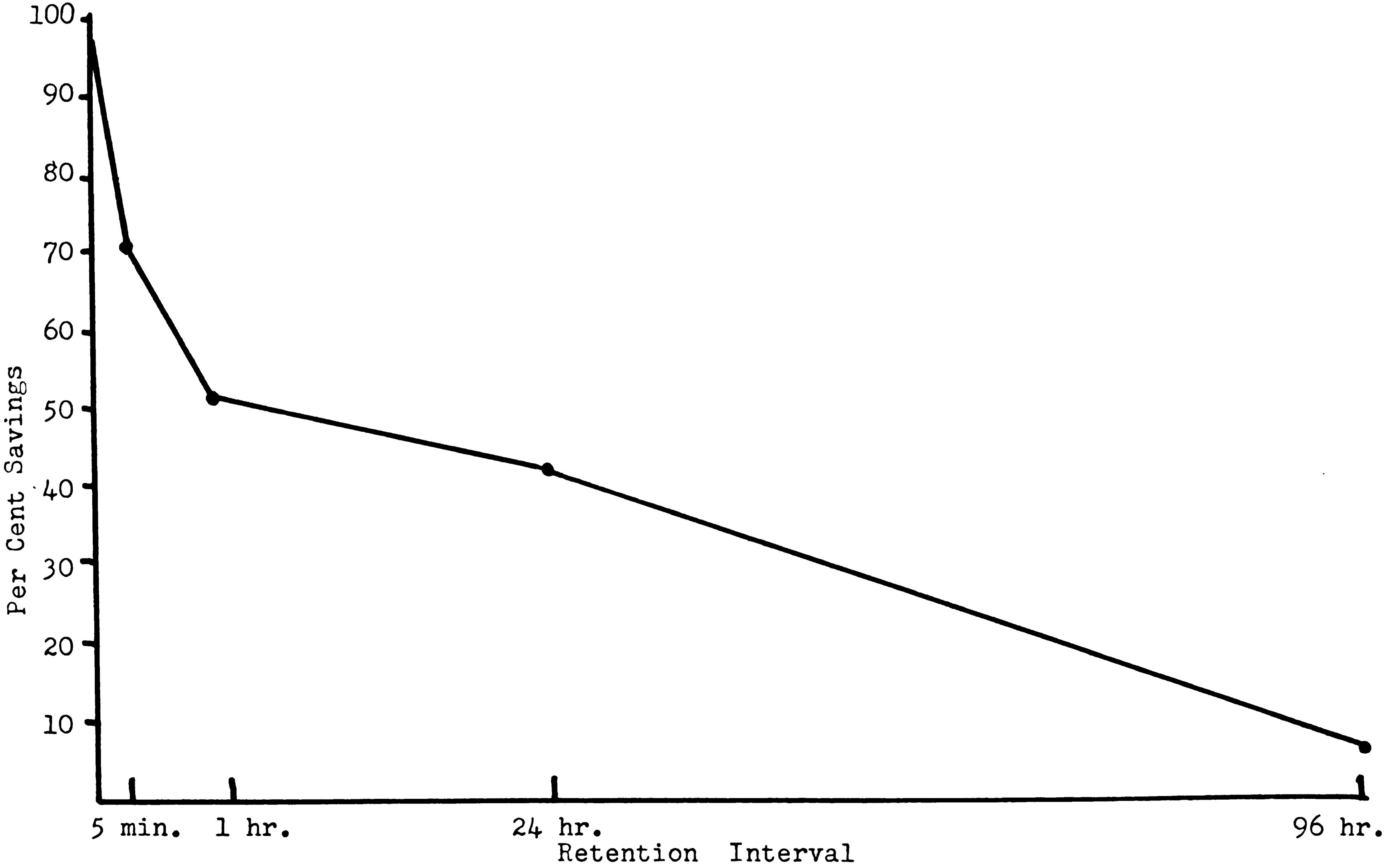

Figure 4.--Savings score as a function of retention interval.

Table 7. Means, standard deviations and differences between means for retention intervals in Experiment III.

Interval	5 min.	1 hr.	24 hr.	96 hr.
Mean	70.7	51.8	44.0	9.2
S. D.	15.96	9.31	40.32	43.29
Interval				
5 min. 70.7				
1 hr. 51.8	18.9			
24 hr. 44.0	26.7+	7.8		
96 hr. 9.2	61.5*	42.6*	34.8*	

*p < .05

\+ almost sig (diff. $\geq$ 26.82)

Table 8. Correlation coeficients (Pearson's product moment) between habituation trials and rehabituation trials to criterion in Experiment III.

Retention Interval	5 min.	1 hr.	24 hr.	96 hr.
	-.18	.44	-.14	.21

variance was performed on each category of responses (summarized in Appendix Tables II;6 - II:9). The analysis revealed a significant effect of trial block on posterior contractions but not for the other three categories. Means, standard deviations and differences between means for posterior contractions are presented in Table 9. A Duncan's range test was performed on the posterior contraction data (significant differences are indicated in Table 9). Several differences are significant in the expected direction. The frequency of posterior contractions from trial block I is significantly higher than any of the succeeding trial blocks. Means and standard deviations for all anterior responses, anterior turns, and anterior contractions are presented in tables 10-12, respectively. The data suggest a differential habituation rate for posterior contractions and anterior responses; the former exhibit a decrement from the first trial, the latter showed no significant habituation. Trends in these curves, however, suggest that additional research might be profitable.

Rehabituation curves are shown in Figures 7-8. This data was not analyzed because of difficulties created by the trials to criterion approach which was used in this experiment to obtain the retention data.

