A STUDY ON DRIVE SUMMATION*

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The purpose of this experiment is a study on drive summation in the conditioning process. Generally speaking, when we think of behavior in its relation to the incentive, we find the following two kinds of drives in behavior evocation: (a) drive which is decreased by incentive in a given situation, i.e., the drive which evokes such behavior that causes acquisition of the incentive or escape from it, and (b) drive having no such relation as (a) has. We may call (a) relevant drive and (b) irrelevant drive. For the study of drive, it is an usual procedure to observe under various experimental conditions the effect of a single drive (e.g., hunger drive) and other drive conditions are always held constant. It is, however, impossible at the present stage to conclude that the evocation of certain behavior in the above situation depends on only the given drive, that the experimenter intends to study.

On this point, Hull (1943) has stated, " D (total effective drive) is decided by $\bar{D}$ (the dominant drive in the situation concerned) and $\dot{D}$ (other drives) and there is the following relation among them:—

$$D = \frac{\bar{D} + \dot{D}}{\bar{D} + 100} \text{ ,}$$

In other words, in the above formula, irrelevant drive which was neglected heretofore, is considered as a factor of the total effective drive.

Thereupon, Amsel (1949, 1950 a) has actively taken up this drive summation problem. Different from the past similar experiments which were generally done on the homogeneous drives (e.g., hunger

and thirst), the experiment on the summation between the heterogeneous drives has been enforced by him. In particular, with the purpose of certifying that the relation of summation between the heterogeneous drive (the drives based on hunger and electric shock) meets the Hull's hypothetical formula, he attempted the experiment by the straight runway with an electric grid. The result of his experiment was as follows: (1) When the irrelevant drive based on 22-hour-hunger was summated to the relevant drive caused by harmful stimulation, no distinct difference was observed in the total drive strength measured by running time, but (2) the same irrelevant drive summated to the anxiety conditioned by the electric shock, and, as compared with the running in the condition in which only the relevant drive (anxiety) was present, its running time was shorter, and the distinct summation effect was found. From the above-mentioned results, Amsel pointed out that Hull's hypothesis was not necessarily wholly reasonable, but it was effective in a certain sphere. The appropriateness of this conclusion of Amsel's has been supported by the additional experiment conducted by the writer (Matsunaga, 1952).

Accordingly, there arises the question why, in a case of anxiety conditioned by electric shock as relevant drive, the summation is found, whereas, in a case of the electric shock as relevant drive, no summation to the irrelevant drive "hunger" is admitted. For the above question, if Hull's formula of D is appropriate, the interpretation is possible that in the case of the relevant drive $\bar{D}$ being very strong and the irrelevant drive $\dot{D}$ being weak the existence of the irrelevant drive might not

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give so much summation effect as to reflect on a response measure. And the appropriateness of this interpretation can be checked by ascertaining if the drive summation is found when the relevant drive caused by the electric shock is weak in its intensity, or when the relative intensity of the irrelevant drive is strong.

From the above viewpoint, this experiment was attempted to study the drive summation phenomenon by weakening the intensity of the electric shock, so as to establish a basis for the study of drive in the future.

EXPERIMENT I

Method

Subjects: 20 white albino rats weighing about 100 g were used for this experiment. Careful attention was paid to the time and quantity of the feeding of them from one week before the experiment.

Apparatus: Modified Amsel's apparatus (Amsel, 1950 a) was used. The apparatus consisted of the starting box of 7.5 in. in length and 4 in. in width, the runway of 60 in. in length and 4 in. in width and the goal box of 13 in. in length and 4 in. in width. The bottom of the starting box and the runway was made of electrifiable grid floor. The electric shock used in this experiment was given by a transformer with an output voltage of 500 AC. A voltage divider, with a total resistance of 100,000 ohms was used to control the voltage of the electric shock which was delivered with 50,000 ohms variable resistor with the animal. And the shock intensity was measured by voltage of AC.

Procedure: The experiment consisted of the three periods, i.e., training, conditioning and extinction, and it took 13 days for the whole period to be completed.

Training session (10 days). From the 1st up to the 6th day, the rats were put in each part of the apparatus individually for 15 minutes per day and allowed to move freely in it. On the 7th day, as soon as the door of the starting box was opened, the electric shock of 10 V strength was charged on the grids of the starting box and

the runway. The rat could escape from the electric shock by running through the runway into goal box where it was detained for 30 sec. In a similar way, the electric shock of 15 V, 20 V and 25 V was given on 8th, 9th and 10th day, respectively. The rats were given one trial per day in this period.

