is the equation obtained from Eq. (1) by operating with H twice; namely

$$H^2\psi = \lambda\psi \qquad (10)$$

where λ is the Lagrange multiplier, and which must be equal to W^2. Therefore, we can conclude similarly to the Ritz method that $I_2 \geqslant W_j^2$, where W_j is the smallest energy level in absolute value of Eq. (1). If we subtract a constant V from Eq. (8), and apply this result we get Eq. (4).

[1] Courant-Hilbert, *Meth. Math. Phys.*, 149, Springer (1930).

[2] J. K. L. MacDonald, *Phys. Rev.*, **43**, 830 (1933); see also C. Eckart, *Ibid.*, **36**, 878 (1930).

[3] D. H. Weinstein, *Ibid.*, **40**, 797 (1932); **41**, 839 (1932).

A DISCRIMINATION WITHOUT PREVIOUS CONDITIONING

BY B. F. SKINNER*

BIOLOGICAL LABORATORIES, HARVARD UNIVERSITY

Communicated August 6, 1934

If two stimuli, $S_{AB..}$ and $S_{AB..L..}$, differing with respect to the property L, are conditioned to elicit a common response R, a discrimination may be established by extinguishing the response to one of them (say, to $S_{AB..}$) while continuing to reinforce the response to the other. The extinction interferes with the reinforcement (and vice versa) through "induction," to an extent determined presumably by the degree of community of properties of the stimuli. The discrimination curve obtained with the present method[1] is an extinction curve resulting from (1) the previous reinforcement of the extinguished reflex $(S_{AB..}-R)$, (2) the previous reinforcement of $(S_{AB..L..}-R)$, affecting $(S_{AB..}-R)$ through induction and (3) the concurrent inductive effect upon $(S_{AB..}-R)$ of the periodic reconditioning of $(S_{AB..L..}-R)$. If, in a special case, $(S_{AB..}-R)$ has not been conditioned before the beginning of the discrimination, the resulting curve will be composed of responses from only the last two of these sources. This case has been reported.[2] The present experiment reduces the problem a step further by beginning the discrimination before either reflex has been conditioned.

The apparatus has been described elsewhere.[1] It consists of a lever, which may be pressed downward by a white rat, the movement of which releases a pellet of food from a magazine into a tray at the will of the experimenter. A light directly above the lever may be turned on as a discriminatory stimulus. All responses to the lever are recorded automatically in the form of graphs showing number of responses vs. time.

In this apparatus eight rats were given the usual training prior to conditioning, which served to adapt the animals to the experimental box and to set up discriminatory responses to the tray based upon the sound of the food-magazine. The response to $S_{AB..L..}$ was then periodically reinforced, and all resulting responses to $S_{AB..}$ were extinguished.

A typical result is shown in figure 1, which gives records for six successive days for one rat. At the release of the rat on the first day the light was on. An investigatory response to the lever occurred quickly and was reinforced. The light and food-magazine were then disconnected. According to earlier investigations[3] some conditioning of $(S_{AB..L..} - R)$

