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PARTIAL REINFORCEMENT: CONTINUOUS REINFORCEMENT TRANSITIONS — NEUTROCHEMICAL AND BEHAVIOURAL CORRELATES*

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SINOPSIS

Kajian ini bertujuan mengkaji kesan peralihan dari ganjaran separa kepada ganjaran berterusan ke atas prestasi aktiviti tekan tuas. Pada masa yang sama, perubahan paras biokimianya akibat dari proses tersebut juga diukur. Kesemua subjek dilatih pada mulanya dengan menggunakan jadual ganjaran separa dan kemudian diuji dengan perlakuan berikut: i) diberi ganjaran secara berterusan (PR.CR) dan ii) diberi perlenyapan jenis 1 (PR. EXT1). Keputusan kajian menunjukkan tidak ada kesan yang signifikan ke atas kegiatan tekan tuas apabila ganjaran diberi secara berterusan. Kesan "elasi" tidak dapat disokong. Apabila kumpulan kawalan dibanding dengan kumpulan eksperimen, didapati tidak ada perubahan yang signifikan dalam sama ada paras 11-OHCS maupun monoamina otak. Dengan itu peralihan dari PR ke CR tidak mempengaruhi sebarang perubahan yang signifikan dalam prestasi pembelajaran dan paras biokimia haiwan.

SYNOPSIS

The aim of this research was to investigate the effects or partial: continuous transitions (PR.CR) which should provide the least frustration on the subject involved in the bar press activities. At the same time, the biochemical changes due to such transitions were also measured. All the subjects in the experiment were initially PR-trained and then tested by the foloowing treatment: i) continuous reinforcement schedule of food presentation (PR.CR) and ii) extinction procedure type one (PRE.EXT1). The result demonstrated that there was no significant increase in bar press activities when reward presentation frequencies were increased. The "elation" effect was not then substantiated. When the result of the experimental group was compared with that of the control, there seemed to be no significant changes in either the level of plasma 11-OHCS or the whole brain monoamines levels. Thus, the transitions from CR to PR schedule did not induce any significant increase in bar press activities and at the same time produce no significant changes in the biochemical levels of the animals.

INTRODUCTION

It was presumed that in the presence of the original training stimuli, the maximum drive due to frustration will enhance the ongoing response when

* Part of this article is extracted from part of the findings in the author's Ph.D thesis presented to the University of Newcastle, Australia.

the nonreward condition is introduced. Included in the original stimuli are all those conditioned stimuli and rewards presented during acquisition phase. There are a number of requirements of experimental procedures if the role of the original stimuli in boosting and maintaining the ongoing behaviour is to be dimonstrated. First, all the training stimuli must be present during extinction. Second, food must be initially available, becoming unavailable only after the presentation of sight and smell during frustration trials. An apparatus suitable for such an experiment is a modified Skinner box. The food can be made available on every press during training In order to frustrate the animal, the food cup can be modified in such a way that its base can be moved in and out so letting the food pellet fall away whenever the rats are about to consume it.

Rats were trained using food reward in a bar press procedure. Acquisition training was given using either a CR or PR (FR10) schedule and rats were then tested on one of a combination reinforcement schedules and methods of food withdrawal. It was hypothesized that the training stimuli would play an important role in maintaining the bar pressing in frustrating situations.

In a previous experiment (Yahaya 1948a) the CR.EXT1[1] group showed a significantly elevated bar press response frequency compared to the CR.CR control group, whereas in another experiment (Yahaya 1984b) the PR.EXTa group exhibited a significanlty lower bar press response compared to the PR.PR control group. However, when EXT1a method was applied to CR-trained subjects, the bar press responses in the CR.EXT1a group did not differ significantly from those of CR.CR control group (Yahaya 1985).

