A TEST OF THE MECHANISMS OF LEARNING PROPOSED BY HULL AND GUTHRIE

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Guthrie and Hull have different theories about how learning takes place. Guthrie (2) says that the necessary and sufficient condition for learning is the temporal contiguity (or overlap) of stimulus and response. Hull (3) would agree on the necessity of S–R temporal contiguity but he would insist that drive reduction or some stimulus surrogate of drive reduction be present to complete the sufficient conditions for learning. We have tried to devise an experimental arrangement in which these two views make different predictions.

The elements of the arrangement are simple. A rat in a box is presented with a stimulus situation including a bright light. He makes some arbitrarily selected response such as walking across the box, following which *E* turns off the light. Under these conditions the rat learns to cross the box when the light is presented. This much is already known (5, 9) and can be accounted for by either Guthrie or Hull. Hull would say that the bright light creates a drive state for the rat as well as illuminating the box stimuli. The crossing response is contiguous with the illuminated box stimuli and is followed by the drive reduction of the light-off. Thus there are present the necessary and sufficient conditions for learning a crossing response in the presence of light. Guthrie would hold that the experimentally forced correlation of light and crossing is a sufficient condition for the learning of the connection, the light-off serving merely as a big enough change in the stimulus situation to

protect the light and associated stimuli from being conditioned to a new, noncrossing response.

Different predictions are made by the Guthrie and Hull theories when we reverse the conditions of the experiment. Now the rat starts from a dark box, runs, and his running turns *on* the light. Under these conditions we have the contiguity of dark-box stimuli and running, but no obvious drive reduction. According to Guthrie's principle we should expect the learned association of this S–R sequence, according to Hull we should not. It is our purpose to check the actual outcome by experiment.

APPARATUS

A plywood box, 28 in. long, 8 in. wide, and 7½ in. high with a transparent lid made up the experimental chamber. It was painted white throughout. In order to better define a crossing response, the box was mounted on a center fulcrum so that a lengthwise crossing of the box would cause it to tilt through 4° of rotation. The tilt of the box also served to trip microswitches controlling a light source and timing clock.

The apparatus was located in a dark room. Illumination came from a 100-w lamp whose light was directed into the box by a large mirror suspended over the box at a 45° angle. This arrangement prevented the box from being heated by the lamp and made easy the observation of *S*. Light intensity in the box was 31 ml. when the light was on, .001 ml. when it was off.

The apparatus was equipped with contacts, switches, and clocks such that either *E* could control the onset, duration, and termination of the light and dark periods, or control could be given to the rat in accordance with a procedure to be described.

The basic idea of this tilt-box light-aversion apparatus was originated by Keller and Oberlin (5).

PROCEDURE

The two major experimental sequences are (a) light-to-dark (L-to-D), and (b) dark-to-light (D-to-L).

L-to-D.—Animals run under the first condition are manually placed in one end of the box with the bright light on. The light remains on until S crosses the box, whereupon the light goes off and stays off for 1 min. During the 1 min. of dark, S is free to do as he likes within the box. This completes one trial. The second trial begins immediately with the light going on regardless of which side of the box S is on. As soon as S crosses the box, the light goes off again for 1 min. to complete the second trial. Ten such trials are given each day. If learning takes place, the crossing response should become progressively more prompt when the light is presented. The measure to be taken is latency, i.e., how long it takes S to turn *off* the light.

D-to-L.—Rats run under the dark-to-light condition are also subjected to the above procedure but with conditions of light and dark interchanged. The S is started in the dark. As soon as he crosses, the light goes on and remains on for 1 min. Trial 2 then starts immediately with the termination of the light. Latency here is how long it takes S to turn *on* the light.

Extra responses.—Under Cond. L-to-D S is free to make crossings during the 1 min. of darkness in each trial. A record of these is kept. They are called extra responses. Extra responses in the D-to-L condition are made during the light period of each trial.

