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Weak-Light Reinforcement and Response Facilitation

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WEAK-LIGHT REINFORCEMENT AND RESPONSE FACILITATION

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WEAK-LIGHT REINFORCEMENT AND RESPONSE FACILITATION

The purpose of this study was to eliminate an artifact that is believed to be present in previous studies of weak-light reinforcement in rats. Various experiments (reviewed in Appendix II of this paper) have found that rats tend to press a Skinner bar more frequently when bar-pressing leads to the onset of a weak light. It has generally been assumed that the light exerts the same kind of control over the response as would be exerted by food or water. That is, a rat is supposed to learn any response that is followed quickly by the light. It is possible, however, that this apparent reinforcement effect is an artifact of the Skinner-box technique. Kling, Horowitz, and Delhagen (1956) suggest that the flashes of light might "...somehow result in greater activity which is seen as an increase in the measured response." To equalize any effect of the sheer occurrence of the flashes on general activity (and indirectly on lever-pressing), Kling, et al. wired a pair of Skinner boxes so that whenever an experimental S received the light, so did a control S. Here the experimental Ss responded more frequently than did their controls, suggesting that the light had reinforced, and not merely facilitated, bar-pressing.

It may be doubted, however, that this "yoked-box" method entirely controls facilitation. Since the experimental S necessarily is close to the bar whenever the light occurs, and since the control S can be anywhere in the apparatus, any activity resulting from the light flashes would be expected to produce more presses by the experimental Ss than by their controls even if the light had no reinforcing power. Fortunately,

the yoked-box technique is not the only way to control facilitation. An alternative technique is the so-called "retention" method (Crowder, Wilkes, and Crowder, 1960). Here the test for bar-pressing is made some time after the lever-training session; the S is returned to the apparatus on the next day and responses are recorded. Since the light is never presented during this test, facilitation is thought to be eliminated entirely.

The present study included three tests for weak-light reinforcement, one of which endeavored to control facilitation by the yoked-box method and another by the retention method; the third did not purport to control facilitation. Two questions were asked: (a) Do the three tests lead to the same conclusion regarding the reinforcing power of the light? (b) According to the (presumably) more valid retention test, does weak-light onset exhibit reinforcing properties?

METHOD

Subjects

The Ss were 58 naive Holtzman male albino rats, approximately 75 days old at the start of the experiment. Six additional Ss were discarded before the test day: two due to an error on the part of E and four that failed to respond on the training day. Three discarded Ss were from the experimental group and three were from control groups. This left 29 Ss in the experimental group, 15 Ss in the "conventional" control group, and 14 Ss in the "yoked-box" control group.

Apparatus

The apparatus consisted of two Skinner boxes and appropriate control and recording devices. A Skinner box was a wire-mesh living cage,

9 in. wide by 14 in. long by 7 in. high. The lever was made of .02-in. stainless sheet steel, 4 in. wide, with one end rolled into a 1-in. cylinder which extended 1½ in. into the cage, 5 in. above the floor. It was mounted on a ball-bearing shaft and was equipped with felt stops limiting the lever travel to less than ¼ in. and providing almost noiseless operation. A force of 10 gm. was required to actuate the bar. The reinforcing light came from a 6-w., 115-v. lamp centered 6 in. above the lever. The Skinner boxes were light- and sound-shielded by large Masonite cover boxes, lined with 1-in. thick Fiberglas and ventilated by means of a blower. The control and recording apparatus was located in a separate room.

Procedure

The Ss were run in pairs. The members of a pair were housed together with food and water available at all times. The experiment lasted 2 days: one day of lever training and one day of testing for retention of the lever training.

Lever Training--On the first day one member of each pair was randomly assigned to the experimental group. The other Ss were assigned approximately equally and at random to the "conventional" and the "yoked-box" control groups. The Ss were placed in the Skinner boxes for 25 min. The first 10 min. was a habituation period during which no signals were presented. Its purpose was to reduce the unconditioned rate of responding, which tends to be higher when the animals are first placed in the apparatus.