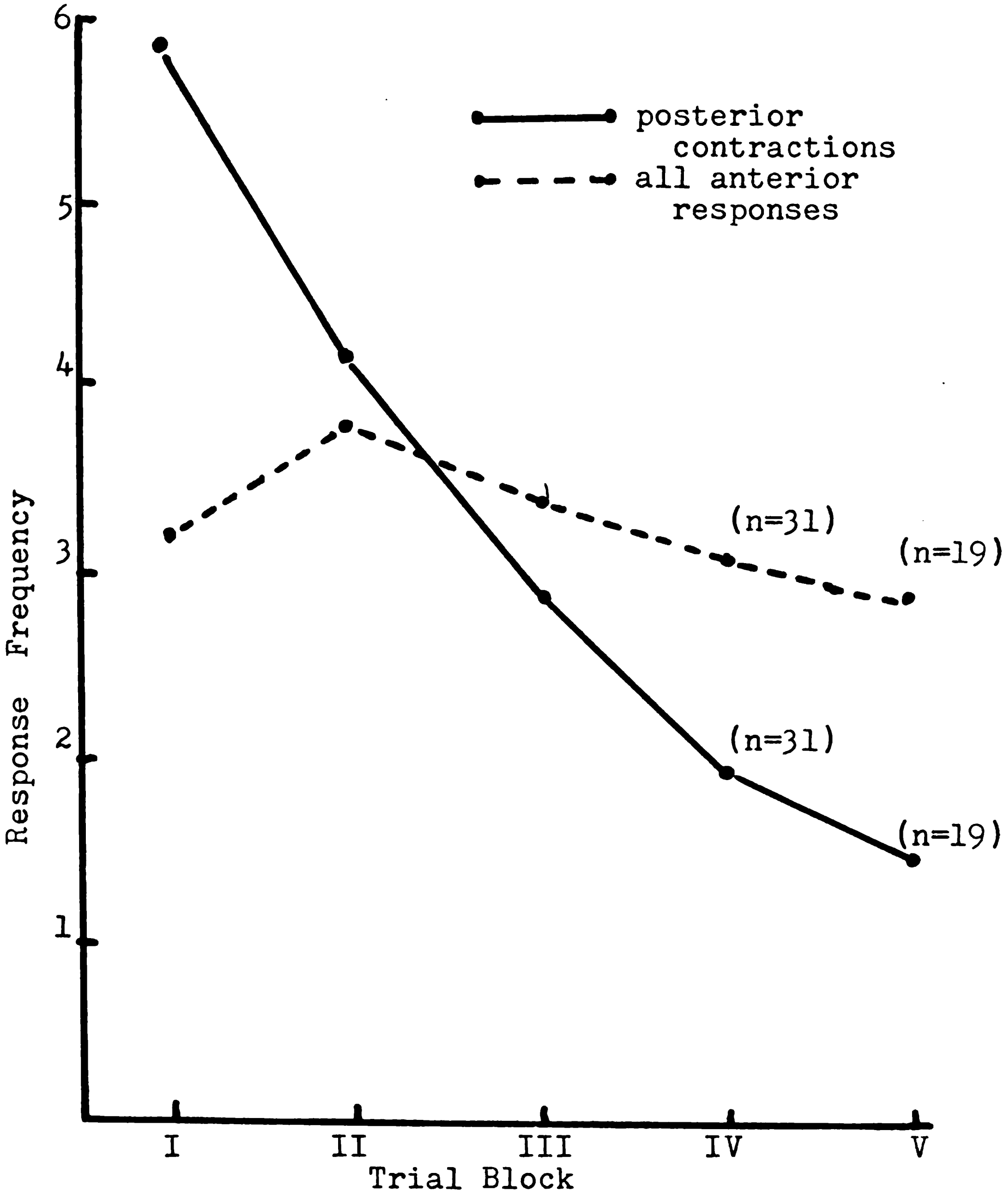

Figure 5.--Posterior and anterior responses as a function of blocks of ten trials in Experiment 33 Figures in parentheses indicate the number of Ss remaining in the sample, i.e., those Ss which have not met criterion. When not indicated, n is 40.

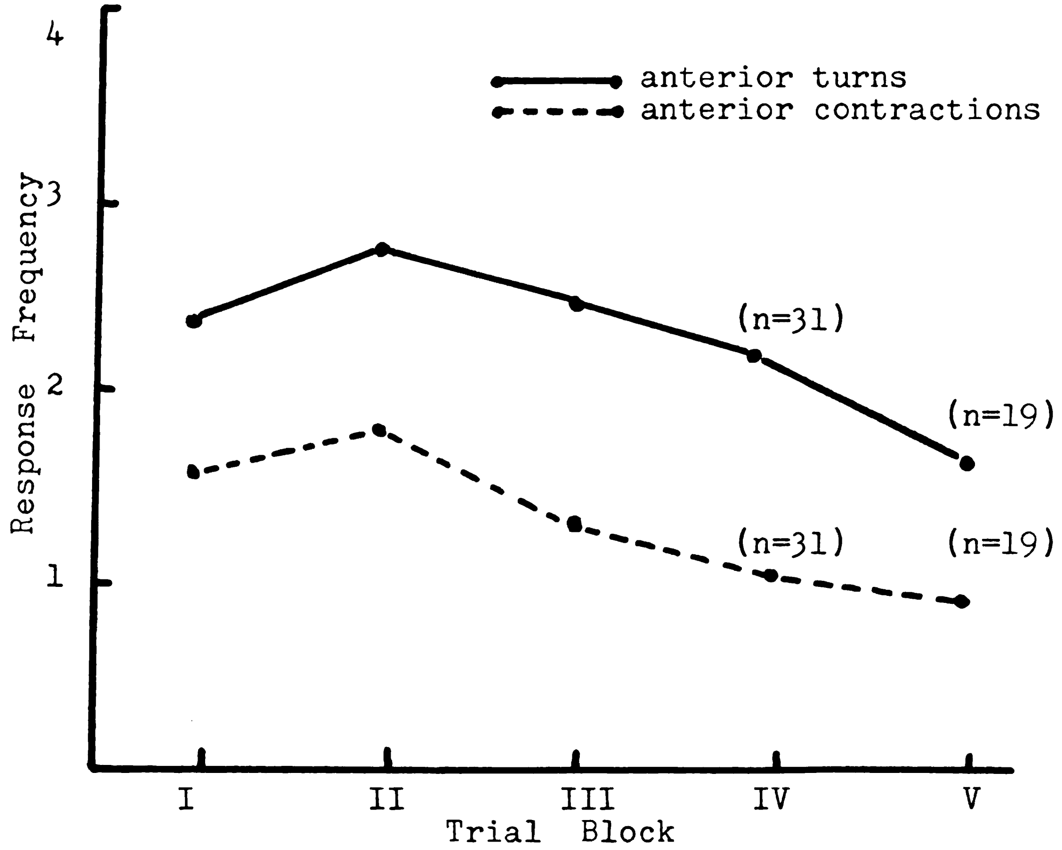

Figure 6.--Anterior turns and anterior contractions as functions of blocks of ten trials for Experiment 3. Numbers in parentheses represent the number of Ss remaining in the sample, *i.e.*, the number of Ss not meeting criterion.

