Effects of reinforcement on response alternation[1]

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The alternation between two lever-pressing responses, maintained by sucrose solution reinforcement, was observed in hooded rats under conditions of no differential reinforcement of alternation (baseline condition) and under conditions where differential reinforcement of alternation was in effect (experimental condition). Exposure to the experimental condition produced both immediate and cumulative increases in relative frequency of alternation.

Numerous theoretical and experimental papers have considered the subject of behavioral variability, and it is possible to classify such research by the type of independent variables involved. Independent variables employed in past research include amount of deprivation (Carlton, 1962; De Valois, 1954), drugs (Carlton, 1961; Hearst, 1959), magnitude of reinforcement (Carlton, 1962), frequency or schedule of reinforcement (Antonitis, 1951; Gates & Fixsen, 1968; Herrnstein, 1961; Millenson & Hurwitz, 1961; Notterman, 1959), intertrial interval (Heathers, 1940; Still, 1966), apparatus characteristics (Dember, 1961; Dember & Fowler, 1958), and variability-dependent reinforcement (Carlton, 1961; Hearst, 1959, 1962; Schoenfeld, Harris, & Farmer, 1966; Still, 1966).

It is possible to consider alternation between two qualitatively different responses as an instance of behavioral variability, although this is perhaps the most limited range of variability that can be allowed an organism. Such behavior has been extensively treated in the literature on "spontaneous" maze alternation (Dember, 1961; Dember & Fowler, 1958) and, more recently, in free-operant studies (Carlton, 1961; Hearst, 1959). The above-mentioned experiments have examined relatively transitory, "local," or short-term effects of experimental variables on response alternation. The present study was concerned with possible long-term or cumulative effects of differential reinforcement of alternation upon subsequent "spontaneous" alternation.

APPRATUS

Two sound-insulated operant conditioning chambers, measuring 10 x 8½ x 10 in., were used. Each chamber had a grid floor and two response levers mounted 3 in. apart on the front wall. Two metal barriers were mounted between the levers in order to prevent their simultaneous operation. Between the levers and their respective barriers was mounted a 2 x 2 in. Plexiglas door, which the rat could nuzzle open to gain access to a lick-hole under which a stream of sucrose solution could be passed. A dim houselight was positioned at the rear of each chamber, while a bright light was mounted 2 in. above the Plexiglas door.

SUBJECTS

Fourteen naive female hooded rats (150-175 g, Blue Spruce Farms) were used. During magazine training, the Ss were 22 h food- and water-deprived, whereas during all subsequent experimental stages, Ss were 22 h food-deprived and given free access to water. Following each experimental session, the Ss were given 1 h access to standard laboratory chow.

PROCEDURE

Magazine Training

During magazine training, Ss were 22 h food- and water-deprived and placed in the experimental chambers for 15-min sessions. The bright front-wall light was illuminated and extinguished on a variable-interval schedule, and door-nuzzling responses produced 32% sucrose solution only when this light was on. This procedure established the front-wall light as a discriminative and conditioned reinforcing stimulus.

Lever-Response Training

In the first baseline stage ($Base_1$), all Ss were exposed to a procedure in which the depression of either the right or the left lever produced the onset of the front-wall light in whose presence a door-nuzzling response produced a 1-sec sucrose stream. Light offset was simultaneous with offset of the sucrose stream. Each session was terminated after 15 min or after the rat had obtained 100 reinforcements.

Measurement of Alternation

The number of response alternations occurring within each session was recorded for each S. In this experiment, a response alternation was defined as the depression of the response lever *other than* the lever that last produced reinforcement. For instance, if an animal pressed the right lever, was reinforced, and then pressed the left lever, an *alternation* was said to have taken place. If, however, the rat pressed the right lever, was reinforced, and then pressed the right lever again, a *repetition* was said to have occurred. Only the first lever response after each reinforcement was considered in measuring alternations and repetitions. A "relative frequency of alternation" measure was calculated for each S for each session according to the formula: Relative frequency of alternation = (No. alternations)/(No. reinforcements).

