Frustration effects after varied numbers of partial and continuous reinforcements: Incentive differences as a function of reinforcement percentage*

JAMES J. HUG
University of Toronto, Toronto, Canada

Magnitude of the frustration effect (FE) was assessed after 16, 40, and 64 acquisition trials under continuous (CRF) and partial (PRF) reinforcement conditions. The data indicated that FE magnitude increased with the number of training trials under both reinforcement schedules and that, although the effect was more pronounced under CRF conditions with relatively few reinforcements, there was no difference in the magnitude of the effect as a function of CRF vs PRF after additional reinforcements. Assuming that the strength of incentive or expectancy is a factor in the magnitude of the FE, these data can be taken as confirming Spence's (1960) speculation that PRF decelerates the conditioning of incentive but does not affect its asymptotic strength.

In what has come to be referred to as the Amsel (1958)-Spence (1960) theory of instrumental reward learning, the strength of primary frustration (R_F) has been assumed to vary as a positive function of the strength of anticipation of reinforcement (r_R - s_R). Since it has also been assumed that the strength of r_R - s_R is partially determined by the number of reinforcements, the magnitude of primary frustration should vary directly with the number of prior reinforcements. The recent data of Patten & Myers (1970), Stimmel & Adams (1969), and of Yelen (1969) tend to support this proposition.

Spence has further addressed himself to the strength of r_R - s_R under continuous (CRF) vs partial (PRF) reinforcement conditions. He tentatively assumed (1960, Chap. 6) that early in training the strength of r_R - s_R will be weaker in the PRF condition, which typically involves only half as many rewards as compared to CRF at any point in training, but that relatively later in acquisition, the difference in strength of r_R - s_R will be markedly reduced, if not eliminated entirely. One way in which Spence's further hypothesis can be examined is in the double-runway situation in which the number of reinforcements can be varied, and hence the strength of r_R - s_R manipulated, in the first runway and the magnitude of R_F can be measured in the second. (Using this type

of procedure, differences in the strength of primary frustration are inferred from differences in the magnitude of the frustration effect (FE), which is the difference between second-runway performance following reward and nonreward in the first runway.) In the present experiment, number of reinforcements and CRF vs PRF were varied orthogonally.

If differences in FE magnitude as a function of CRF vs PRF were found after a small number of reinforcements (acquisition trials) but not after a larger number, these differences might be interpreted as supporting Spence's hypothesis. If, on the other hand, the CRF vs PRF difference in FE magnitude were

found to be independent of the relative amount of training, then one might conclude that percentage of reinforcement has an effect on the asymptotic strength of r_R - s_R .

METHOD

Forty male albino rats of the Wistar strain, approximately 50-60 days old, were obtained from Woodlyn Farms, Guelph, Ontario. For 8 days they were housed two per cage and were given ad lib food with tetracycline added to the drinking water. After 12 days on a 12-g/23-h food-deprivation schedule (which was continued throughout the experiment) with ad lib tap water and living in individual cages, 3 days of runway exploration began. The Ss were 73-83 days old on the first day of acquisition.

An L-shaped double-alley runway was used. Alley 1 was painted flat black, covered with clear Plexiglas, and contained in series: an 11-in. entrybox, 11-in. startbox, and 47-in. alley. Guillotine doors separated the start and entry chambers and formed a 21-in. goalbox (GB). The food pellet was concealed in a small black metal cup placed approximately 2½ in. above the runway floor on the side of the end wall opposite to the door leading to Alley 2. Alley 2 was placed perpendicular to Alley 1, was 45 in. long, unpainted pine, and had a hardware cloth floor with a 14-in. GB. It was also covered with clear Plexiglas. Guillotine doors controlled access to Alley 2 and formed the GB. In the second alley the food pellet was concealed in a gray metal trough, extending the length of the end wall at a