Table 9. Means, standard deviations, and differences between means for trial blocks of posterior contractions in Experiment III.

Trial Block	I	II	III	IV	V
Mean	5.95	4.18	2.80	1.90	1.68
S. D.	2.24	1.69	1.19	1.73	1.57
N	40	40	40	31	19

Trial Block					
I	5.95				
II	4.18	1.77*			
III	2.80	3.15*	1.38		
IV	1.90	4.05*	2.28*	0.9	
V	1.68	4.27*	2.5*	1.12	0.22

*$p < .05$

Table 10. Means and standard deviations for trial blocks of all anterior responses in Experiment III.

Trial Block	I	II	III	IV	V
Mean	3.3	3.85	3.4	3.2	3.1
S. D.	1.69	2.09	1.67	1.82	1.81
N	40	40	40	31	19

Table 11. Means and standard deviations for trial blocks of anterior turns in Experiment III.

Trial Block	I	II	III	IV	V
Mean	2.3	2.75	2.55	2.22	1.90
S. D.	1.66	1.58	.77	1.53	2.24
N	40	40	40	31	19

Table 12. Means and standard deviations for trial blocks of anterior contractions in Experiment III.

Trial Block	I	II	III	IV	V
Mean	1.55	1.75	1.3	1.19	1.05
S. D.	1.20	1.30	1.45	1.28	1.22
N	40	40	40	31	19

Discussion

Retention of habituation to a tactile stimulus, when all responses are considered, appears to persist longer than 24 hours but less than 96 hours. Scores for response components were not considered separately, rather total scores involving both anterior and posterior responses were used. The extreme variability of the component scores led to their rejection. The correlation coeficients (see Table 8) between total habituation scores and rehabituation scores indicates the low reliability of rehabituation. This may be due partially to the procedure. The posterior stimulation data of Experiment 1 and the anterior stimulation data of Experiment 2 appears, upon inspection, to be less variable than the medial stimulation data. This would suggest that a future attempt to replicate Experiment 3 but using posterior or anterior stimulation would be more successful in providing reliable data. One other source of unreliability may derive from differential starvation periods within the retention intervals. Time since last feeding may increase or decrease the extent of differences between individuals or within individuals. These effects have not been studied and should be examined before further research is conducted. Another source of unreliability might arise from the difficulty in stimulating the same area during medial stimulation as compared to anterior or posterior stimulation because of the change in the configuration of the subject's body while it is moving. Between individual variation may have been caused by the width of the subject's body. The impression was obtained that thicker subjects tended to make more anterior contractions than turns.

If posterior and anterior responses are considered separately, Experiment 3 suggests that (1) posterior responses show a different habituation course than do anterior responses (the former showing a decrement from the beginning, the latter not exhibiting a significant decrement) and (2) anterior turns and anterior contractions (other anterior responses - head waving and cessation of locomotion - did not occur with sufficient frequency to analyze) appear to have the same form (see Figure 6). It is possible, then, that both anterior turns and contractions are equivalent responses. No anterior contractions were observed with anterior stimulation in Experiment 2. Hyman (1951) indicates that tactile receptors (hairlike projections which tend to cluster at the sides of the body) are densest near the anterior and diminish in number toward the posterior; thus contractions may reflect difficulty in stimulus localization for the subject when the stimulus is applied at the medial region.

Examination of Figures 7-8 gives one the impression that the shorter the retention interval, the more closely the rehabituation function resembles the last