Differential Reinforcement of Alternation

For the first experimental stage (Exp_1), the rats were divided into two groups of seven rats each, and two separate reinforcement schedules were in effect for the two groups:

For the ALT group during Exp_1, only one of the response levers was "set up" at any one moment to produce the onset of the front-wall light and the opportunity for reinforcement. After each reinforcement, control of the light-and-reinforcement sequence was shifted to the opposite lever. This shift of control from lever to lever was determined solely by the occurrence of a reinforcement and not by the particular sequence of left and right presses performed by the S.

For the control group (CON), Exp_1 conditions remained the same as those that prevailed in $Base_1$. At any one moment, *both* levers were capable of producing the light-and-reinforcement sequence so that neither alternation nor repetition was differentially reinforced.

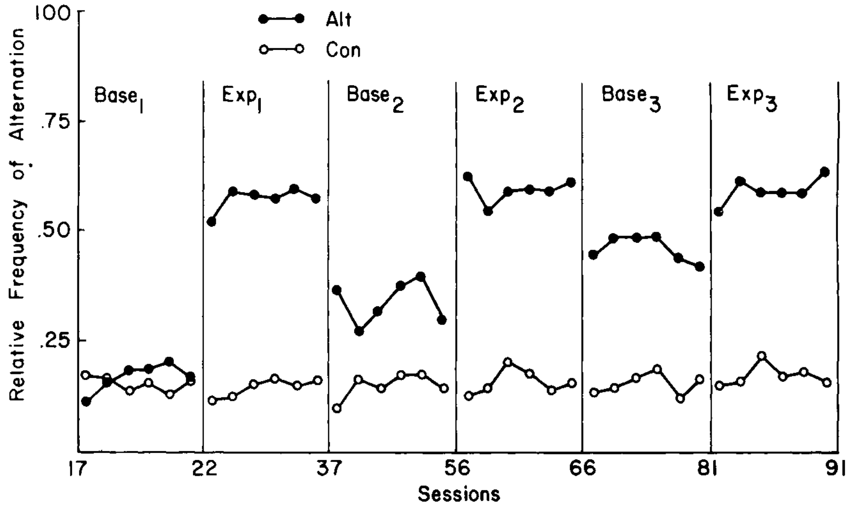
For both groups, as in the $Base_1$ condition, only the first lever response after each reinforcement was considered in measuring alternations and repetitions. Session durations in the Exp conditions were of the same length as those in the Base conditions, i.e., 15 min or 100 reinforcements.

Blocks of baseline-condition sessions were then alternated with blocks of experimental-condition sessions. Relative frequency of alternation measures were

Table 1
Mean Relative Frequency of Alternation and Mean Standard Deviation for ALT and CON Groups, Arranged by Blocks of Baseline-Condition and Experimental-Condition Sessions. (Group means, last six sessions per block.)

	Group			
	ALT		CON	
Block	Mean	SD	Mean	SD
Base 1	.17	.17	.16	.17
Exp 1	.58	.14	.15	.19
Base 2	.34	.20	.15	.18
Exp 2	.60	.11	.16	.18
Base 3	.46	.24	.16	.19
Exp 3	.60	.13	.17	.20
Mean of Means for Base 1, Base 2, Base 3	.32	.20	.16	.18
Mean of Means for Exp 1, Exp 2, Exp 3	.59	.13	.16	.19

Fig. 1. Relative frequency of alternation as a function of sessions (group means, last six sessions of each condition).



taken throughout all stages, and these measures were allowed to stabilize before conditions were changed. The order of baseline and experimental stages and the number of sessions devoted to each were as follows: $Base_1$, 15 sessions; Exp_1, 15 sessions; $Base_2$, 19 sessions; Exp_2, 10 sessions; $Base_3$, 15 sessions; Exp_3, 10 sessions.