Immediately following the habituation period, 15 min. of lever training were given. Whenever the experimental S responded, a 1-sec.

light-flash was presented to it, and, if its control S were a yoked-box animal, to the latter as well. The conventional control Ss received no light at any time. All responses were recorded on magnetic counters. Neither food nor water was available in the Skinner boxes.

Retention Test—The S were placed in the Skinner boxes for 20 min. All responses were recorded but the light was not presented to any animal.

RESULTS AND DISCUSSION

Table 1 shows the mean number of responses for each group during lever training and also during the retention test. Table 2 shows the results of t tests performed on differences between groups on each day.

TABLE 1

Mean Number of Lever Presses Made on the Training Day and on the Retention Test Day

Group	Training	Retention
Experimental (N = 29)	65.2	43.2
Yoked-box control (N = 14)	36.6	38.5
Conventional control (N = 15)	27.8	39.6
Both control groups (N = 29)	32.0	39.1

TABLE 2

Group Mean Comparison Between Experimentals, Yoked-box Controls, Conventional Controls, and Combined Controls

Group Compared	t	df	p
Training Day			
Experimentals vs. yoked-box controls	4.05	41	<.001
Experimentals vs. conventional controls	5.66	42	<.001
Yoked-box controls vs. conv'l controls	2.06	27	<.05
Retention Test Day			
Experimentals vs. yoked-box controls	.56	41	>.50
Experimentals vs. conventional controls	.48	42	.60
Experimentals vs. combined controls	.69	56	.50
Yoked-box controls vs. conv'l. controls	.17	27	.80

Three measures of reinforcement were taken. The first measure compared the experimental group with the "conventional" or no-light control group *during* lever training as most previous studies have done. The experimental *Ss* pressed the bar more than twice as frequently as did the conventional controls (65.2 vs. 27.8 responses). This difference was highly reliable according to the *t* test ($p < .001$), confirming the findings of previous investigations.

The second measure compared the experimental group with the yoked-box control group, again during lever training. Like Kling, *et al.* (1956), who also used yoked-box controls, the present study found significantly more responses by the experimental *Ss* than by the yoked-box controls (65.2 vs. 36.6 responses; $p < .001$). Hence, by this more

stringent test, the light still appears to have been reinforcing.[1]

The third ("retention") measure compared the experimental group with both control groups on the day after lever training. The light was absent during this test. If the experimental Ss had learned to press the bar, they would be expected to have retained the "habit" for at least a day. On the other hand, the light could not have evoked bar-pressing during the test for retention, since at that time the light was never presented. On the retention test, the experimental group pressed slightly more often than did either control group (43.2 vs. 39.6 and 38.5 presses respectively). Neither difference approached statistical significance: both levels of confidence exceeded .50. The retention scores of all 29 control Ss were then combined and were compared with those of the 29 experimental Ss. Again, the experimental-control difference failed to reach significance ($p = .50$). What had seemed to be a marked reinforcing effect during lever training could not be detected on the retention test. The results of the present experiment thus suggest that the light did not reinforce bar-pressing, but only served to facilitate it.

A number of previous studies have employed the retention measure. Crowder, et al. (1960), like the present study, gave a single day of lever training with a retention test on the following day. One

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[1]The yoked-box control group made significantly more presses than the conventional control group. This could have resulted either from response facilitation or from "chance" occurrences of the light just after presses by yoked-box Ss. The absence of any difference on the retention test points to the first explanation.

experiment found no retention of the preference. The other found a small but significant preference for the previously rewarded bar; however, an unpublished replication of it failed to show a significant retention of the lever preference. Kish (1955) gave mice 6 days of operant level testing, 1 day of conditioning with light-onset, and 4 days of extinction. A significant difference between the experimental and control groups was found on the first day of extinction. Stewart and Hurwitz (1958) employed an extinction measure to compare two experimental conditions (rather than an experimental with a control condition), and found a significant difference between the groups. Hurwitz (1956) found an apparent retention of light reinforcement on the first day of extinction but did not report any significance tests. Kling, et al. (1956) gave 4 days of operant level testing, 11 days of lever training via light, and 3 days of extinction. Although the difference between the experimental and control groups was not significant during extinction, it did approach significance on the first day. Forgays and Levin (1958) presented 14 days of lever training and 7 days of extinction. During extinction, significantly more responses were made by the experimental Ss than by the controls. Thus theirs was the only study to find unequivocal evidence that weak-light onset is reinforcing to rats.

