Planaria: Memory Transfer through Cannibalism Reexamined

Abstract. *Planaria which have cannibalized untrained planaria exposed to photic stimuli only, handling only, or previous conditioning, all require significantly fewer trials in a conditioning situation than naive planaria.*

In recent years, studies suggesting specific memory transfer through cannibalism in planaria have received a great deal of attention. Studies by McConnell (*1*) and others have demonstrated that naive planaria which have cannibalized other planaria conditioned in a light-shock situation will become conditioned in fewer trials than naive controls. In addition, the more rapid conditioning is comparable to that shown by previously conditioned worms. The experiment described here was both a replication and elaboration of McConnell's work and was designed to investigate more carefully the possibility that the results of previous studies may be attributed to factors inherent in the experimental procedure, such as sensitization to light or shock, or the effects of feeding or handling.

The apparatus consisted of four U-shaped plastic troughs 25 cm in length, each filled with 10 ml of aged tap water. Twenty-five centimeters above each trough a bare, 100-watt light bulb was suspended. Cardboard partitions separated each trough, so that a minimum amount of light leaked between the troughs. Copper electrodes, with diameters identical to the inside diameter of the trough, were implanted in each end of the troughs and a 2-ma current was delivered to the electrodes from a student inductorium supplied by 6 volts, direct current. A central switching console allowed the experimenter to deliver the light-shock sequence to any trough at any time. In addition, since it has been reported that planaria condition faster when facing the cathode, the polarity of the shock was controlled at the console so that the cathode was always in the direction the worm was gliding.

The criterion of conditioning was 23 conditioned responses out of 25 consecutive trials. All conditioning was done with two experimenters present. Each experimenter independently scored every response and both had to agree that a worm had reached criterion before it could be considered conditioned. All responses were scored according to the criteria of Cornwell and Cornwell (*2*).

Following McConnell's procedure, the conditioning sequence consisted of 3 seconds of light and 1 second of shock, with shock administered during the last second of light. The interval between trials was usually 30 to 60 seconds, though it varied since a worm had to be gliding for a trial to be administered.

Twelve groups of 12 planaria each were utilized in the experiment. Of these 12 groups, 5 groups were cannibalized, 5 groups were cannibals of the first 5 groups, and 2 groups were neither cannibals nor cannibalized. The experiment was run in six blocks or replications of 2 days each, with two worms per group. On the first day of each replication of the experiment, four worms, later to be divided into two groups (groups C_1 and C_2) were exposed to the light-shock conditioning procedure, and conditioned to criterion. A third group (group L) was exposed to photic stimuli only, and a fourth group (group S) to shock only. Each of the planaria in groups L and S was matched with a conditioned worm in respect to the number of exposures to stimuli, the intervals between exposures, and the duration, and intensity of the stimuli. Thus a planarian in group L (light only) received the same number, duration, and intensity of exposures to light as a conditioned planarian. Planaria in a fifth group (group H) received handling only. Whenever it was necessary to handle a worm which was being conditioned (groups C_1 or C_2) during the procedure (that is, to touch it with a paintbrush or squirt it with an eyedropper of water to stimulate gliding), the planarian in group H (handled only) with which it was paired was treated in the same manner. The amount of handling required for any worm varied considerably as did the intervals at which handling was necessary. On an average, however, handling was required prior to approximately 10 percent of the trials.

At the end of the first day, the conditioned planaria were randomly divided into groups C_1 and C_2. The planaria in groups L, H, S, and C_1 were then individually ground up and placed in labeled containers. Four groups of naive planaria which had been deprived of food for 7 days were placed one in each container, and each was allowed to cannibalize the fragmented worm therein. The planaria in the remaining conditioned group (group C_2) were merely placed, whole and alive, in individual containers so that they could be tested again the following day to determine the number of trials required for a previously conditioned worm to reach criterion. Planaria in two additional groups were also placed in individual containers at this point. Group F consisted of naive

Table 1. Performance during conditioning trials. Significance is indicated by underscoring. Any two means not underscored at any point by any one line are significantly different at the level indicated. ....., 0.01 level; ———, 0.05 level; and _____ 0.10 level. L-ca, Cannibals of group L (planaria exposed to light only); H-ca, cannibals of group H (planaria which were handled only); C-ca, cannibals of group C_1 (planaria which had been conditioned); C_2-2, second day performance of group C_2 (planaria which had been conditioned and not cannibalized); S-ca, cannibals of group S (planaria exposed to shock only); F-ca, cannibals of group F (naive, unstimulated planaria); N, naive, unstimulated, unfed planaria (group N); and I, performance on first day of planaria known to be naive and unfed (groups C_1 and C_2).

L-ca	H-ca	C_1-ca	C_2-2	S-ca	F-ca	N	I
			Mean trials to criterion				
58.0	60.8	67.5	69.9	88.3	90.0	153.9	157.3
			Mean conditioned responses in first 25 trials				
16.9	14.7	13.9	12.7	11.6	10.2	7.6	7.1

planaria which were each allowed to cannibalize another naive worm, and group N consisted of naive planaria which remained unfed.