Table 1
FE Magnitudes as Functions of Trials and Reinforcements

Four-Trial Block	Group 0C/80P		Group 16C/64P		Group 40C/40P		Group 64C/16P	
	Reinforcement	FE	Reinforcement	FE	Reinforcement	FE	Reinforcement	FE
1	1-2	-.02	1-4*	.04	1-4*	.02	1-4*	.01
2	3-4	.05	5-8*	.00	5-8*	.08	5-8*	.04
3	5-6	-.08	9-12*	-.03	9-12*	-.03	9-12*	-.02
4	7-8	.01	13-16*	-.01	13-16*	-.05	13-16*	.03
5	9-10	-.06	17-18	.19	17-20*	-.01	17-20*	.07
6	11-12	.03	19-20	.23	21-24*	.03	21-24*	-.06
7	13-14	.13	21-22	.30	25-28*	.01	25-28*	.03
8	15-16	.09	23-24	.28	29-32*	.04	29-32*	.05
9	17-18	.15	25-26	.31	33-36*	.06	33-36*	.02
10	19-20	.27	27-28	.18	37-40*	.02	37-40*	.01
11	21-22	.22	29-30	.29	41-42	.48	41-44*	.05
12	23-24	.31	31-32	.37	43-44	.53	45-48*	.03
13	25-26	.39	33-34	.40	45-46	.45	49-52*	-.01
14	27-28	.46	35-36	.35	47-48	.49	53-56*	.02
15	29-30	.40	37-38	.43	49-50	.52	57-60*	.01
16	31-32	.45	39-40	.49	51-52	.57	61-64*	.03
17	33-34	.49	41-42	.52	53-54	.53	65-66	.55
18	35-36	.56	43-44	.50	55-56	.58	67-68	.62
19	37-38	.50	45-46	.54	57-58	.54	69-70	.59
20	39-40	.53	47-48	.59	59-60	.61	71-72	.66

Note—FE magnitudes are the differences between Alley 2 speeds (feet per second) after nonreward and reward in Alley 1, calculated in blocks of four trials. * represents CRF trials.

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height of 2½ in. above the floor. Both runways were 2-7/8 in. wide x 3-7/8 in. high. Microswitches on the start doors, silent photoelectric circuitry, and .01-sec clocks were used to obtain 1-ft measures of response time. In Alley 1 these measures were obtained over the first 36 in. of the runway; in Alley 2 measures were obtained over the first 24 in.

All Ss received 80 acquisition trials with a 300-mg food pellet in each GB. The two daily trials were separated by an ITI of approximately 30 min. The Ss were randomly assigned to four groups on arrival. Group OC/80P received 50% reinforcement in GB1 on all 80 trials. Groups 16C/64P, 40C/40P, and 64C/16P were switched from CRF to 50% after 16, 40, and 64 trials, respectively. All groups received CRF in GB2 throughout. The Ss were run as two squads, with an equal number of Ss from each group per squad. Running order varied randomly across days; the same running order was followed for the two squads on both trials of any experimental day. The Ss were not run on weekends. The 50% reinforcement schedule consisted of the recursive sequence, RRNNRRNNRRNNRR, having all four first-order transitional probabilities equal to .50; Ss began this sequence at the 1st, 5th, 9th, and 13th elements so that any given experimental trial consisted of both R and N goal events.

The Ss were hand carried from the colony to the experimental room. After orienting to the Alley 1 start door, they were released into the first runway. On rewarded GB1 trials they were released into the second runway 5 sec after completion of eating; approximately 15 sec were required to consume the 300-mg pellet. On nonrewarded GB1 trials they were released into Alley 2 after a 20-sec confinement to GB1. Removal from GB2 occurred upon completion of eating.

RESULTS

The five latency measures were converted to speed scores by reciprocal transformation. Alley 1 data are irrelevant here and are not presented.

Alley 2 data were analyzed as a Groups (4) by Goal Event (2) by Blocks (20) design. The triple interaction among these variables was significant in both the start, $F(57, 684) = 9.56$, and run, $F(57, 684) = 3.56$, measures, both $p < .01$. Separate analyses of variance were computed on the trials following reward in GB1 (TFR). As there were no groups or Groups by Goal Event effects ($p > .10$) in either measure, it would appear that the differences in FE magnitude reflect differences in performance on trials following GB1 nonreward (TFN) but not TFR differences. The further analyses

necessitated by the significant triple interaction were based on blocks of trials as well as on blocks of reinforcements.