In the present experiment, the EXT1 method was expected to produce more bar press responses. With continuous presentation of food reward and conditioned stimuli, the frustration due to non-reward should provide drive to boost the bar press response. In addition, as in previous experiment (Yahaya 1984a) the frequent presentation of food reward and associated conditioned stimuli should direct the rats toward the instrumental response (bar press) rather than to competing emotional behaviour. The bar press response if not boosted, at least should not be significantly different from that of the PR.PR control group. In the same context, the continuous presentation of food (available to be consumed) should be much stronger in maintaining the bar press response than the PR.EXT1 procedure as was the PR.PR method over that of the PR.EXT1a method. The result in Experiment 3 (Yahaya 1984a) gave an indication that the presentation of food at the end of the 10th press which then could be consumed was important in order to maintain the bar press response. Furthermore the frequent presentation of food should produce a facilitative effect of reward increase (elation effect) which could energize more responses (Meyer &

[1]The terms used herein and elsewhere shall be explained in Table 1.

McHose 1968). Hence, the aim of the present experiment was to determine whether the continuous presentation of food (either available or unavailable to be consumed) and its associated conditioned stimuli would be more effective in maintaining bar press responses.

One result of Experiment 3 (Yahaya 1984b) showed that there was no significant change in plasma 11-hydroxycorticosterone (11-OHCS) and whole brain monoamines in extinction of PR-trained rats in relation to the control group. However, the introduction of the CR schedule in testing was expected to initiate changes in plasma steroids and whole brain monoamines.

TABLE 1. Summary of the Testing Behavioural Procedures Used

Procedure	Schedules Used During Testing
*CR	One pellet was dispensed by every press.
EXT1	The pellet was dispensed into the food cup every time the bar was pressed. The pellet disappeared when the rat attempted to obtain it.
EXT2	Only the "click" was sounded every time the rat pressed the bar but no food was delivered.
EXT3	Neither pellet nor the mechanical noises associated with the delivery was presented when the bar was pressed.
PR	The pellet was dispensed at every 10th bar press.
EXT1a	Similar to EXT1 except that the pellet was delivered at every 10th bar press (instead of continuously).

*The prefix, either PR or CR will represent the schedules *methods* used during training e.g. PR.CR.

A study relevant to the present experiment was that of Goldman, Coover & Levine (1973) which showed that PR-trained rats exhibited a significant lowering of plasma 11-OHCS when put on a CR schedule. The major differences between the present experiment and that of Goldman et al (1973) lie in the training days and fixed ratio (FR) number. Goldman et al (1973) took 50 days to train their rats and used FR20 compared to the present experiment which used only 14 days and FR10. The difference in methods used provides an important reason for measuring plasma 11-OHCS. The continuous introduction of training stimuli in extinction is another reason for determining the changes of plasma 11-OHCS. Thus, the other aim was to determine the level of plasma 11-OHCS as a consequence of PR.CR transitions.

Changes in monoamines were expected to occur with the introduction of continuous training stimuli. As reflected by the previous experiment (Yahaya 1985), there was a significant decrease in whole brain serotonin (5-HT) when food was introduced at each 10th bar press. With the introduction of continuously available consumable food, lowering of whole brain 5-HT would be expected. Thus it is important to determine the changes in whole brain 5-HT as a result of PR.CR transitions.

Transitions of CR:PR caused a significant change in whole brain Noradrenaline (NA) levels but no significant change in whole brain Dopamine (DA). In the present experiment, it was expected that the change of PR in training to the CR schedule in testing would produce change in whole brain NA level, and at the same time a change in whole brain DA level as the introduction of food could motivated the PR-trained rats. Thus, another aim of this experiment was to determine the changes in whole brain monoamines due to PR.CR transitions.

METHOD

SUBJECTS

Eighteen naive male albino Wistar rats were used, aged between 90 – 100 days at the start of the experiment. The rats were housed individually in stainless cages (25 cm × 14 cm × 20 cm). The temperature of the holding room was 23 ± 1 C and 12:12 hour light/dark cycle was maintained.