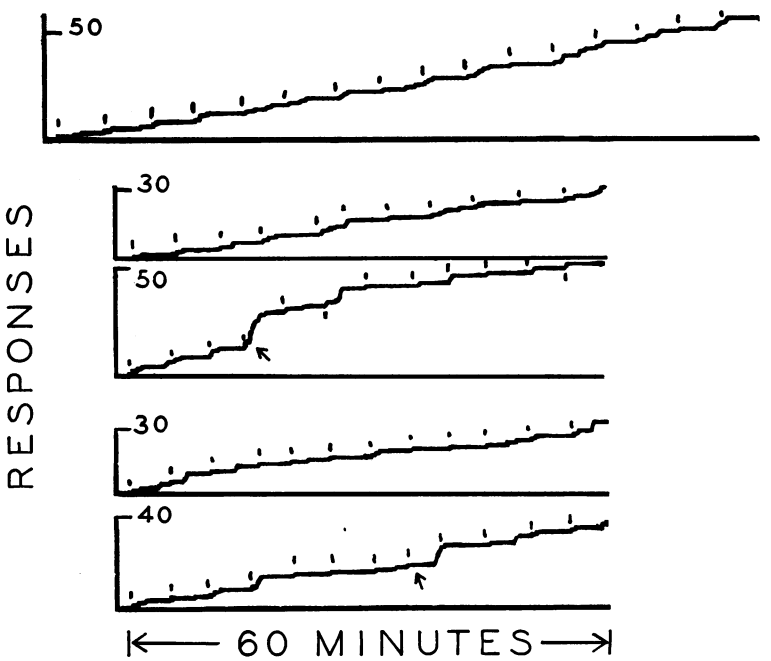

FIGURE 1

very probably occurred. If there were an inductive effect upon $(S_{AB..} - R)$, an extinction curve should follow in the absence of the light. Actually only two responses were forthcoming during the next five minutes, and it is difficult to say whether they show induction or are investigatory responses also. When the light was turned on again (at the second dot over the first record in the figure), the rat responded after 39 seconds. Both light and magazine were then turned off, and two more responses in the dark occurred during the next five minutes. This procedure was repeated for $1^1/_2$ hours, with the result shown in the figure. By the seventh reinforcement the latency of $(S_{AB..L..} - R)$ had reached a more or less

stable value of about 20 secs., which was maintained throughout the rest of the experiment. The rate of conditioning to be inferred from this drop is much lower than that previously reported. It obviously shows interference from the extinction of $(S_{AB..}-R)$.

The strength of $(S_{AB..}-R)$, on the other hand, increases slightly through induction during the first $1^1/_2$ hours to yield a rate of responding of about four responses per reinforcement. On the following day it has dropped to an average of about two responses again, and continues to decline as the discrimination becomes more effective. On the third day an extinction curve appeared spontaneously after the fourth reinforcement, and a similar effect was observed in two other cases. It is as if the response at this point were made in the absence of the light—as if the reinforcement were applied to $(S_{AB..}-R)$. We can account for this anomalous record

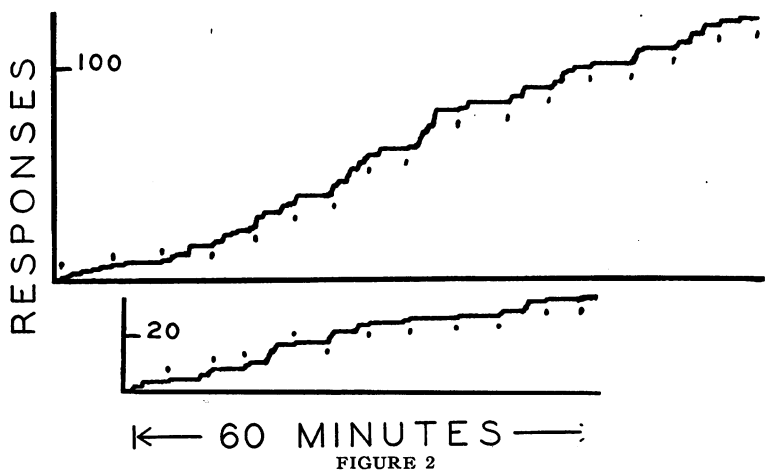

FIGURE 2

by supposing either that the rat was in the course of a response to $S_{AB..}$ when the light was turned on, or that it responded to the lever in the presence of the light but in such a way that the light was not an effective part of the total stimulus. In support of this explanation fairly similar curves can be obtained by allowing one reinforcement to take place in the dark. This was done at the arrows in the last records of figures 1 and 3. In contrast with the spontaneous curves the extinction begins in these two cases only after a delay of approximately three minutes.

Whatever the explanation of this effect may be, it does not seriously disturb the present conclusion, which is that, if a discrimination is begun before either member has been conditioned, the inductive effect may be very slight. Figure 1 is typical of six out of the eight cases. Of the six the greatest induction was observed in the case of figure 2. (This

series was broken on the third day through a technical fault.) The least induction was observed in the two remaining cases, in which an induction in the opposite direction resulted in the early disappearance of all responses. In figure 3 a similar reciprocal induction nearly brought the series to an end in the last part of the second record, where the strength of $(S_{AB..L..} - R)$ (as measured from its latency) fell severely. On the following day there was an adequate recovery, although the latency for the whole series was consistently high, averaging 41.0 secs. as against 15.5 for the other five rats. The average latency of 19.7 secs. for all six rats is approximately three times the latency observed with previous methods,[1] and indicates that with this method the extinction of $(S_{AB..} - R)$ has in general a more marked effect upon the strength of $(S_{AB..L..} - R)$.