Conditioning session (11th–13th days). Before the experiment on the 11th day, the 20 animals that finished the above training were divided into 4 groups, at random. Every group was given ten trials per day (30 trials in total) respectively with electric shock. The electric shock used in the above case was 40 V from the 1st to 5th trials and from the 6th trials 50 V strength was used for A and B groups (to be called W group hereafter), and 60 V strength from 1st to 5th trials was used for C and D groups (to be called S group hereafter). In this S group, 75 V strength was used from the 6th trials. In the above, the running of A(W-22) and C (S-22) groups was done under 22 hrs hunger, and that of the others just after the feedings: B (W-0) and D (S-0). In none of these groups was electric shock given at the goal box. In other words, this experiment formed the conditioned escape-training situation, using the running response. The time required for the rat to reach the goal box after the door of the starting box being opened was measured.

Non-Shock Session (the 13th day after finishing the conditioning session). After the conditioning session, rats were given running trials as before but without the electric shock until the rat did not complete the run to the goal box within 120 sec. Number of unshocked responses required to reach the above criterion was recorded.

Results

Conditioning session: The mean reciprocal running times (running speed) by each group at 10th, as a block for each group was used. And as Bartlett's test did not preclude the assumption of homogeneity of variance ($\chi^2=2.68$, $df=3$, $0.5 < P < 0.3$), a 2×2 factorial analysis of variance was carried out. These results are summarized in Table 1.

Table 1
Summary of Analysis of Variance

Source	df	Conditioning Session		Non-Shock Session	
		MS	F	MS	F
Shock intensity (S)	1	0.002	<1	0.269	<1
Hours of Hunger (H)	1	0.186	46.5**	3.84	<1
H×S	1	0.180	45.0**	24.49	4.764*
Residual	16	0.004		5.14	
Total	19				

* $P=0.05$ ** $P=0.01$

Table 2
Summary of the Results of Comparison between Each pair of Groups

Groups Compared	Value of F	
	Conditioning Session	Non-Shock Session
Group A (W-22): Group B (W-0)	79.75**	4.61*
Group C (S-22): Group D (S-0)	<1	<1
Group A (W-22): Group C (S-22)	27.25**	1.926
Group B (W-0): Group D (S-0)	18.25**	2.879

** $P<0.01$ * $P<0.05$ $df=1$ and 16

As the effect of hunger and the $H \times S$ interaction were highly significant, the difference of each pair of groups was tested respectively as shown in Table 2. These results indicate that the stronger shock evoked the faster running response than the weaker one did. And when the intensity 15th, 20th, 25th, 30th trials are plotted in Fig. 1.

Fig. 1 indicates that: (1) In the weak shock groups, a clear difference was observed between Group A (W-22) and Group B (W-0). (2) But in the strong shock groups, the systematic and distinct difference was not observed between Group C (S-22) and Group D (S-0).

To test the above results statistically, mean speed of last five trials of shock (relevant drive) was not so high, the running speed became faster with 22 hrs hunger (irrelevant drive) than with 0 hrs of it.

Non-shock session: The numbers of unshocked running responses required to reach the criterion of non-shock session were as follows.

Fig. 1. Mean running speeds for groups reinforced under different conditions of drives.

Group A (W-22): 151, 36, 82, 38, 35

Group B (W-0): 51, 24, 7, 10, 37

Group C (S-22): 27, 78, 35, 40, 10

Group D (S-0): 62, 34, 21, 54, 10

A $\sqrt{X}$ transformation was carried out for these data in order to obtain the homogeneity of variance (Result of Bartlett's test: $\chi^2 < 1$, $df=3$). By a 2×2 factorial analysis, it was found that the F value of interaction of $H \times S$ reached the .05 level of significance (Table 1). And further analysis shows that the significant difference was observed between Group A (W-22) and Group B (W-0).

Conclusion

Summation between drives based on hunger and electric stimulation: The following important point was made clear by this experiment: As the response studied in this experiment was escape from electric shock, and the goal box did not contain any food, the drive caused by electric stimulus would be dominant, relevant in the present situation, and the hunger drive based on the deprivation of food would be an irrelevant or subsidiary drive for the running response. When the relevant drive was based on the weak electric shock and the irrelevant drive on 22 hrs hunger, the summation of them was found. Because the running speed of W-22 group were significantly greater than that of W-0 group. But when the stronger electric shock was used as relevant drive, the addition of hunger drive did not influence the running speed. In conclusion, it is suggested by this experiment that Hull's hypothesis of drive summation is plausible in the case of the intensity of $\bar{D}$ (relevant drive) being not so high.

The summation of anxiety caused by electric shock and hunger: In the present experiment, state of anxiety which was conditioned to the stimulus cue of apparatus by the experience of electric shock in the conditioning session was expected to function as a relevant drive in the non-shocked session. Because the anxiety would be

reduced by the running response to the goal box where the electric shock was never given. And the hunger drive based on 22 hrs of food deprivation was considered as an irrelevant drive for the running response in non-shocked session as in conditioning session. It was considered, therefore, that the summation of relevant drive of anxiety and irrelevant drive of hunger was demonstrated by the fact that the significant difference between Group A (W-22) and Group B (W-0) was found.