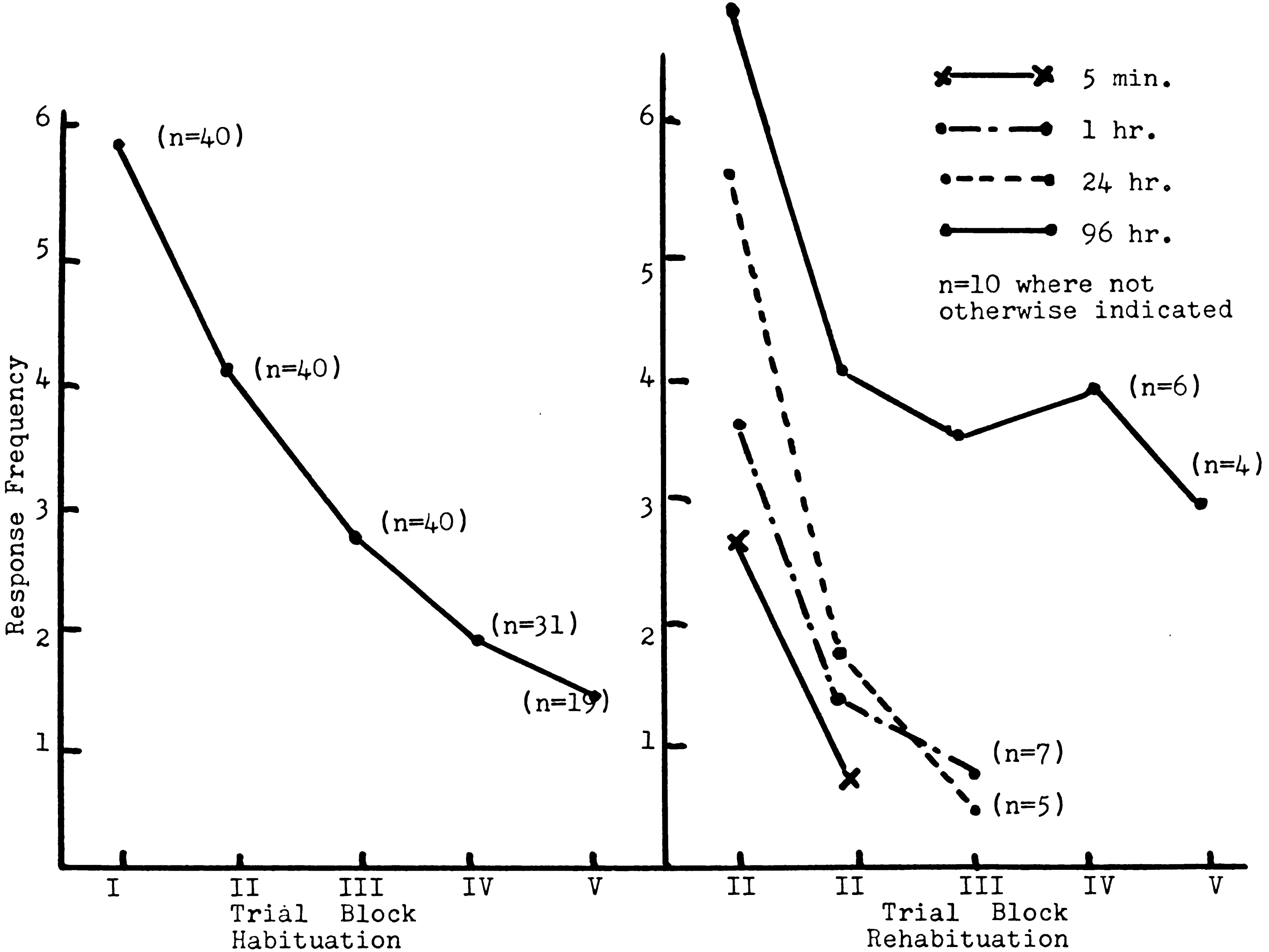

Figure 7.--Comparison of posterior contractions as functions of blocks of ten trials for habituation and rehabituayion in Experiment 3. Numbers in parentheses indicate the number of Ss remaining in the sample, i.e., the number of Ss not meeting criterion.

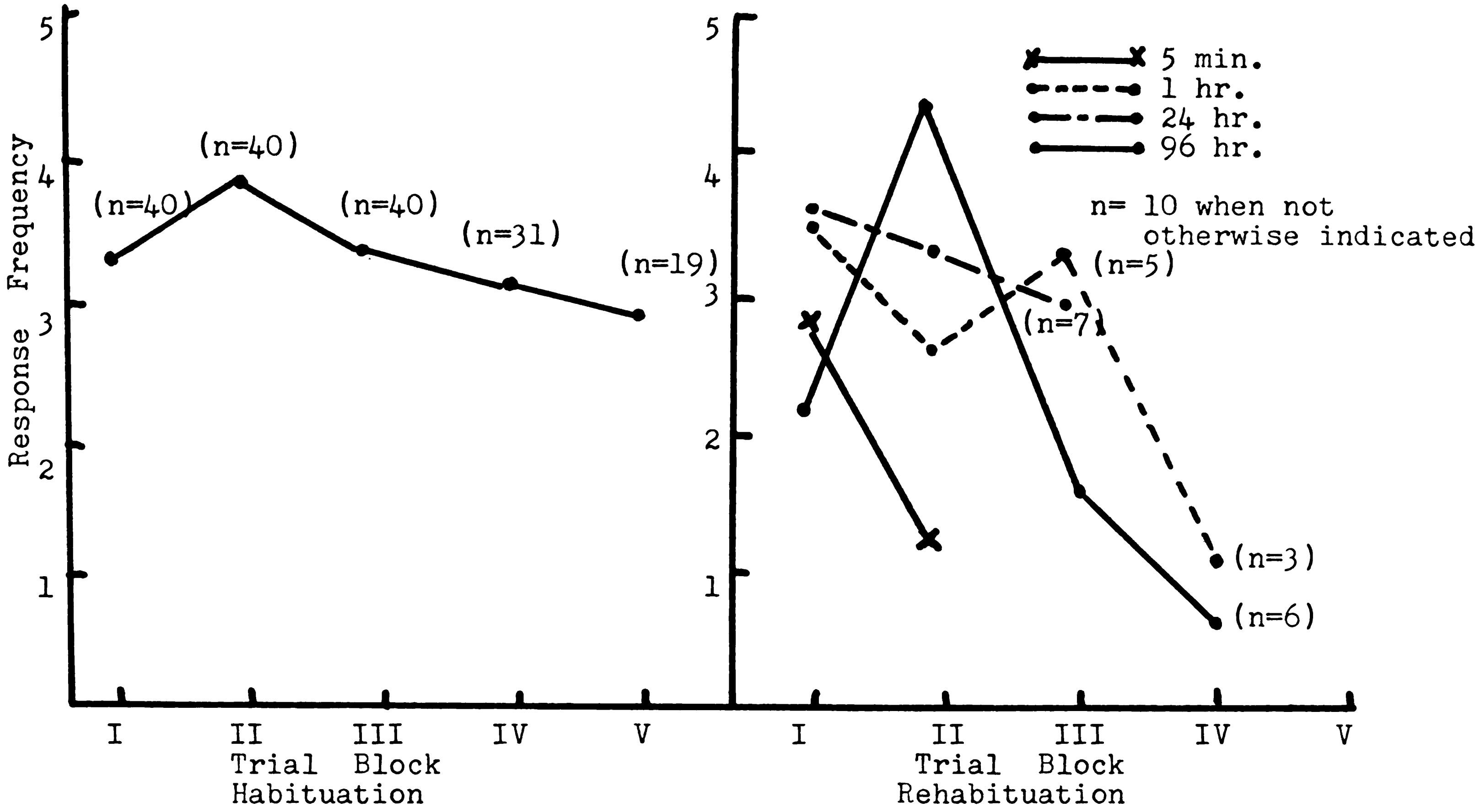

Figure 8.--Comparison of anterior responses as functions of blocks of ten trials for habituation and rehabituation in Experiment 3. Numbers in parentheses indicate the number of Ss remaining in the sample.

trials of the habituation function, i.e., the first rehabituation trials for the shorter retention intervals appear as if one were coming on the scene in the middle of habituation. This is true of both posterior response frequencies and anterior response frequencies.

The results of Experiment III generally indicate the necessity of identifying the sources of noise before additional research is contemplated.