Forced responses.—After the start of a trial, S may fail to respond for a long time and hold up the experiment indefinitely. To prevent this we adopted the procedure of waiting for a given period of time (criterion latency—3 min. of no response, or in some cases, 1 min.) and then very gently nudging the unreactive rat with a finger until he made a crossing response. These were recorded as forced responses with criterion latencies.

General conditions.—Animals were run 23 hr. hungry at approximately the same time each night. A feeding of wet mash followed each nightly session by ½ hr. When Ss were not in the experimental box, they were caged in the general colony room and there exposed for the most part to normal night-day light cycles.

Experimental design.—Each S served as its own control by running under both of the main experimental conditions. Eleven Ss (Group I) ran for five days under L-to-D and then changed to D-to-L for five days. Five Ss of Group I stayed under the D-to-L condition for a total of
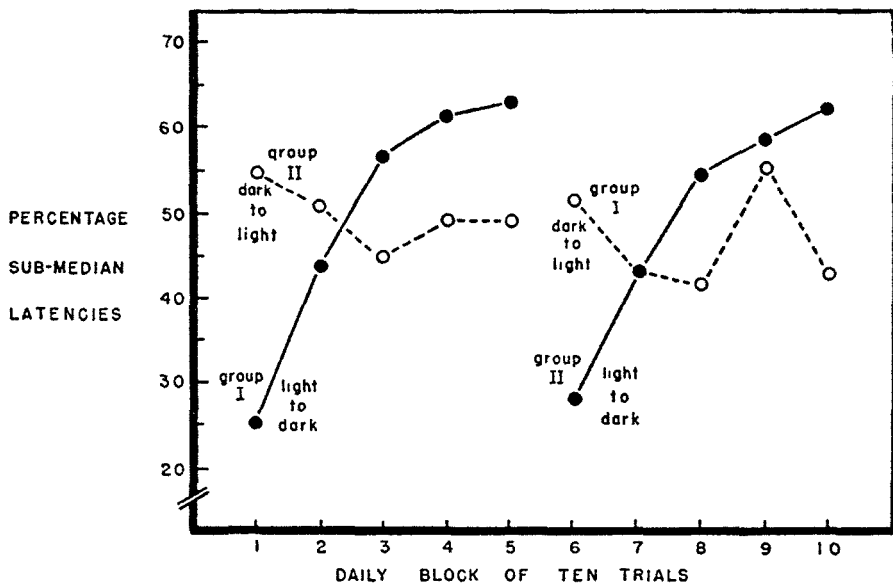

FIG. 1. The percentages of submedian latencies for Groups I and II under both conditions of light and dark sequence are presented as a function of the daily block of ten trials. The light-to-dark condition produces learning curves, the dark-to-light does not. There are 11 rats in Group I and 14 in Group II.

11 daily sessions. Group II (14 Ss) started under D-to-L, switching after five days to the L-to-D condition for five further sessions.

Subjects.—The Ss were a fairly heterogeneous group of 25 male albino rats, 17 of them at approximately 100 days of age, 8 at about 400 days. Eighteen of them were of Wistar strain, and 7 were Sprague-Dawley rats.

RESULTS

The main findings appear in Fig. 1. The percentages of submedian latencies are plotted for both groups on each day. A rising function here denotes a progressive improvement or shortening of latencies as would be expected if the rats were learning to cross the box. For both groups the condition of running from light to dark yields regular learning curves. Contrasted with them are the curves representing the performance of rats running from the dark to light. These undergo no very regular course of change. Even after the six additional days of D-to-L training the subgroup of five rats from Group I failed to improve their performance. In fact, their latencies during Days 11 through 16 (not plotted) showed some slight tendency to become lengthened. The same effect can perhaps be seen in the slightly falling L-to-D curve of Group II. More evidence of a general weakness of responding under the D-to-L condition is available when we consider the matter of forced responses. First, however, the computations and rationale behind Fig. 1 should be given.