The discrepancy between the results obtained by Forgays and Levin and those of other studies suggests that some crucial determiners of weak light reinforcement might be revealed through an examination of the unique features of their method. One such feature is their inclusion of female Ss (60%), whereas the other rat experiments mentioned above have used exclusively male animals. While Forgays and Levin did not

report any sex differences, it is possible that weak light is more reinforcing for female rats. Another difference was the duration of the light. In the study by Forgays and Levin, the light stimulus lasted 5 secs. following each response by an experimental S. In the other studies the light remained on for only 1 sec. (present study) or as long as the S pressed the lever (Davis, 1958; Kling, et al., 1956). Perhaps longer flashes of light are more reinforcing than short flashes. A third difference is the size of the bar in relation to the floor area of the Skinner box. Forgays and Levin employed a small lever (2 in. by 1 in.) and a much larger box (21½ in. by 11¼ in.) than any other weak light study. The effect probably was to reduce the operant level, which was only about 5 responses during the first 15 min. that S was in the apparatus. Kling, et al., Davis, and the present study all found much higher operant levels than were shown by the Ss of Forgays and Levin.

Presumably the generally low level of responding in the Forgays and Levin apparatus resulted in longer times between flashes. If, as some writers believe, the light stimulus is reinforcing by virtue of its novelty, its reinforcing power should diminish with massed presentations of it. This speculation might account for another unusual finding of Forgays and Levin, namely, that the response rate increased markedly over successive lever-training days. Kling, et al., as well as Davis, found the response rate to be maximal on the first day of lever training and to decrease thereafter. Thus Forgays and Levin found gradual improvement during lever training and complete retention. In contrast, other studies typically find high response rates on the first training days, declining rates with further training, and no significant retention.

These differences could be understood in terms of the hypothesis stated above (weak light onsets are reinforcing only to the extent that they are distributed), together with the low initial response rate shown in the apparatus of Forgays and Levin. Slow responding produces gradual development of a strong "habit" while rapid responding produces abrupt development of a weak "habit," and, with further training, even a decline in strength.

SUMMARY

The purpose of this study was to investigate the reinforcing power of the onset of a weak light, while controlling for any direct facilitating or evoking effects of the light. Rats were given 15 min. of lever training in a Skinner box, with each response producing a 1-sec. presentation of light. Just as in previous studies, the rats receiving the light for responding pressed more often than did rats not receiving the light. This difference could have been due to reinforcement, facilitation, or both.

A partial control for facilitation was provided by presenting the light to a third group of Ss ("yoked-box" controls) whenever the experimental Ss responded and received the light. Again, more responses were made by the experimental Ss.

In an attempt to eliminate all possible facilitation effects, an additional test for reinforcement was made. This test consisted of placing all Ss back in the Skinner box on the day following lever training, and recording the bar-presses but never presenting the light. It was supposed that the light's reinforcing effects—if any—would be retained for at least one day, but that the light, being absent, could

not elicit or facilitate the lever response. The combined control groups (N = 29) made almost as many responses as did the 29 experimental animals. The difference between the groups reached only the 0.50 level of significance.

These data do not appear to support the hypothesis that the onset of a weak light acts as a reinforcer with white rats. An alternative interpretation was suggested, however. The reinforcing power of the light may depend upon its novelty and hence may weaken if the light is presented frequently, as in the present experiment. Indirect evidence supporting this interpretation was presented.