EXPERIMENT II

The purpose of the Experiment II was a study on the problem of the relevant-irrelevant drive summation, whereas Experiment I was on that of relevant-irrelevant drive summation. One of relevant drives in Experiment II was a hunger drive based on 22 hrs of food deprivation that was reduced by the running response to food incentive in goal box. And the other drive caused by electric shock was also reduced by the same running response into goal box.

Method

Subjects: The subjects were 42 experimentally naive male albino rats and their mean weight was approximately 100 g. The feeding condition is the same as that of the Experiment I. But seven of them were excluded.

Apparatus: The same experimental apparatus and the electric shock mechanism as that of Experiment I were used. And the intensity of electric shock was same that of weak shock group in the Experiment I.

Procedure: One trial per day was given for 25 days and these experimental days were divided into the following three sessions. The condition of hunger drive was maintained by 22 hrs food deprivation schedule for all animals.

Preliminary session (Approach-to-goal training). From the 1st to 20th day of this session, the running trials from the starting box to the goal box were given where the animal received a reinforcing stimulus, food. The 42 animals were divided randomly into three groups of 14

each. The conditions of them were differed in the quantity of food given in the goal box as follows: 1 pellet (weight of a pellet was 0.5 g) of food (Group A—11 rats), 5 pellets (Group B—12 rats), 9 pellets (Group C—12 rats). 3 rats of Group A, 2 rats of Group B and C respectively were discarded in this session, because of their condition of health.

Experimental session (Double training of approach-to-goal and taking-refuge-in-goal) (21st–25th day). The above-mentioned groups were further subdivided into two respectively. Group A (5 rats), Group B (6 rats), and Group C (7 rats) were given the same running trials as the preliminary session. But Group A' (6 rats), Group B' (6 rats) and Group C' (5 rats) were given electric stimulus in the starting box and runway in addition to the food-reinforcing stimulus at the goal box. The electric stimulus was given immediately after opening the door of the starting box, and the animals could not escape until they entered the goal box where the electric stimulus was not present and the food-reinforcing stimulus was contained.

Extinction Process. On the 25th day, after finishing the experimental session, all animals were given extinction trials. In this session, food reinforcing stimulus was removed from goal box and the electric stimulus was also

omitted. This extinction session lasted until the running time exceeded a 2 min criterion, and the interval of successive trials was five min during which the animal was given a rest in its home cage.

Results

Preliminary session: Fig. 2 shows mean speed of running responses of each group from the 11th to the 20th days. In Fig. 2, it was clearly observed that there was a general tendency of the faster running responses of groups with greater number of pellets than that of groups with smaller number of ones. In order to test this result statistically, mean speed of last five trials as a block of each group was used. An analysis of variance was carried out, because the assumption of homogeneity of variance was not rejected by Bartlett's test ($\chi^2=2.255$, $df=2$, $.30 > P > .050$). As the result of analysis of variance was highly significant ($F=89.64$, $df=2$ and 32 , $P < .01$), the differences between each pair of groups were tested statistically. And it was found that the running speeds of each

Fig. 2. Mean running speeds for groups reinforced under three different amounts of pellets.

Fig. 3. Mean running speeds for groups reinforced under different conditions of drives.

Table 3
Analysis of Variance of Experimental
Session of Experiment II

Source	df	MS	F
Shock (S)	1	0.031	37.349**
Pellet (P)	2	0.045	54.216**
S × P	2	0.064	77.108**
Residual	29	0.00083	
Total	34		

** $P < .01$

Table 4
The Summary of the Results of Comparison
between Each Pair of Groups

Groups Compared	t	df
Group A (1): Group A' (1)	6.344***	10
B (5): B' (5)	1.954*	11
C (9): C' (5)	6.612***	11
A (1): B (5)	3.741**	10
A (1): C (9)	10.706***	11
B (5): C (9)	6.284***	12
A' (1): B' (5)	<1	11
A' (1): C' (9)	10.323**	10
B' (5): C' (9)	11.582***	10

* $P = .05$ ** $P = .01$ *** $P = .001$

group were in order of Group C (9 pellets) > Group B (5 pellets) > Group A (1 pellet). (Group C : A, $t = 17.57$, $df = 22$, $P < 0.01$; Group B : A, $t = 5.96$, $df = 22$, $P < .05$; Group C : B, $t = 10.29$, $df = 23$, $P < .01$).