The recorded measures of performance were latencies. From these it seemed advisable to derive a frequency measure which would wash out two sources of variation in absolute level of latency not of immediate concern to our study. One source was from the wide individual rat differences in over-all level of latencies due probably to the wide range in ages, the other was from the activity-level differences known to exist between the conditions of running in the light and running in the dark (4, 9). A measure which compared each rat's latency on a given trial with his own median latency for the condition he was running under would be insensitive to these sources of variation but at the same time be sensitive to the latency changes produced by some process such as learning. In detail the measure was derived as follows. A median latency was found for each rat from the distribution of 50 latencies recorded for him during the five days under a single condition. A rat received a frequency score each day equal to the number of latencies *below* his condition median. The number of daily submedian latencies for all Ss was counted and divided by $10N$ (ten trials times the number of rats in the group) to give the plotted measure of *percentage of submedian responses.*

The data on forced trials show Ss running into the dark to be more responsive than those running into the light, although in general there were only a relatively small number of forced trials under either condition. The median number of forced trials per daily block of ten trials for each S was zero under both conditions. The mean number of forced trials under the L-to-D condition was .01; under D-to-L, 2.02. Other than this obvious difference between the two conditions there were no important trends in the forced-trial data.

The data on extra responses did not prove to be of significance for our major theoretical purpose. They are not reported.

DISCUSSION

Taken at their face value the data support Hullian drive-reduction principles but disconfirm Guthrie's notion of the sufficiency of S–R contiguity for learning. The experimentally forced contiguity of the stimuli from a darkened box and a crossing response failed to produce evidence of learning, while the experimentally forced contiguity of the stimuli from a lighted box and a crossing response did produce and sustain learning when followed by the reduction of a light drive.

Before any general conclusion is accepted, two related questions must be answered: (a) Is this a fair test of Guthrie's theory? (b) Can an alternative explanation of these results be found without abandoning his contiguity principles?

With regard to the first question, it must be shown (a) that the conditions of the experiment conform to the variables specified in the theory, and (b) that the theory provides for the deduction of a definite behavioral outcome concerning which observations may be made. Guthrie has never formally organized his system, but Voeks (8) has formulated a set of definitions and postulates based on Guthrie's publications which are reported to be completely acceptable to Guthrie (7, p. 30). The postulates are important and brief, so they are reproduced in full:

Postulate 1: Principle of Association.—(a) Any stimulus-pattern which once accompanies a response, and/or immediately precedes it (by $\frac{1}{2}$ sec. or less), becomes a full-strength direct cue for that response. (b) This is the only way in which stimulus patterns not now cues for a particular response can become direct cues for that response.

Postulate 2: Principle of Postremity.—(a) A stimulus which has accompanied or immediately preceded two or more incompatible responses is a conditioned stimulus for only the last response made while that stimulus was present. (b) This is the only way in which a stimulus now a cue for a particular response can cease being a cue for that response.

Postulate 3: Principle of Response Probability.—The probability of any particular response's occurring at some specified time is an increasing monotonic function of the proportion of the stimuli present which are at that time cues for that response.

Postulate 4: Principle of Dynamic Situations.— The stimulus pattern of a situation is not static but from time to time is modified, due to such changes as result from the subject's making a response, accumulation of fatigue products, visceral changes and other internal processes of the subject, introduction of controlled or uncontrolled variations in the stimuli present (8).

Applying these postulates systematically to the present experiment we have the following:

Light-to-dark condition.—During the light many responses can occur but the last one is always locomotion across the box. A combination of Postulates 1a and 2a predict the association of the lighted-box stimuli with crossing. Postulate 4 says there will be from trial-to-trial uncontrolled variation in the stimuli present characteristic of the lighted box. With more trials, more of these stimuli get connected to the crossing response. As this happens, the probability of crossing within the specified time (median-latency criterion) will rise monotonically, according to Postulate 3.