APPENDIX I

RAW SCORES FOR INDIVIDUALS AND SUMS OF SQUARES FOR GROUPS

Numbers of Lever Presses for Each S

Training Day		Retention Test Day	
Experimental	Yoked-box	Experimental	Yoked-box
95	40	46	35
68	35	28	18
84	38	45	45
52	41	18	42
126	56	50	51
78	22	22	34
43	23	37	63
80	26	72	19
96	31	102	24
48	51	3	58
52	24	46	82
84	24	61	17
51	49	50	36
85	52	55	15
	Conventional		Conventional
102	24	69	53
42	15	35	26
86	18	33	26
52	15	36	32
68	18	50	36
34	28	20	28
21	39	24	38
42	41	41	42
56	32	26	61
62	29	40	30
57	41	42	44
53	29	10	76
39	28	19	38
41	13	34	36
95	47	139	28

Sums of Squares (x^2)

Training Day		Retention Test Day	
Experimental	16805	Experimental	20929
Yoked-box	1869	Yoked-box	5147
Conventional	1616	Conventional	2808
		Combined control	7964

APPENDIX II

REVIEW OF PREVIOUS WEAK-LIGHT REINFORCEMENT STUDIES

INTRODUCTION

The initial work in the field of weak-light reinforcement was done by Kish in 1955 with mice as Ss. About the same time Marx, Henderson, and Roberts (1955) reported a series of experiments using rats. In both of these early studies the light appeared to be reinforcing.

Between 1955 and 1960, some 19 additional studies of weak-light reinforcement have been reported. Many of them attempted to answer questions concerning the existence of unconditioned reinforcing powers of the onset (or sometimes offset) of a weak light. Others assumed that reinforcement had been demonstrated, and sought to discover the specific variables which affected it. The present review is an attempt to bring together a description of the various experimental methods used and to mention some of the results that have been presented.

METHODS

Subject Variables

Species and Strains—Most of the studies have employed domestic rats, with albino and hooded rats about equally divided. Monkeys were used in one experiment (Moon & Lodahl, 1956), and mice in another (Kish, 1955).

Ages—The ages of the Ss ranged from approximately 1 to 6½ months. Levin and Forgays (1959) investigated the relationship between the age of Ss and the response rate when each response was followed by a flash of light. With high illumination, older Ss responded more frequently

than did younger animals. In the case of low illumination, the results of their two experiments did not agree; one found more responses from younger Ss and the other from older Ss.

Sex—Both sexes have been used, but males have been employed exclusively in about 2/3 of the studies. No sex differences are reported.

Apparatus

Cages—All cages used for experimentation were modified Skinner boxes. Those used with rats varied in size and shape from 8 by 8 by 8 in. to 21½ in. long by 11¼ in. wide by 15½ in. high. About half of the cages described were constructed of wood, either unpainted or painted flat black or flat gray. One box was made of Plexiglas (Forgays & Levin, 1959), one of brown Masonite (Levin & Forgays, 1959), two of wire mesh (Crowder, et al., 1960; Present study), and one was constructed from an aluminum ice chest (Segal, 1959). Most of the boxes had floors made of wire mesh.

Lights—

Type. About half of the studies employed some sort of diffusion plate (frosted glass, plastic, or white paper) behind which was mounted a bulb. Of the remaining studies, several used just clear glass bulbs, and three (Hurwitz, Unpublished manuscript; Hurwitz & Appel, Unpublished manuscript; Appel & Hurwitz, 1959) used bulbs covered with red plastic.

Amount of light. Some investigators reported lamp intensities, others illuminations, and still others brightnesses. The source intensities reported varied from 7 to 15 watts, the illuminations from 1 to 20.7 foot-candles, and the brightnesses from .01 to 36 mL. Levin and Forgays (1959) investigated the relationship between brightness (of the

lever) and rate of responding following light onset. They found that dim light was a more effective reinforcer than bright light for young animals. For older Ss the results of their two experiments did not agree. One found that bright light was more reinforcing; the other that dim light was more reinforcing. Marx, Henderson, and Roberts (1955) reported a series of experiments using brightness levels of .024 mL, 1.18 mL, 6.97 mL, and 16.56 mL. They found significantly positive reinforcing effects for all levels.