The rats were randomly allocated to two groups (n = 9). The groups were: the partially reinforced-continuously reinforced group (PR.CR) and the partially reinforced-extinction 1 group (PR.EXT1). As with the other experiments (Yahaya 1985) the groups from the previous experiments (the HCD, HCF[2] and PR.PR group) (Yahaya 1984b) were included in the Results for baseline and control comparison.

APPARATUS

The equipment and apparatus used were similar to those described in the previous experiment (Yahaya 1984a).

PROCEDURE

The procedure used here were pretraining and acquisition training as described in the previous experiment (Yahaya 1984a) and acquisition/ training in experiment 3 (Yahaya 1984b).

TESTING

Following the procedures described in the previous experiments (Yahaya 1981a, 1984b, 1985), testing was carried out when rats had reached a stable

[2]Rats in the HCD group were given 12 gm of pellets each day while rats in the HCF group were given free access to food.

bar press response. Both groups were trained initially on an FR10 schedule. The procedures in the next stage were:

Partially reinforced-continuously reinforced (PR.CR group). In testing the schedule of continuous reinforcement was applied in this group.

Partially reinforced-extinction 1 (PR.EXT1 group). The rats in this group were tested with EXT1 schedule.

RESULTS

Two behavioural and four biochemical measurements were recorded for analysis:

i/ Frequencies of the bar press response,

ii/ Percentages of "emotional" behaviours,

iii/ Plasma 11-OHCS levels (μ g/100 ml blood plasma),

iv/ Whole brain 5-HT levels (ng/g brain tissue),

v/ Whole brain NA levels (ng/g brain tissue), and

vi/ Whole brain DA levels (ng/g brain tissue).

i/ *Frequencies of the bar pressing responses.* The mean frequencies and the standard errors (SEs) of the bar pressing responses for the three treatment conditions are presented in Table 2. A one-way ANOVA was used to analyse bar press responses separately for the pretest day and the test day. The summary of the analyses is presented in Table 3. The result shows that for th pretest day, the treatment effect was not significant while there was a significant treatment effect for the test day ($F(2,24) = 621.83$, $p < .0001$).

TABLE 2. Means and Standard Errors of the Bar Press Responses for Three Groups

Treatment Group	Pretesting Day (P)	Testing Day (T)	T/P × 100 (%)
PR.PR	957 ± 97.698	1079 ± 107.157	112.79 ± 1.715
PR.CR	1004 ± 51.420	169 ± 10.345	17.06 ± 1.252
PR.EXT1	828 ± 75.155	365 ± 33.136	45.21 ± 2.772

Figure 1 present the frequencies of bar press responses on the test day relative to the pretest day under three treatment conditions. The mean bar press responses separately for the pretest day and the test day. The sum-the other groups (Table 2). Post hoc comparisons using the Newman-Keuls test, show that the PR.CR group has significantly fewer bar press responses compared with the PR.CR ($p < 0.1$) and the PR. EXT1 group ($p < .05$). Also the bar press response of the PR. EXT1 group was significantly lower that of the PR.PR control group ($p < 01$).