During the dark cycle many responses can occur, but there is no consistent "last" response. From trial to trial, stimuli characteristic of the dark box as well as those common to both the light and dark box can become conditioned to either a crossing response or some response incompatible with crossing. Consequently, the postulates predict no progressive or cumulative association of these stimuli and responses. However, the Postremity Principle does tell us that during the dark period, the stimuli characteristic of the lighted box must remain faithfully connected to the crossing response.

The consequences of this theoretical analysis are in agreement with the observation of a rising probability curve of learning for the L-to-D condition.

Dark-to-light condition.—Interchange the words "dark" and "light" in the above analysis and it applies verbatim to the L-to-D condition. The empirical consequences are deduced to be the same but are not observed to be so in Fig. 1. We con-

clude that a logical relation has been shown between theory and data, and that in part the data deny the theory. Now the possibility is to be considered that alternative explanations of these results can be made without altering the basic postulates.

One reason likely to be offered by contiguity theorists for the failure of rats to learn to run *into* a light assumes the presence of a "freezing" response to light or some other response incompatible with the to-be-learned crossing response. A "freezing" response, if it exists, would be immediately preceded by dark-box stimuli and become associated with them according to Postulate 1. The "freezing" response would follow the crossing response, hence the Postremity Principle predicts that it would be dominant. This is an adequate alternative explanation if a good case can be made for the "freezing" response. Such a response must be inferred. It is not easily observed to light, as it is to other strong stimuli such as shock or sound. Some indirect evidence for it consists of the fact that there is lowered activity level in the light (4, 9) and that there is some suggestion of a progressive *weakening* of the response of crossing into the light in the present experiment. More evidence than this will be required to make the inference secure, however. What is needed here is a program of research on the molecular analysis of a rat's unlearned responses to the onset of a light. The crucialness of the present experiment for theory depends on the outcome of such a program. We have some experiments on this problem underway.

A second reason for the failure of learning when the response turns on a light may be that the light merely adds stimuli and does not remove those of the dark box. There could be no last or "postreme" response,

then, as far as the dark stimuli are concerned. Both crossing and not-crossing responses could occur in their presence at different times and become associated in a nonsystematic fashion. Consequently the postulate set would predict the absence of any cumulative learning effect.

This, too, is an adequate alternative explanation provided that we can accept a specification of stimuli that gives the dark box no unique stimuli in our set-up. The definition of stimulus accompanying the Voeks-Guthrie postulate set uses a criterion of afferent impulses in the CNS. If the rat eye is like the rabbit eye in displaying an "off-response" (1, p. 281ff.), there is some physiological basis for assuming stimulus elements present in the dark not present in the light. But whatever the physiological picture may turn out to be, there is other evidence of a behavioral nature that a stimulus specification of light as mere addition of stimuli leads to trouble when certain facts of discrimination are considered. We know that rats in a Skinner box can associate an R (acquisition of a lever press) with the cues provided by the dark box, and associate a not-R (extinction of lever press) with the cues of the same box lighted (6, p. 167ff.). This would not be possible if the dark cues were all present during the light. Postulate 2 would lead us to the contrary-to-fact conclusion that the dark cues, unprotected by the light, would become associated with the not-R every time an extinction trial was run. It is concluded that this is the weaker of the two alternative explanations.

These alternatives are not regarded as exhaustive of the reasonable possibilities. Others may undoubtedly be found which are testable and suggestive of further research. A highly probable alternative, or perhaps the

best contiguity postulate set, for these data has not yet been uncovered.

SUMMARY

The fact that rats will learn a response that turns off a light but not one that turns on a light is offered as a test of two theories of the mechanism of learning. Hull's reinforcement theory adequately accounts for the data. Guthrie's contiguity theory as formalized by Voeks is not directly confirmed. The crucialness of the data for Guthrie's theory is seen to be dependent upon the outcome of further research on the nature of a rat's unlearned response to light.

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