EXPERIMENT IV: THE EFFECT OF CONCURRENT STIMULATION

During the pilot study a few subjects were stimulated with the tactile stimulus in the presence of high illumination. The presence of the latter seemed to increase the speed of habituation. For this reason, the data of Experiments 1, 2, and 3 were collected under a very low level of illumination so that the course of habituation might be extended long enough for study. The effects of changes in concurrent stimulation have not often been studied. The few which have, however, indicate a variety of effects with a variety of situations. VanDeventer and Ratner (1964) have found that responsiveness to light decreases in containers which provide maximum body contact. Ratner and Gardner (1967) report the same effect for the earthworm, _Lumbricus terrestris_. Ratner and VanDeventer (1965) have also found that occasional rheotactic stimulation induces a greater responsiveness to light in _D. tigrina_. Gee (1912) has noted that hunger in the leech is associated with repeated responses to stimulation and a full crop is associated with positive thigmotaxis and a negative response to light. The present Experiment was thus designated to assess the effects of concurrent stimulation, _viz._, high illumination, on responsiveness to a tactile stimulus.

Method

Subjects. 10 D. tigrina as described in Experiment 1 were used and compared with data from Experiment 1 (as it were, subjects in the present Experiment were run alternately with those of Experiment 1).

Apparatus and Procedure. The procedure was the same as that followed in Experiment 1 (posterior stimulation) except as follows: When the Us were introduced into the test chamber, a 100 watt bulb, which was suspended 8 inches above the test chamber, was turned on. The light remained on for the duration of the habituation procedure. A glass dish filled with water was placed between the bulb and the test chamber to act as a heat filter. Trials to criterion (S's failure to respond 7 out of 10 consecutive trials) were recorded..

Results and Discussion

Means, standard deviations and differences between mean frequencies of response for the high illumination group of Experiment 4 and the low illumination group of Experiment 1 are presented in Table 13. An F-test indicated that there was no significant difference between the variances of the two distributions. A t-test was performed on the difference between the two means. The difference was significant ($t=3.93$, $p < .0005$). It may be concluded that habituation to a tactile stimulus for dark adapted D. tigrina is much more rapid under conditions of high illumination than is

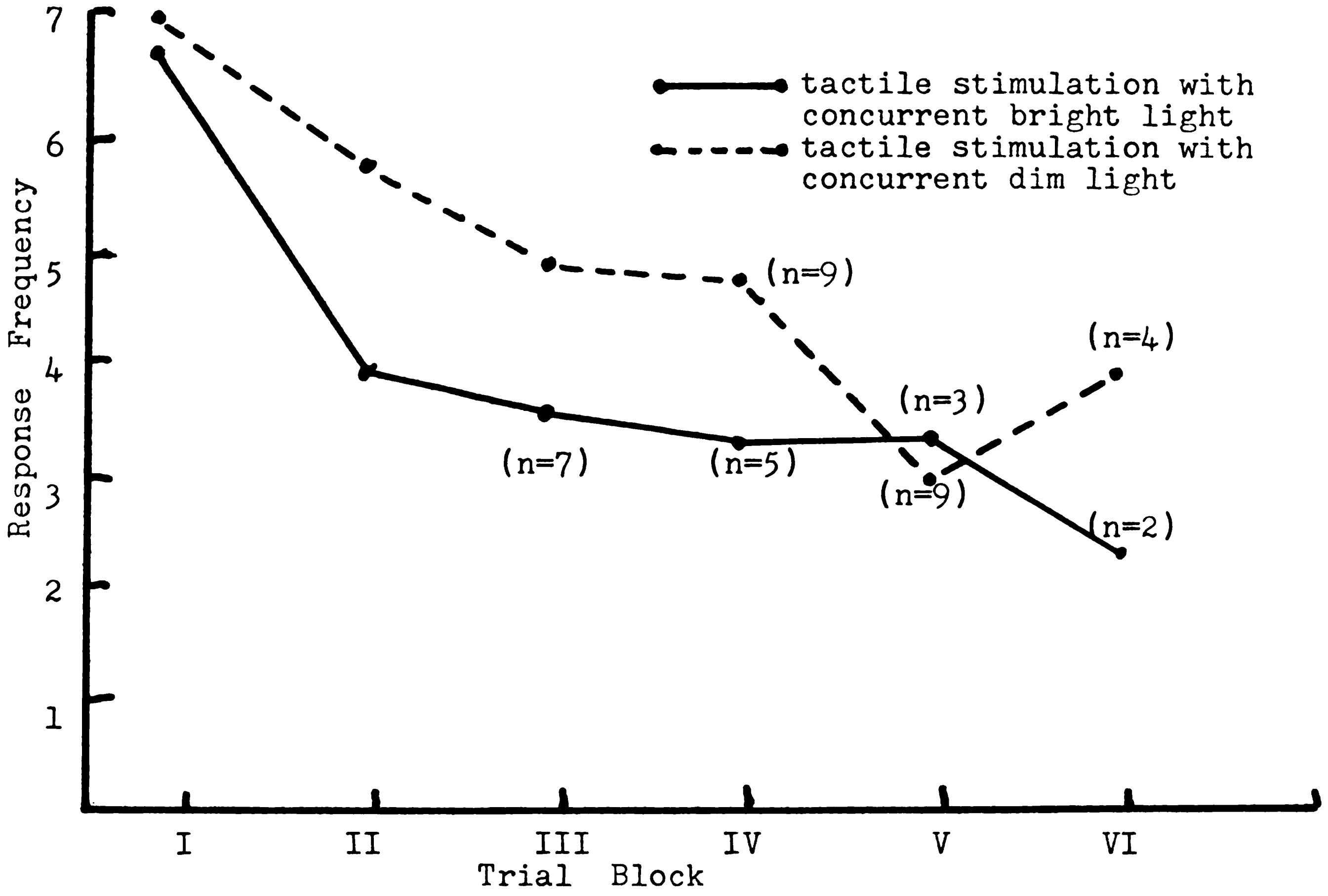

Figure 9.--Posterior contractions for subjects with and without concurrent light stimulation as a function of blocks of ten trials in Experiment 4. Stimulation in the dark data is from Experiment 1. Numbers in parentheses indicate the number of Ss not meeting criterion. When not indicated, n=10.