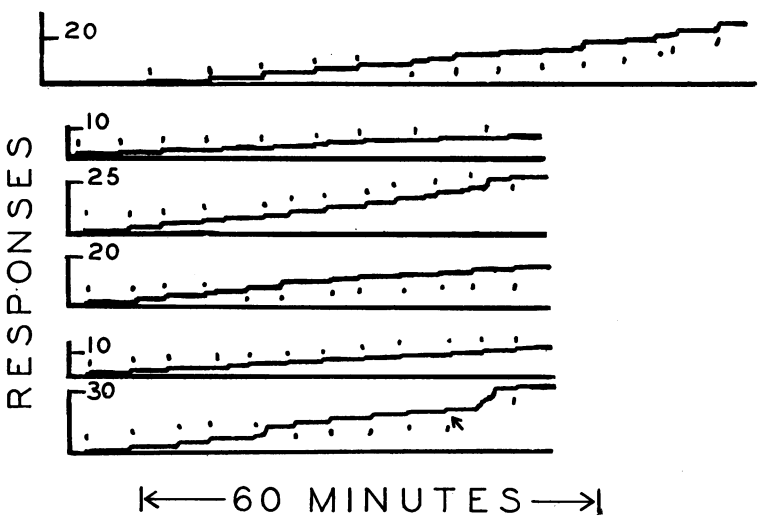

FIGURE 3

The positive induction follows a course to be expected on the basis of previous results. The typical curve for the total series is a protracted S, although the positive acceleration at the beginning may be slight. The greatest slope is never very high, and the subsequent decline is of the sort previously observed.

To control for any unconditioned difference in rate of responding in the presence and absence of the light, half of the above cases were actually of the opposite sort. The experiment in figure 1 was as described, but in figures 2 and 3 $(S_{AB..L..} - R)$ was extinguished and $(S_{AB..} - R)$ reinforced. The two cases in which the rate dropped to zero under negative induction were of the light-on-at-reinforcement type, and this agrees well with a previous report of a depressive effect of the light.[2] Eight cases

are not enough to establish the complete indifference of this condition for the present result, but it is apparent that no very great effect is felt.

* Society of Fellows, Harvard University.

[1] "The Rate of Establishment of a Discrimination," *J. Gen. Psychol.*, **9**, 302–350 (1933).

[2] "A Discrimination Based upon a Change in the Properties of a Stimulus," *Ibid.* (in press).

[3] "On the Rate of Formation of a Conditioned Reflex," *Ibid.*, **7**, 274–286 (1932); and " 'Resistance to Extinction' in the Process of Conditioning," *Ibid.*, **9**, 420–429 (1933).

EXPERIMENTS ON EARLY DEVELOPING STAGES OF FUNDULUS

BY JANE M. OPPENHEIMER

OSBORN ZOÖLOGICAL LABORATORY, YALE UNIVERSITY

Communicated July 21, 1934

Hitherto the ultimate fate of the cells in Fundulus was thought to be established during gastrulation (Lewis,[1,2] Hoadley[3]). The present investigation presents results obtained from explantation and transplantation experiments which give evidence that differentiation is controlled in part by inductive processes. Blastoderms separated from the yolk were cultivated to study the movements and the differentiation of the cells when freed from the mechanical influences afforded by the yolk. Transplantations of materials from the dorsal lip of the blastopore and from the embryonic shield were made to embryonic and extra-embryonic regions of shield stages; the donors of grafts were studied for defective parts. Experiments on Perch eggs (Oppenheimer[4]) have shown that dorsal lip transplants induce embryo-formation, and that grafts of cells from gastrulating stages continue to differentiate when implanted upon the yolk-sac epithelium or in the embryonic body of host embryos.

The explanted blastoderms were separated from the yolk and periblast between the one and the one hundred and twenty-eight cell stage. Morgan[5] secured perfect embryos after one-half to two-thirds of the yolk was removed, but failed to obtain further development if the yolk was reduced to the same size as the blastoderm. The isolated blastoderms in my experiments form spheres; cleavage proceeds at the normal rate but the cleavage planes are in different relationship to each other than those of the blastoderm cleaving on the yolk. After about eighteen hours a large central cavity develops within the round mass of cells. Slightly later a thin-walled vesicle with an epithelium one cell in thickness arises at one pole; at the other pole the remaining cells form a solid mass.