Duration. In about half of the studies the light remained on as long as the lever was held down. In others the response produced a light-flash of fixed duration ranging from ½ sec. to 5 sec. in different experiments. Several studies did not report on the duration of the light.

Location. Most of the studies have centered the light source either directly above the lever (adjacent to 7 in. above) or in the roof of the box. Two studies (Stewart & Hurwitz, 1958; Hurwitz & De, 1958) placed the light source slightly to the left and above the lever, and one study (Clayton, 1958) reflected the light through the floor by means of a mirror. Thomas, Appel, and Hurwitz (1958) investigated the effect of the position of the light with respect to the lever. No effect was found.

Light onset vs. light offset. Four studies have reported information concerning light onset vs. light offset as reinforcers. Moon and Lodahl (1956) reported that both illumination increase and decrease significantly augmented the rate of responding in monkeys. Roberts, Marx, and Collier (1958) reported that light offset produced fewer responses than light onset. Robinson (1959) reported that light onset significantly increased the response rate in rats but that light offset

was not reinforcing. Hurwitz (1956) also investigated the effects of light onset vs. light offset but did not report any tests of significance.

Levers--

Size and shape. The sizes and shapes of levers have varied greatly, ranging from a 1/8-in. bar extending 1 in. into the cage (Roberts, et al., 1958) to a lever made of sheet steel, 4 in. wide, with one end rolled into a 1-in. cylinder which extended 1½ in. into the cage (Present study). One study (Marx, et al., 1955) used an L-shaped bar, and three (Kling, et al., 1956; Kish, 1955; Forgays & Levin, 1958) have used U-shaped bars. Many of the studies did not describe the levers. Thomas, Appel, and Hurwitz (1958) investigated the effects of lever size and of changes in lever size. They reported that a larger lever leads to a greater number of responses than does a smaller lever during initial conditioning. They also reported that a shift in lever size, regardless of the direction, also produces more responses to light onset than are found in the Ss first encounter with the experimental situation. However, their design did not in fact permit a crucial test of the effect of changing the lever size.

Location. In the rat studies, levers were placed from 3/4 in. (Segal, 1959) to 5½ in. (Levin and Forgays, 1959) above the floor. Some reports did not specify the location of the lever. This variable was not investigated specifically.

Force and travel. Pressures between 2 gm. (Hurwitz, Unpublished manuscript) and 30 gm. (Robinson, 1959) were required for the operation of the levers. Most of the studies did not report the extent of travel although two studies (Kling, et al., 1956; Kish, 1955) used fixed,

contact-sensitive bars.

Lever sounds. Only a few reports gave any indication of the quietness of their levers. Those reporting indicated that the levers operated very quietly.

Two-lever apparatuses. Two studies (Crowder, et al., 1960; Forgays & Levin, 1959) employed pairs of levers, with responses to one of the levers producing the light. Here, each S serves as its own control.

Recording Devices—Most of the studies employed magnetic counters. One study (Kling, et al, 1956) used also a kymograph, and another (Forgays & Levin, 1958) used a cumulative recorder.

Procedures

Food and Water Deprivation—In about half of the studies Ss were placed on food deprivation; in two others (Clayton, 1958; Thomas, et al., 1958), on water deprivation; and in one (Segal, 1959), on food and water deprivation. Clayton (1958) found a significant interaction effect between water deprivation and weak-light reinforcement; that is, weak light was more reinforcing for the water-deprived Ss. Davis (1958) and Segal (1959) found the same to hold for food deprivation, and further that the effect was greater for increased deprivation. On the other hand Hurwitz and De (1958) and Forgays and Levin (1958) failed to find such an interaction between hunger and weak-light reinforcement.