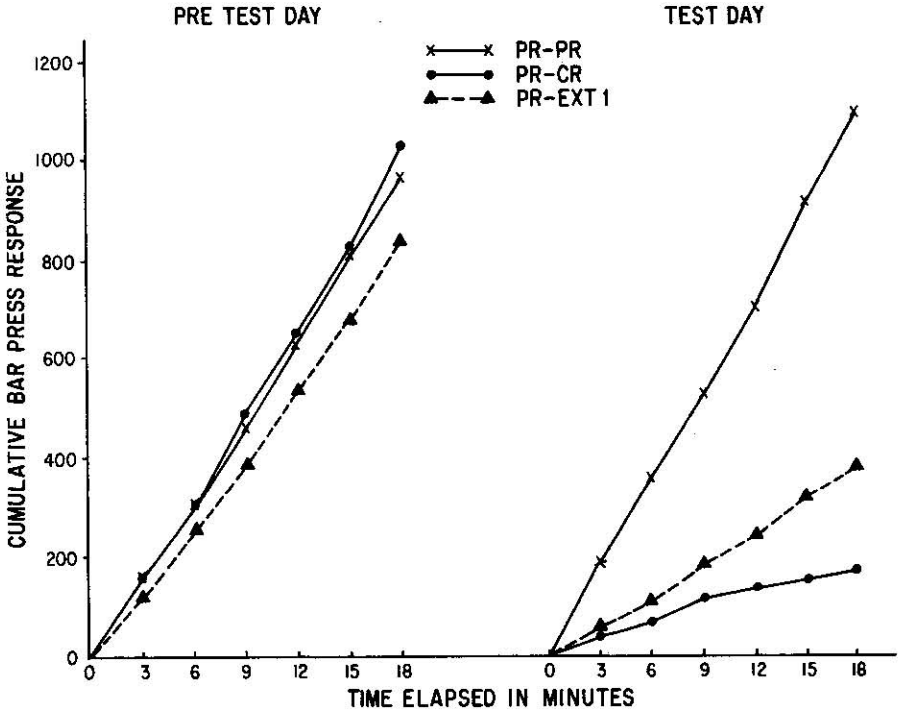

FIGURE 1. Mean Bar Press Responses Under Three Treatment Conditions

ii/ *The analysis of "emotional" behaviour.* Percentages of "emotional" behaviours are presented in Table 4. Wandering and negative bar press occurred more frequently in the PR.CR and PR.EXT1 groups. This

TABLE 3. Summary of One-Way ANOVA for Bar Press Responses on the Pretests and Test Day

Source	df	MS	F
T	2	77959	[a]1.48
E	24	52595	
T	2	21787.322	[b]621.83*
E	24	35.037	

* = $p < 0.0001$
a — pretest day
b — test day
T — Treatment
E — Error

TABLE 4. Percentages of "Emotional" Behaviour of Rats Under Three Conditions

Behaviour	Treatment Groups		
	PR.PR	PR.CR	PR.EXT1
Biting	0.00	0.00	44.44
Washing	33.33	0.00	0.00
Nosing	55.55	44.44	77.78
Rearing	44.44	22.22	22.22
Climbing	0.00	00.00	22.22
Wandering	44.44	66.67	55.55
Negative Bar Press	0.00	77.78	100.00

measurement was included merely as a guide to interpretation of the bar press and biochemicals variable. As a datum, it is not as rigorous as the other dependent variables.

iii/ *The analysis of the biochemical variables.* The means and SEs of PR.PR levels were included for baseline and control comparisons. The differences in the means of the biochemicals level for the five treatment conditions were analysed using one-way ANOVA. The result of the analysis are presented in Table 6. Significant treatment effect were found in plasma 11-OHCS levels ($F(4,40) = 6.89$, $p < .001$); in whole brain 5-HT levels ($F(4,40) = 5.03$, $p < .01$); in whole brain NA level ($F(4,40) = 18.59$, $p < .0001$) and in whole brain dopamin ($F(4,40) = 7.05$, $p < .001$).

TABLE 5. Means and Standard Errors of Plasma Corticosterone (μg/100 ml blood plasma) and Whole Brain 5-HT, NA and DA (ng/g Brain Tissue) for Five Groups

Groups	Plasma 11-OHCS	Whole Brain		
		5-HT	NA	DA
PR.PR	22.47 ± 2.939	584.88 ± 67.517	544.25 ± 12.210	1208.78 ± 23.53
PR.CR	14.24 ± 2.254	456.08 ± 31.399	510.88 ± 9.477	1146.44 ± 40.92
PR.EX1	20.39 ± 2.901	581.49 ± 38.879	495.36 ± 9.607	1081.34 ± 32.93
HCD	31.87 ± 3.272	617.29 ± 27.584	525.27 ± 10.144	1214.80 ± 50.78
HCF	15.1 ± 1.902	406.46 ± 32.201	423.67 ± 11.904	980.92 ± 29.81