RESULTS

Group means and mean standard deviations of the relative frequency of alternation were computed for the last six sessions of each block of baseline and each block of experimental sessions. These means and mean standard deviations are presented in Table 1. The effects on the ALT group of exposure to Exp conditions are evident in the increase in relative frequency of alternation during Exp stages as compared to the relative frequency of alternation during Base stages. The calculated t for the difference between the ALT group's mean Base and mean Exp relative frequency of alternation was 4.57 ($p < .01$, two-tailed test, 6 df). The effects of exposure to Exp conditions are also evident in the higher relative frequency of alternation displayed by the ALT group during Exp conditions as compared to the CON group during Exp conditions. The calculated t for the difference between the ALT group's and the CON group's mean Exp relative frequency of alternation was 5.209 ($p < .001$, two-tailed test, 12 df).

As can be seen from Table 1, the ALT group showed a progressive increase in its Base relative frequency of alternation with repeated exposures to blocks of Exp sessions. This increase is presented more clearly in Fig. 1, where group means of relative frequency of alternation are plotted for the last six sessions of each condition. The calculated t for the difference between the ALT group's $Base_1$ and $Base_3$ mean relative frequency of alternation was 3.48 ($p < .02$, two-tailed test, 6 df).

Since the relative frequency of alternation measure is a ratio defined as (No. alternations)/(No. reinforcements), it is possible that the increases in the ALT group's relative frequency of alternation scores were due, not to increases in the number of alternations, but to decreases in the number of obtained reinforcements. Examination of the data revealed that such decreases in number of reinforcements did occur, but that they were quite small in comparison with the increases in number of alternations. The difference between the ALT group's mean Base and mean Exp relative frequency of alternation was due to a 2% decrease in number of reinforcements and a 78% increase in alternations over Exp_1, Exp_2, and Exp_3. The difference between the ALT group's $Base_1$ and $Base_3$ mean relative frequency of alternation was due to a 4% decrease in number of reinforcements and a 152% increase in number of alternations. The difference between the ALT group's and the CON group's mean Exp relative frequency of alternation was due to the ALT group's obtaining 4% fewer reinforcements and displaying 283% more alternations than the CON group. Appropriate t tests for each of these comparisons revealed no significant differences in number of reinforcements obtained.

DISCUSSION

The results replicate the previous finding that lever-response alternation can be increased in frequency through the differential reinforcement of alternation (Carlton, 1961; Hearst, 1959). Marked differences were obtained between conditions where no differential reinforcement of alternation was in effect (Base conditions) and conditions where differential reinforcement of alternation was imposed (Exp conditions).

More importantly, with respect to the main concern of this experiment, the results indicated that repeated exposure to sessions of differential reinforcement of alternation had a cumulative or residual effect upon the ALT group's rate of "spontaneous" alternation observed in Base conditions. This group displayed a large increase in relative frequency of alternation between the first and third Base blocks, two blocks of sessions of differential reinforcement of alternation having intervened. This suggests that such "historical" variables as previous schedules of reinforcement may be of equal significance in determining "spontaneous" alternation as "concurrent" variables, such as deprivation, drugs, apparatus characteristics, or reinforcement magnitude.

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NOTES

1. The experiment was initiated as part of the NSF Undergraduate Research Participation Program at the University of Tennessee, in which W. S. Foster was a participant, financed by NSF Grant GY-4546. The experiment was continued as part of a research program on the Amount of the Reinforcement Value of Various Conditioning Procedures under the direction of H. M. B. Hurwitz and S. F. Walker, USPHS Grant MH12115-03.
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Effect of visual pattern restriction in early life on brain enzyme in the rat[1]

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The present study was conducted to ascertain whether the visual patterning or the intensity of environmental light in early life is the critical factor in inducing reported behavioral and physiological changes in adult animals (cf. Singh et al, 1967). After weaning, littermate female rats were raised in either total darkness, facing a black-and-white striped or a flat-white enclosure for 70 days. Results show that these visual conditions produce differential body weight gains and melatonin activity in the pineal gland. On the basis of these findings, it appears that previously reported physiological changes were not due to the intensity of environmental light.