Table 13. Means, standard deviations and differences between means for tactile stimulation with and without concurrent light stimulation, low illumination data from Experiment I.

	Trials to criterion	
Group	low illumination	high illumination
Mean	44.9	21.7
S. D.	15.38	21.22
N	10	10

Group		
Low illum.	44.9	
High illum.	21.7	23.2*

*p < .0005

habituation under conditions of low illumination. Several explanations are plausible at this time. Since the subjects were dark adapted prior to administering both the tactile stimulation and the high level of illumination, it may have been that the light was the center of "attention" for the subject, _i.e._, the light stimulation may have blocked other sensory inputs. Were this the case, light adapted Ss would show little or no difference under either illumination condition during habituation. On the other hand, it is possible that the visual input may be functionally equivalent to the tactile input with respect to whatever occurs during habituation. In this case, light adapted Ss would probably habituate more rapidly when tested in the dark and certainly when tested in the light. In addition, habituation to light should generalize to tactile stimulation. It is not within the scope of the present paper to pursue these questions further at the moment. Preliminary research underway indicates that this latter hypothesis is probably incorrect; there does not appear to be any generalization from tactile habituation to light stimulation (and if the hypothesis were correct there should be reciprocal generalization). Inspection of Figure 9, which shows the functions obtained with the two groups, gives more support to the first hypothesis suggested. If the concurrent stimulation were dominating Ss "attention" then we would expect the ends of both curves to resemble each other as the S habituates to the strong stimulus. In Figure 9, the High illumination group shows a rapid drop in the beginning and then begins to parallel the low illumination group.

The findings of Experiment 4 support the previous findings of the effects of concurrent stimulation on response levels.

SUMMARY AND CONCLUSIONS

The primary aims of the present study were to explore the possibilities of the use of planaria in the study of habituation and, if this were plausible, to identify those sense modalities which might be most useful to meet the task of answering questions concerning habituation. A more general aim was to draw attention to the weakness of defining habituation as a response decrement and unnecessarily tying it to the concept of learning. Generally speaking, the results of the present study encourage the continued use of planaria for this task with some reservations. The poor reliability of the data in Experiment III suggests that some noise is associated with the procedure, at least with the use of medial stimulation. If this can be identified and controlled, the animals would lend themselves to further research concerning the effects of repeated stimulation. That the noise occurred was not altogether surprising if one is familiar with the literature on conditioning in planaria where a considerable amount of variation occurs not only between investigators but also within studies. A study is currently being undertaken to clarify some of these issues.

The more important findings may be summarized: (1) a clear response decrement to tactile stimulation occurs in *D. tigrina*; (2) both sensory adaptation and "fatigue" have been adequately ruled out; (3) response topography may change during the course of habituation (future research should not use a trials to criterion technique when examining this particular aspect of behavior); (4) response topography does change as a function of site of stimulation; (5) habituation is retained for more than 24 hours but less than 96 hours; (6) no permanent effects after 96 hours are indicated; (7) and concurrent stimulation (high background illumination) increases the speed of response decrement to repeated tactile stimulation.

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APPENDIX I

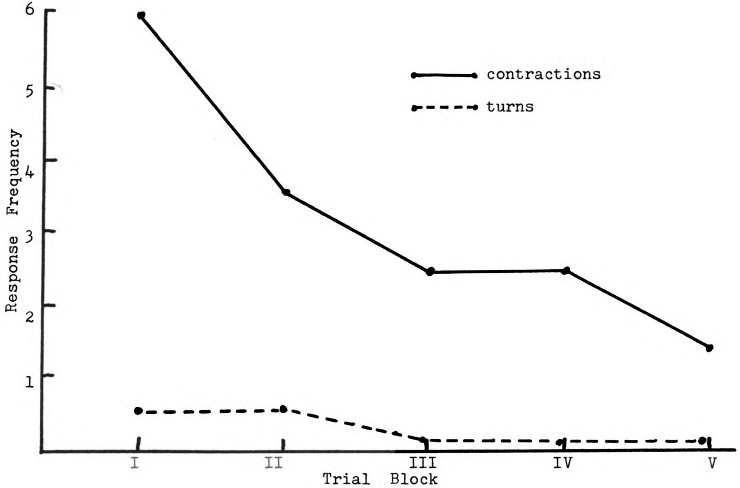

Figure I:1.--Contractions and turns in response to light as a function of blocks of ten trials; results of pilot study 1. Ss are light-adapted. N=10.