TABLE 6. Summary of One-Way ANOVA for Biochemical Variables for the Five Groups

Biochemicals Variables	Source	Df	MS	F
11-OHCS	T	4	452.068	6.89**
	E	40	65.621	
5-HT	T	4	76515	5.03*
	E	40	15224	
NA	T	4	192665	18.59***
	E	40	10366	
DA	T	4	85975	7.05**
	E	40	12204	

* = $p < .01$

** = $p < .001$

*** = $p < .0001$

T = Treatment

E = Error

iv/ *Post hoc comparison.* Post hoc comparisons using the Newman-Keuls test demonstrated a number of significant differences between the groups involved. It is found that the HCD group had a significantly higher level of plasma 11-OHCS compare to the PR.PR control group ($p < .05$), the PR.CR group ($p < .01$), PR.EXTl group ($p < .05$) and the HCF group ($p < .01$). In whole brain 5-HT levels, the HCF had the lowest mean compared with the PR.PR control group ($p < .01$), the PR.EXT1 ($p < .01$), the PR.EXT1 group ($p < .01$) and the HCD group ($p < .01$) and the PR.CR group has a comparatively lowest whole brain 5-HT than HCD group ($p < .05$). For whole brain NA levels, the HCF group again was significantly lower than of the PR.PR control group ($p < .01$), the PR.CR group ($p < .01$), the PR.EXT1 group ($p < .01$) and HCD group ($p < .01$) and finally for whole brain DA levels, the test showed that the HCF group had significantly lower mean levels compared to the PR.PR control group ($p < .01$), the PR.CR group ($p < .05$) and the HCD group ($p < .01$).

DISCUSSION

The present experiment showed that the EXT1 method, similar to PR.EXT1a, produced a significantly lower mean bar proses response than the PR.PR control group. The PR.EXT1a group exhibited a significantly lower mean bar press response compared to the PR.PR control group. The increase in frequency of food reward and conditioned stimuli

(EXT1method) did not result in any greater mean bar press response than the decrease in the frequency of food reward and conditioned stimuli presentation (EXT1a method). Whatever the schedule used, when the food reward is not available to be consumed, the PR-trained animal is unlikely to boost its response even though the response can be maintained for quite some time in the extinction condition.

An interesting result was that of the PR.CR group where an "elation" effect due to an increase in magnitude of reward should have increased the response rate (Meyer & McHose 1968). In the present experiment, the bar press response of the PR.CR group was significantly very low compared to the PR.PR control as well as PR.EXT1 groups. The result is in contrast with the result of Meyer and McHose (1968) where an increase in reward magnitude (number of 45 mg pellets) enhanced the level of response. Increase in the number of rewards (compare to the training schedule, in the present experiment) did not however boose the rate of bar press (BP) response. The BP in the first 3 mins during training was 157 (the rate = 52.33 BP/min) whereas in the first 3 mins during testing BP was 40.88 (the rate = 13.63 BP/min). A number of reasons can be advanced to account for this accurrence of a low rate of bar press response. First in the schedule of testing, the rats had no frustrative drive to boost the bar press response and secondly, because relatively much of their time had been spent on "consummatory" behaviour. Thirdly, it might be that rats were experiencing a decreasing motivation due to the increase in frequency of consumable food reward.

Under a PR schedule, the rats should have been more motivated to bar press for food reward probably by the frustrative nonreward implicit in the schedule. The rats were also "driven" to boost or at least maintain bar press in the presence of occasional or continuous food reward (even though unavailable for consumption, as in EXT1 or EXT1a method). However, when food was available to be consumed continuously, the response seemed to be less frequent than the response in experiments using either the EXT1, EXT1a, or PR method. The facilitative effect of increasing reward frequency (elation) was not demonstrated in the present experiment (see Meyer & McHose 1968; Shrier 1967).