Table 1 contains FE-magnitude data for the four groups on the start measure, along with the number of reinforcements that had been received prior to and during a particular block of trials. Detailed data for the run measure are virtually identical and are not included in Table 1. The Groups by Goal Event interaction, indicative of group differences in FE magnitude, was significant ($p < .05$) on all blocks of trials except for Blocks 1-4 (start and run measures), 5 (run), 7 (run), and 17 (start and run). Subsequent Tukey-A contrasts for those blocks having a significant Groups by Goal Event interaction served to further isolate group differences in FE magnitude. During Blocks 5-10 (Trials 17-40), Groups OC/80P and 16C/64P were receiving partial reinforcement necessary to measure the FE. For the 10 sets of contrasts in both start and run measures, Group 16C/64P showed an FE on eight occasions, as inferred by FE magnitudes significantly greater than for both Groups 40C/40P and 64C/16P, which were then receiving only R trials in GB1. In contrast, Group OC/80P, which received PRF throughout and hence fewer reinforcements, showed only one FE. Furthermore, the FE magnitude in Group 16C/64P was greater than in Group OC/80P on 8 of these 10 occasions.

The next group of contrasts encompassed Blocks 11-16 (Trials 41-64). Over these blocks all groups except 64C/16P were on partial reward in the first alley and, in principle, could show the FE. Groups 40C/40P and 16C/64P, which had received, respectively, 40 and 28 reinforcements prior to Trial 41, gave FEs on all 12 occasions, as inferred by FE magnitudes greater than those for Group 64C/16P, which was still a control, i.e., CRF, condition. By the same criterion, Group OC/80P, having received 20 prior reinforcements, gave 10 FEs. Comparisons among the three then-partial groups indicated that on seven occasions FE magnitude was larger in Group 40C/40P than in Group OC/80P. On two occasions Group 40C/40P gave a larger FE than did Group 16C/64P. However, the difference in FE magnitudes between this latter group and Group OC/80P was reliable on only 1 of the 12 occasions.

The final group of contrasts involved Blocks 17-20 (Trials 65-80). Up to this point, the respective groups had received 32, 40, 52, and 64 reinforcements. In the six sets of contrasts, no significant differences were obtained. Examination of Table 1 and consideration of the statistical summary apparently warrants the

following conclusions. Regardless of the number of prior CRF trials, all groups gave reliable FEs. For groups having relatively few CRF trials prior to partial reinforcement, i.e., Groups OC/80P and 16C/64P, FE magnitude increased from zero to a rather substantial level. Alternatively, for groups having more prior CRF trials, i.e., Groups 40C/40P and 64C/16P, FE magnitude was large and relatively constant over the series of partial reinforcement trials. Comparing FE magnitudes after 16 CRF (16 reinforcements) or 16 PRF (8 reinforcements) trials, there was apparently a difference that was maintained until the groups had received, respectively, 28 and 20 reinforcements. Comparing after 40 CRF (40 reinforcements) and 40 PRF (20 reinforcements) trials, the difference in FE magnitudes again appeared to be substantial and was maintained until Trial 64, at which point 52, as opposed to 32, reinforcements had been received. And finally, there appeared to be no difference in FE magnitudes after 64 CRF vs PRF trials, as Groups OC/80P and 64C/16P did not differ reliably during Trials 65-80. Looking next at FE magnitude after 0, 16, 40, and 64 CRF trials, a negatively accelerated increasing function results. Thus Group OC/80P showed no immediate FE, Group 16C/64P had an initial FE of approximately .20 (TFN-TFR speeds in feet per second), Group 40C/40P had one of approximately .50, and Group 64C/16P had one of approximately .55.

A second set of analyses was based on data points for which the number of prior reinforcements was constant but the number of prior trials varied as the between-group parameter. The FE can be measured in both Groups OC/80P and 16C/64P as these Ss obtained reinforcements 17-40. The former group had had 32 prior trials on a partial schedule, and the latter 16 on CRF. The Groups by Goal Event interaction was significant, when blocks was used as a repeated measure, but in the start measure only, $F(1, 684) = 16.33$, $p < .01$. This interaction resulted from the larger FE displayed by Group 16C/64P. The FE can also be measured in Groups 16C/64P and 40C/40P as these Ss obtained their 41st-48th reinforcements. The former group had, at that point, received 16 reinforcements on a partial schedule and 24 on CRF, while the latter had received all 40 prior rewards on CRF. In this case, the Groups by Goal Event by Blocks analysis of variance revealed no significant Groups by Goal Event or triple interaction in either start or run measures. Looking at percentage reward effects when number of prior reinforcements had been equated,

there is a weak indication that schedule effects are of consequence with relatively few rewards, but apparently no evidence for differential FE magnitude resulting from different percentages of reinforcement after additional training trials had been given.