Twelve hours later, after all worms had had plenty of time to feed, a third person transferred each worm of the seven groups to a new individual container, identical with all other containers, and coded each so the experimenters had no clues concerning the group to which any worm might belong. After this, the experimenters then conditioned each worm to criterion, using the same conditioning procedure as before and again independently scoring the responses of each worm. The overall percentage of agreement between experimenters was 96.3 percent.

The results of the second day's testing are presented in Table 1, along with the mean for conditioning the naive worms on the first day. This latter measure is included as a base line. Table 1 also presents the results according to two different response measures, since both have been used at various times by other authors and the inclusion of both allows direct comparison to a wider range of studies. Since the significance levels between the various groups are not identical for both measures, interpretation of the results may differ slightly, depending upon the response measure used. However, the order of the means is identical for both measures, and therefore both measures would seem to support the more important conclusions one might draw from the data. In either case there was no difference between the naive planaria conditioned the first day (group I) and those naive, unfed worms trained on the second day (group N), and a Duncan's multiple range test indicates that, with either response mean, these two groups are significantly different, at the 0.10 level or beyond, from all other groups, including the group of worms which cannibalized naive worms (group F-ca).

Based on the measure of the number of trials required for the worms to reach criterion, there was virtually no difference between worms which cannibalized handled worms (group H-ca), previously conditioned worms (group C-ca), or worms exposed to light (group L-ca); and no difference between groups which cannibalized shock-exposed (group S-ca) and naive worms (group F-ca). The performance of the cannibals of the shock-exposed (group S-ca) or the naive groups (N-ca) or both were different from the performance of the cannibals of the previously conditioned (C_1-ca), handled (H-ca), and light-exposed (L-ca) groups between the .05 and .10 levels, depending upon which groups are compared. These relationships between groups do not emerge as clearly when the response measure is number of conditioned responses in the first 25 trials, since, when this latter measure is used, the means for the groups appear more evenly spaced and do not seem to cluster into subgroups as with the former measure. The very high mean number of conditioned responses in the first 25 trials for the group which cannibalized light-exposed worms (group L-ca) reflects the fact that the group contained four worms which conditioned in only 25 trials on the second day, whereas the groups which cannibalized handled (H-ca) or previously conditioned worms (C-ca) each contained only one such "genius" worm.

Both response measures indicate that the worms which cannibalized trained worms appear to condition more rapidly than naive worms, a result which supports the findings of McConnell and others. However, the worms which cannibalized worms of the light-exposed group (L-ca) and the handled group (H-ca) also conditioned more rapidly than naive controls. It is hard to explain the more rapid conditioning shown by these latter two groups in terms of transfer of specific memories. In addition, the feeding of the worms itself seemed to have some effect, as is shown by the more rapid learning of those planaria which cannibalized naive planaria (group F-ca). The apparent feeding effect is probably not, in itself, however, sufficient to explain the greater savings demonstrated by the cannibals of handled, light-exposed, and previously conditioned groups of worms (groups H-ca, L-ca, and C-ca). The inclusion of group C_2 indicates that the more rapid learning shown by groups L-ca, H-ca, and C_1-ca is similar to the more rapid conditioning one would expect for a previously conditioned worm trained again after 24 hours. The naive, unfed group (group N) included for the second day's testing serves as a very important check on experimenter bias, and the fact that the mean for this group was nearly identical with the mean for the naive, unfed worms conditioned the first day (measure I) suggests that the depression of means for all other groups was probably due to the experimental conditions, and not due to any possible expectations on the part of the experimenters.

The results do not prove that memory transfer through cannibalism may not occur. However, they do suggest that the findings of such experiments with planaria may perhaps be more adequately explained by other than the "memory transfer" hypothesis. Although presenting alternative theories at this time can be done only on a highly speculative basis, one may wish to explore the possibility that changes in nutritional or metabolic factors or resulting changes in the degree of activation or sensitization may be responsible for the reported findings.

ARLENE L. HARTRY*
PATRICIA KEITH-LEE
Psychology Department, Claremont Graduate School, Claremont, California
WILLIAM D. MORTON
Psychology Department, Occidental College, Los Angeles 41, California

References and Notes

1. J. V. McConnell, *J. Neuropsychiat.* **3** (Suppl. 1), S42, (1962).
2. P. Cornwell and G. Cornwell, *Worm Runner's Digest* **1**, 1 (1959); ———, *ibid.* **2**, 1 (1960). The criteria for the scoring of a conditioned response is as follows: C_1 = stop, or slight withdrawal of anterior, or anterior raised off substratum, or "all doubtful responses"; C_2 = smooth contraction of entire body; C_3 = strong or violent contraction of entire body; R_1 or L_1 = anterior end turned to right or left, not abruptly; and R_2 or L_2 = anterior turned to right or left abruptly.

* Present address: Psychology Department, Occidental College, Los Angeles 41, California.

27 August 1964