The rats in the present experiment exhibited "emotional" behaviour such as nosing, wandering and negative bar press response which in the PR.EXT1 group may be regarded as frustrated behaviour. However, in the PR.CR group it could not be regarded as frustration but as distracting behaviour due probably to the decrease in motivation as a result of increased food reward frequency for the PR-trained rats.

As with the previous experiments (Yahaya 1984a, 1984b, 1985) the level of plasma 11-OHCS was elevated in the PR.EXT1 group compared to the HCF group, even though in the present experiment it was not significantly different compared to the control (PR.PR) group. Rats in the PR.EXT1 group experienced some frustration and the drive was orientated

toward other behaviour rather than towards the instrumental response. An intresting result in the present experiment was the level of plasma 11-OHCS which was statistically undifferentiable from the level of plasma steroid of the HCF group. Unfortunately it was also not significantly different from the PR.PR control group. This result is not consistent with the result of Goldman et al (1973) that demonstrated the changes from PR schedule to a CR schedule (the sudden increase in reinforcement frequency) produced a significant decrease in plasma 11-OHCS when compared with the presession levels. The difference was probably due to the difference in training days and PR used.

There was no significant difference between whole brain 5-HT of the PR.PR control group and the PR.CR or PR.EXT1 group. Beninger and Philips (1979) had demonstrated that PCPA-treated rats did not show any significant increase in resistance to extinction relative to untreated rats following a PR schedule. They suggested that prior experience with nonreward may have offset the effect of reduced levels of 5-HT on resistance to extinction. The result of the present experiment showed that the PR-trained rat did not exhibit any significant change in whole brain 5-HT level (relative to PR.PR control group) when exposed to either extinction or the CR schedule in testing. The nonsignificant change in whole brain 5-HT could be due to prior experience of the PR-trained rats with frustrative nonreward.

The mean levels of whole brain NA in both the PR.CR and PR.EXT1 groups were not significantly different from that of the PR.PR control group. As with the PR.PR control group, the rats in the PR.CR and PR.EXT1 groups underwent the same treatment of prior frustrative nonreward and thus became conditioned to frustrative stimuli before they were tested. Thus, when tested with either the continuous presentation of food or extinction, the rats exhibited no changes in whole brain NA. The nonsignificant changes in whole brain NA probably indicated that the rats did not experience any frustration.

As with the other experiments, the PR-trained rats produced no significant changes in the mean level of whole brain DA. The PR.EXT1 and PR.CR method used in the present experiment did not produce any significant effect in the mean level of whole brain DA. The increase in reinforcement frequency stemming from CR schedules did not affect whole brain DA levels. Incentive motivation due to the release of DA (Crow 1972, 1973) was not substantiated. It appears therefore that DA reflects that level of deprivation in the rats but not any other behavioural manipulations such as the introduction of CR schedules.

CONCLUSION

The present experiment showed that the increase in reward frequency (whether available or unavailable for consumption) did not produce a

significantly higher bar press response or at least equalise statistically to the bar press of the PR.PR control group. An unusual result was that the bar press for the PR.CR group was significantly lower than that of the PR.EXT1 group. The increase in reward frequency seemed to suppress comparatively the bar press frequency (as in the PR.CR group). The plasma 11-OHCS level in the PR.CR group was suppressed to a level which was statistically equal to the level of plasma steroid of the HCF group but did not differ significantly however from that of PR.PR control group. In relation to the PR.PR control group, the PR.CR and PR.EXT1 groups did not exhibit any significant changes in whole brain monoamines.

The present experiment indirectly indicated that continuous reward in daily life might not necessarily be a motivating factor to workers who had been rewarded intermittently. The continuous reward might possibly demotivates and causes them to lose their initiative in improving their performance.

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