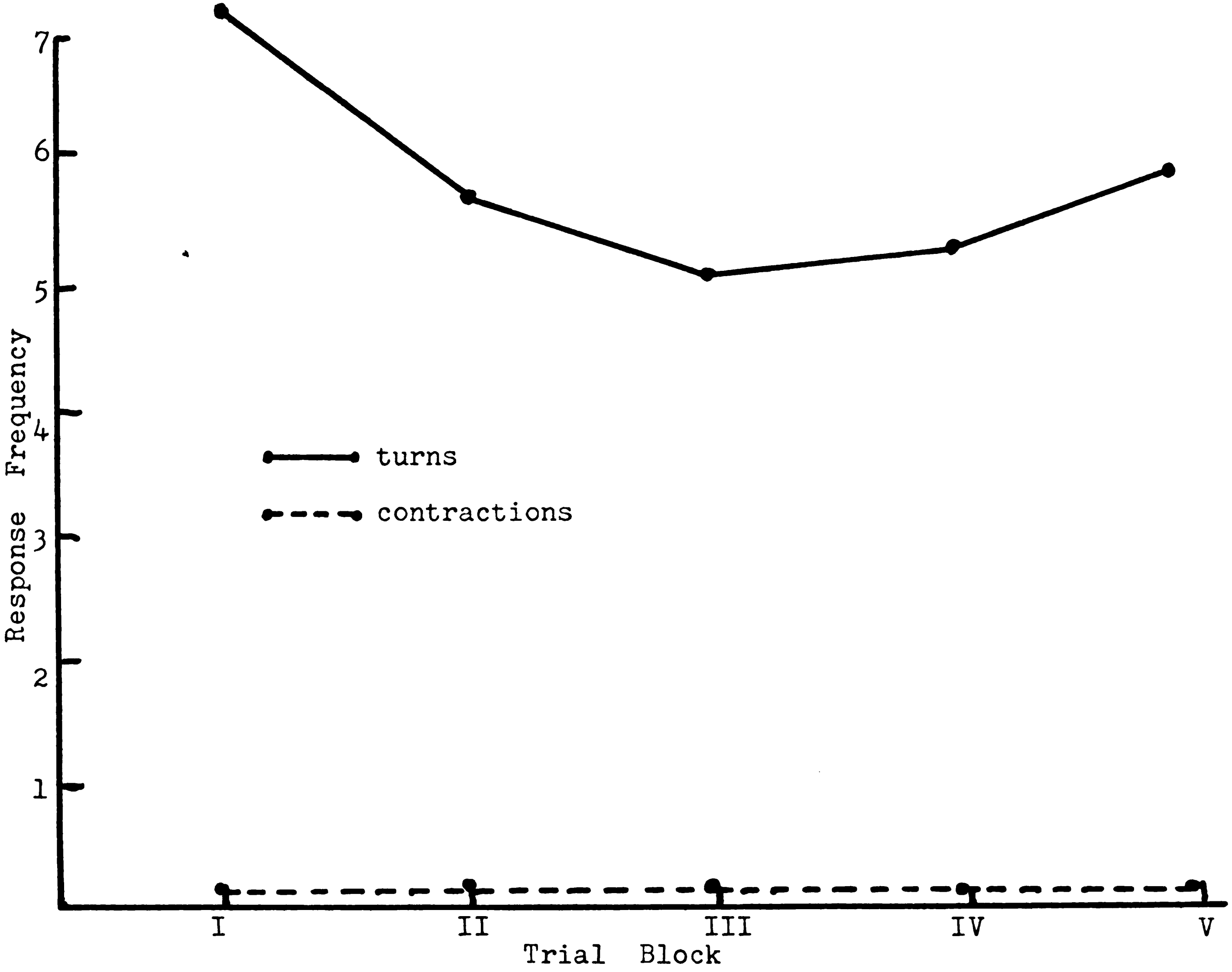

Figure I:2.--Results of pilot study 1; dark-adapted group. Contractions and turns in response to light as a function of blocks of ten trials. N=10.

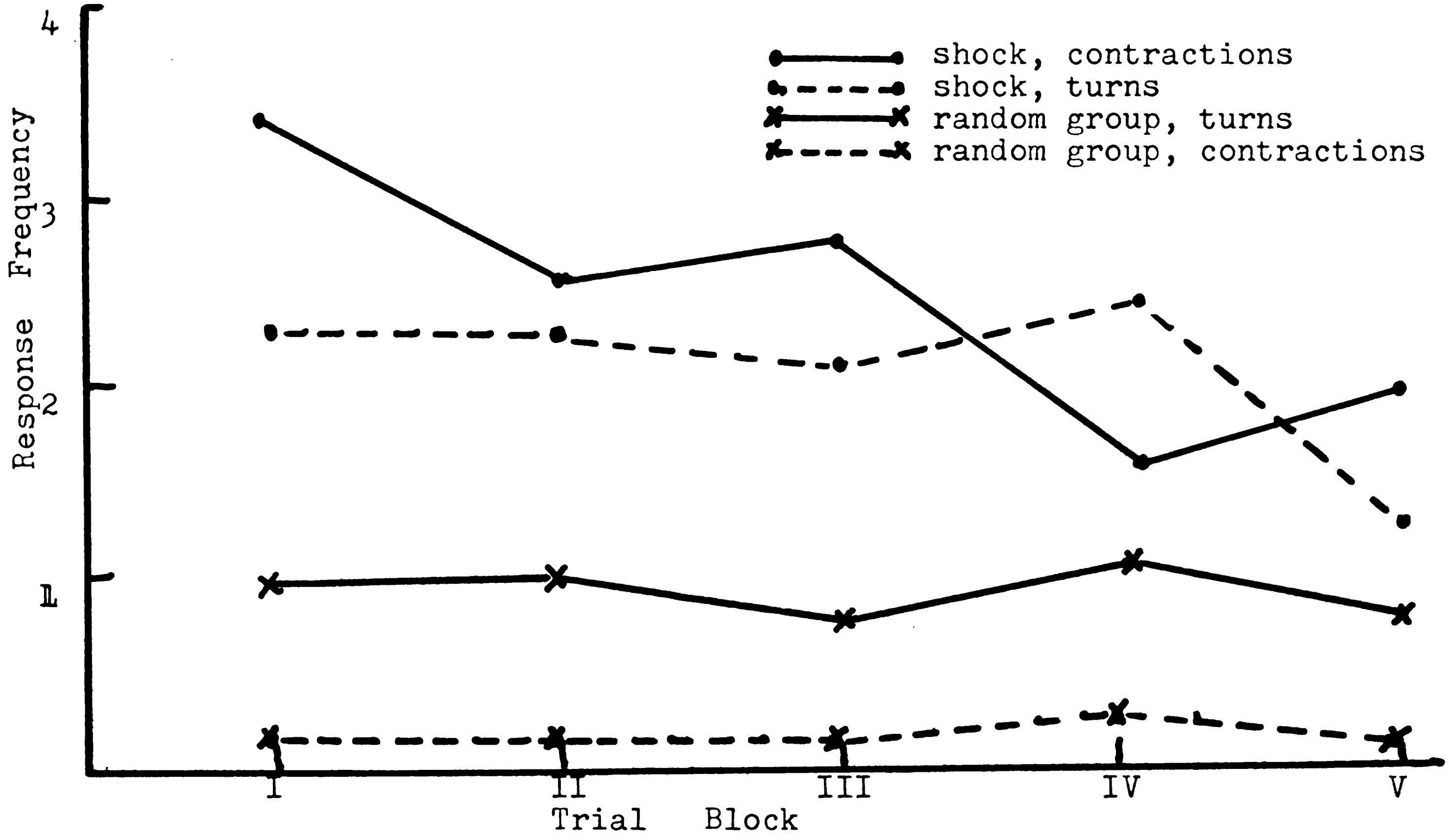

Figure I:3.--Results of pilot study 2. Contractions and turns in response to shock as a function of blocks of ten trials. A random response group is included. N=10.