In an earlier study, Singh et al (1967) reported that rats raised in a visually complex environment gain more body weight and show greater brain acetylcholinesterase (AChE) activity than those rats raised in a less complex visual environment. Specifically, the visual input of those rats raised in a visually complex environment was restricted to a black-and-white pattern, while the rats raised in a less complex visual environment faced only a flat white surface. The obtained differences between these groups were interpreted by the authors as an indication of the role played by visual patterning in inducing physiological changes. However, there are a few studies that have shown that the reduction of environmental light causes increased melatonin synthesizing enzyme [hydroxyindole-O-methyltransferase (HIOMT)] activity in the pineal gland, which in turn seems to affect the functioning of the endocrinological system (Wurtman, Axelrod, & Chu, 1963; Wurtman, Axelrod, & Phillips, 1963). Now, the amount of light reflected by a black-and-white striped field, compared to a flat-white field, is less; though not highly probable, it is possible that the increased AChE activity and greater body weights of rats raised in a black-and-white striped field (complex visual environment) may be due to the reduction of environmental light rather than the visual patterning.

If the reduction of environmental light is indeed the critical variable, then one should find greater HIOMT activity in the pineal gland of rats raised in black-and-white striped environment compared to those raised in flat-white environment. To test this notion, rats were raised in black-and-white striped and flat-white visual environments. A group raised in total darkness was also added, since previous studies have shown that rats raised in total darkness have heavier pineal glands and greater HIOMT activity than rats raised in illumination (Wurtman et al, 1963).

SUBJECTS AND EARLY EXPERIENCE

Sixty-six littermate female albino rats (obtained from Holtzman Company), weaned at 20 days of age and matched for body weight, were assigned randomly to a dark (D), visual pattern (VP), or a restricted visual pattern (RVP) group. The visual environment of the VP group consisted of a board painted with ¾-in.-thick alternating black and white stripes, while the visual field of the RVP group was restricted to a flat-white painted board. All Ss were individually housed in stainless steel cages with wire mesh fronts; the visual pattern boards were hung 12 in. in front of the cage racks. The overhead fluorescent illumination diffused light evenly over all cages, and lights were on throughout the experiment. The D group animals were raised in total darkness until 90 days of age. Ss in all conditions were on ad lib food and water and were never touched, nor were their cages removed throughout the experimental period (70 days), except when the animals were weighed and rated for emotionality at 55 days of age.

PROCEDURE

All Ss were weighed and rated for emotionality on the King scale (1958) at 55 days of age. The King emotionality scale basically consists of lightly tapping the animal on the back, capturing, and handling; scores are assigned for vocalization, jumping, urination, and defecation. After emotionality rating, all Ss continued in their respective experimental conditions until 90 days of age, when all Ss were weighed and tested for emotionality for a second time. Starting at 91 days of age, all Ss were tested for 11 days for sensory conditioning. The procedure and findings of this test are reported elsewhere (Singh, Johnston, & Maki, 1969). At the age of 103 days, all Ss were decapitated, and the pituitary, adrenal, and pineal glands of each S were removed and weighed. The brain of each S was removed, weighed, and divided into four samples (anterior cortex, posterior cortex, anterior subcortex, posterior subcortex) and frozen for biochemical analysis. All brain samples and pineal glands were coded so the analyst was unaware of the treatment conditions to which the samples belonged. The AChE activity of brain samples was determined by the rate of hydrolysis of acetylcholine perchlorate (Ach), employing the procedure as reported by Rosenzweig, Krech, & Bennett (1958). The AChE findings will be reported elsewhere as a

Table 1
Median Body Weights for Dark (D), Restricted Visual Pattern (RVP), and Visual Pattern (VP) Groups for Four Weighing Periods

Rearing Condition	Body Weights (g)	Age in Days 20	55	90	103
Dark	Median	52	162	213	235
	Range	45-57	126-187	179-247	215-264
RVP	Median	51	165	214	231
	Range	45-56	150-182	195-240	214-258
VP	Median	53	171	221	237
	Range	45-58	157-202	198-255	208-266