DISCUSSION

Assuming that the magnitude of primary frustration (R_F), which is indexed by the FE, is influenced by the strength of anticipation of reward (r_R - s_R) or, in Spence's (1960) terms, incentive motivation (K), the present results might be interpreted as suggesting that r_R - s_R reaches the same asymptotic strength under partial as under continuous reinforcement conditions. After a relatively small number of acquisition trials, the FE was larger after prior CRF than after prior PRF training. However, this difference was not obtained after a larger number of acquisition trials.

Logically, if it is assumed that r_R - s_R reaches the same asymptotic value under the two different percentages, it follows that the strength of r_R - s_R is not reduced on N trials of the partial-reward schedule. This implication is apparently in agreement with the present data, especially after a relatively large number of reinforcements. Thus, in the analyses reported here, there was minimal evidence for differences in FE magnitude as a function of percentage of reward, when the number of prior rewards had been equated.

Although the interpretation of these data is somewhat speculative, the data themselves are in agreement with previous studies of this kind. Examining FE magnitude as a function of number of prior CRF rewards, Stimmel & Adams (1969)

found a positive relationship using 35 vs 75 trials (270-mg food reward), as did Yelen (1969), who compared 12, 36, and 60 CRF trials (97-mg food reward). In a slightly different paradigm, Patten & Myers (1970) found a larger FE after 72 than after 12 CRF trials, when the effect was obtained by reducing GB1 reward from 360 mg to 45 mg. Furthermore, Amsel & Ward (1965, Experiment 2) noted a larger FE after 48, when compared to 12, reinforcements prior to a test phase involving discrimination learning in the first alley and the measurement of the FE in the second. Finally, Wagner (1959) found no evidence for differential FE magnitude when conditions involving 80 prior CRF vs PRF trials (100-mg food reward) were contrasted.

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Number of food pellets and the development of the frustration effect*

JAMES J. HUG

University of Toronto, Toronto, Canada

Following few-trials partial-reinforcement studies, the effect of number of food pellets (total magnitude of reward equated) on the development of the frustration effect (FE) was investigated. Multiple pellets in the first goalbox resulted in more rapid development of the FE but did not affect its terminal magnitude. In contrast, the number of pellets in the second goalbox had no effect on either the rate of development of the terminal strength of the FE. The results were seen as supporting the frustration-theory account of few-trials experiments.

A rather sizable body of experimental data suggests that the presence or absence of the partial-reinforcement effect (PRE) after very limited acquisition, i.e., two to

five trials, is in part determined by the nature of the rewarding condition (e.g., Amsel, Hug, & Surridge, 1968; McCain, 1966). In their account of these findings,

Amsel et al assumed that multiple food pellets or wet mash rewards, as contrasted to one or two food pellets, serve two functions: (1) accelerate the conditioning of expectancy (r_R - s_R) so that extinction is frustrating (R_F) after multiple-pellet acquisition but not after single-pellet training, and (2) result in sufficient r_R - s_R so that nonrewarded acquisition trials produce R_F and thereby allow for the development of the persistence mechanism, i.e., the counterconditioning of the instrumental response to anticipatory frustration (r_F - s_F). Although a subsequent study by these authors (Amsel, Surridge, & Hug, 1969) cast some doubt on the validity of the second assumption, the first remains viable as an explanatory device.

One implication of the first assumption is that primary frustration (R_F) will develop more rapidly, and possibly have a higher asymptotic value, when multiple pellets, as opposed to few, are used. This implication derives from Amsel's (1958) basic assumption that R_F varies directly with the strength of r_R - s_R . Accordingly, the frustration effect (FE), from which the strength of R_F is inferred, was studied as a function of multiple- vs single-pellet reinforcements with the total magnitude of reinforcement equated.

METHOD

Forty male albino rats of the Wistar strain were obtained from Woodlyn Farms, Guelph, Ontario, and were approximately 80-90 days old on arrival. They were immediately placed on a 12-g/23-h food-deprivation schedule, given 30 min after completion of the daily session, with ad lib drinking water. The Ss were handled for 1 min daily for the 16 days prior to pretraining.

An L-shaped double-alley runway was used. Alley 1 consisted of an 11-in. entrybox, an 11-in. startbox, and a 47-in. alley. It was painted flat black. Guillotine doors separated the start and entry chambers and formed a 21-in. goalbox (GB). The food pellet was concealed in a small black metal cup placed approximately 2½ in. above the runway floor on the side of the end wall opposite the door leading to Alley 2. Alley 2 was placed perpendicular to Alley 1, was 45 in.

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