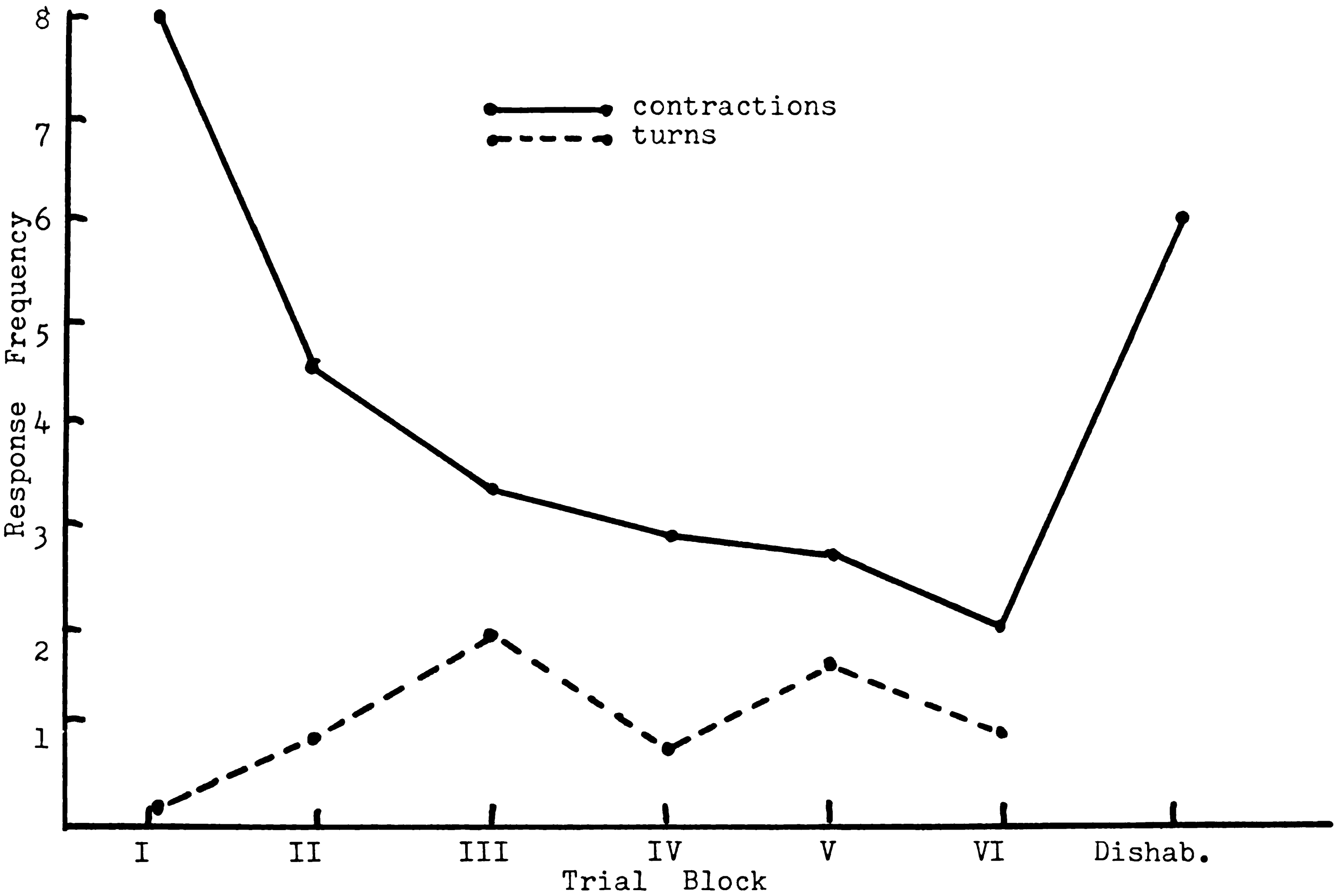

Figure I:4.--Results of pilot study 3. Contractions and turns in response to tactile stimulation as a function of blocks of ten trials. N=5.

APPENDIX II

Table II:1 Summary of the analysis of variance of trial block scores for posterior contractions in Experiment I.

Source	SS	df	MS	F
Trial Block	126.6	6	21.1	5.85*
error	199.5	55	3.62	
total	326.1	61		

*sig. p. < .001

Table II:2 Summary of the analysis of variance of locus of stimulation scores in Experiment II.

Source	SS	df	MS	F
locus	5039.27	3	1679.76	49.8*
error	1212.70	36	33.69	
total	6251.97	39		

*p < .01

Table II:3 Summary of the analysis of variance of trial block scores for turns away from the stimulus in Experiment II.

Source	SS	df	MS	F
Trial Block	270.32	4	67.58	11.15*
error	272.60	45	6.06	
total	542.92	49		

*p < .01

Table II:4 Summary of the analysis of variance of trial block scores for turns toward the stimulus in Experiment II.

Source	SS	df	MS	F
Trial Block	108.08	4	27.05	8.16*
error	148.80	45	3.31	
total	256.88	49		

*p < .01

Table II:5 Summary of the analysis of variance of the retention interval in Experiment III.

Source	SS	df	MS	F
Trial Block	79847.47	3	26615.82	24.8*
error	38419.30	36	1067.21	
total	118266.77	39		

*p < .001

Table II:6 Summary of the analysis of variance of trial block scores for posterior contractions in Experiment III.

Source	SS	df	MS	F
Trial Block	236.175	4+	59.03	14.65*
error	664.895	165	4.03	
total	901.01	169		

*p < .01

Table II:7 Summary of the analysis of variance of trial block scores for all anterior responses in Experiment III.

Source	SS	df	MS	F
Trial Block	12.6	4	3.15	0.71
error	726.2	165	4.4	
total	738.8	169		

Table II:8 Summary of the analysis of variance of trial block scores for anterior turns in Experiment III.

Source	SS	df	MS	F
Trial Block	11.4	4	2.85	1.18
error	396.0	165	2.4	
total	407.4	169		

Table II:9 Summary of the analysis of variance of trial block scores for anterior contractions in Experiment III.

Source	SS	df	MS	F
Trial Block	10.05	4	2.51	1.4
error	280.3	165	1.7	
total	290.35	169		