Light Deprivation—Most of the studies did not indicate the lighting conditions of the home cages; presumably no "special" lighting conditions were maintained. In three studies (Kling, et al., 1956; Hurwitz & Appel, Unpublished manuscript; Robinson, 1959) Ss were maintained in 12-hr. light, 12-hr. dark cycles, in one (Clayton, 1958) they

were always kept in the light, and in one (Marx, et al., 1955) always in "subdued lighting." Roberts, Marx, and Collier (1958) found that animals maintained in the dark responded equally for light onset and light offset, and that Ss kept in the light responded more for light onset. Hurwitz and Appel (Unpublished manuscript) reported no difference between Ss tested for light reinforcement in the light half of a 12-hr. light-dark cycle and those tested during the dark phase.

Control Conditions--One or more control conditions were included in about half of the studies. Typically, the control condition was the same as an operant level test: bar-pressing was recorded but not reinforced. Kling, et al. (1956) used the same "yoked-box" technique employed in the present study. Many studies omitted control groups and merely compared two or more experimental conditions with each other.

Kinds and Numbers of Sessions--Operant level sessions refer to conditions in which a response produces no change in the amount of light present. Operant level is discussed in more detail below. Training sessions refer to those in which light onset (or sometimes offset) is contingent upon the occurrence of some response. There were from 1 to 20 such sessions in the various studies. Six studies (Kling, et al., 1956; Stewart & Hurwitz, 1958; Hurwitz, 1956; Kish, 1955; Robinson, 1959; Present study) employed extinction sessions, the same as operant level sessions except that they followed the training periods.

Duration of Sessions--About half of the studies used 30 min. sessions for all conditions. Others used sessions lasting from 10 to 25 min. with the exception of two experiments (Moon & Lodahl, 1956; Crowder, et al., 1960) which employed 60-min. periods.

Operant Level Sessions--About half of the experiments did not use operant level sessions. Others employed sessions ranging from 60 min. for 1 day (Crowder, et al., 1960) to 25 min. daily for 30 days (Segal, 1959). Robinson (1959) tested the response rate of two groups of Ss, one for which the response led to light onset; the other to light offset. Half of each of these groups had been given operant level pretests in the dark; the other half in the light. No significant effects of the operant level light conditions were found. Appel and Hurwitz (1959) reported that Ss responded significantly more when placed in the apparatus for 5 daily sessions (with no light being presented) before the experimental test day than did Ss that were tested on the first day.

Response Measures--Generally the total number of responses per session was recorded for each S. One study (Hurwitz, 1956) also measured the duration of each response (presumably with a kymograph) but did not use this measure in the statistical analysis. Another study (Roberts, et al., 1958) recorded the number of responses per 5-min. interval and the average response duration (total duration divided by number of responses) for each interval for each S. Some studies also used log transformations of the individual response frequencies.

MAJOR FINDINGS

Some of the studies to be reported are mentioned above, and some previously mentioned studies are not included here because of the inconclusiveness of their findings.

Food and Water Deprivation

The results of the different studies do not agree. Three of them (Clayton, 1958; Davis, 1958; Segal, 1959) found food and/or water

deprivation to increase the effects of the light. Two others (Hurwitz & De, 1958; Forgays & Levin, 1958) failed to find such an effect.

Light Deprivation

Roberts, Marx, and Collier (1958) reported that animals maintained in the dark responded equally for light onset and light offset, and that Ss kept in the light responded more for light onset. However Hurwitz and Appel (Unpublished manuscript) found no difference between Ss tested for light reinforcement in the light half of a 12-hr. light-dark cycle and those tested in the dark phase.

Partial Reinforcement

Stewart and Hurwitz (1958) reported that Ss given lever training with a 3:1 ratio of reinforcement responded significantly more than did Ss reinforced with a 6:1 ratio. This difference was also found during extinction.

Repeated Training Sessions

Kling, et al. (1956) and Davis (1958) found a higher rate of responding on the first day of lever training than on succeeding days. Two studies by Forgays and Levin (1958; 1959), however, found progressively increasing response rates on successive days of lever training.

Previous Light Reinforcement

Forgays and Levin (1959) investigated the effect of 10 days of lever training, beginning at 32 days of age, on reinforced responding at the age of 80 days. More responses were made by the previously trained Ss. However, no such effect was found for animals tested at 130 days of age.

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