Experimental session: Fig. 3 shows the mean running speeds of each group during 21st–25th days. Three circles at 20th day in this Figure indicate the running speeds of the last trials in the preliminary session of each group. A 2×2 factorial analysis was applied to the mean running speed four trials as a block of each group (Table 3). The running speed of 21st trial was excluded, for the electric shock was given for the first time at this trial. (Bartlett's test did not reject the assumption of homogeneity of variance: $\chi^2 = 2.786$, $df = 5$, $.80 < P < .70$.) And further analysis between pairs of groups were shown in Table 4.

From these results, following summaries could be made: (1) Addition of electric stimulus to the hunger drive positively influenced the running speed in all groups. (2) Within shocked groups only. The difference of magnitude of food reward between Group A' (1 pellet) and Group B' (5 pellet) did not effectively affected the running speed. (3) Within non-shocked groups, the tendency of the running speed of each group was same as in the preliminary session.

In this experiment, the first relevant drive (hunger) was reduced after the running response to the goal and the second new relevant drive was also reduced at the goal box by the same response. Therefore, it may be concluded that the above results indicate the heterogeneous relevant-drive summation.

Extinction process: No consistent tendency could be found in the number of runnings. Needless to say, no significant difference could be found between each group statistically.

Conclusions

The relation between magnitude of reinforcing stimulus (food) and running speed: The significant difference was statistically obtained between each pairs of group. And the more pellets were given to rats in the goal box the faster became the running speed. The same result as mentioned above is shown in the experiments by Crespi (1942), Graham (1940), etc.

The problem concerning summation of relevant drives of two heterogeneous kinds: The summation of heterogeneous relevant drives was clearly observed. Detailed analysis indicated moreover, the following interesting fact. On the first trial of this process, the 21st day of the experiment, the running speed of each electrically stimulated group became markedly slower than before when the electric stimulus was not given. Such a tendency is also reported by Ullman (1951). But from the next trial, the running speed rapidly increased and became

greater than that of groups with hunger drive only. It was considered that this tendency was due to the occurrence of the novel escape learning from shock. Since the appropriate response for escape from the noxious stimulus in this process was running to the goal box, established already by the preceding 20 trials, the escape learning was quickly achieved, although the running speed was decreased for the first time by the change of situation. And these electrically stimulated animals received food pellets in the goal box and ate them as before. Food-intake after receiving electric stimulus had been observed by Amsel (1950 b), Ullman (1951, 1952), etc. From the above consideration, it was concluded that the electrically stimulated groups had two heterogeneous drives, and showed that the summation of these was effective for increasing the running speed compared with that of groups without electric stimulus.

The problem of summation of drives in the extinction process (The relation between the anxiety based on electric stimulation and non-reward at the goal box): To investigate the summation of anxiety and hunger drive, the extinction procedure was carried out. And the number of running responses until the extinction criterion was reached, was compared between each electrically stimulated group and without-electric shock group. But a statistically significant difference did not appear.

CONCLUSION AND SUMMARY

Experiment I

The groups which were given electric stimulus 50 V and 75 V strength respectively were used, and those were subdivided into non-hunger and hunger groups. And then all groups were given non-shocked trials. As the result of the experiment, the summation of the relevant drive based on electric stimulation (50 V) and the irrelevant drive based on hunger was found, but when 75 V relevant drive

was used no summation of the drives was observed. In conclusion, when the running speed is used as a response measure in runway situation, the occurrence of drive summation depends on the appropriate relationship in intensity between two drives, relevant and irrelevant. And in non-shocked session, the drive summation of anxiety based on weak electric shock and hunger was found.

Experiment II

If the groups of rats were given food-reinforced trials under the same hunger-drive condition, and then half of the groups were given electric stimulus adding to the hunger drive, both of which were reduced by running into the goal box but another half of them continued to run without electric stimulus, and if the running speed of the former groups were significantly greater than the latter, we would be able to conclude that the superiority of the former groups resulted from the summation of heterogeneous but relevant drives of hunger and of pain.

Procedure: (1) Three groups of rats put under the condition of 22 hrs hunger throughout the experiment were given running trials for 20 days, one trial per day, and received 1, 5 and 9 food reinforcing stimulus at the goal box respectively. (2) After (1), each group was further divided into two sub-groups, and one of them was given escape running trials from 15 V electric stimulus in the apparatus. The other groups was not electrified. Other conditions for both groups, e.g., hunger drive, the apparatus were the same as the Experiment I. And the number of trials in this session was five for both groups. (3) After (2), the extinction procedure was used. All groups were given running trials without food reinforcement for both groups, and also without electric stimulus for the one of them electrified in session (2) until their running times exceeded a 2 min criterion.

Result: (1) In the 20 days experiment,

the running speed differed according to the number of the pellets given and the more they received, the greater became their running speed, and the significant difference was also found. (2) In the experiment during the succeeding 5 days a clearly significant difference was observed between the groups with summation of the two relevant drives based on electric stimulation and on hunger, and the group with the one relevant drive based on hunger only, and thus it was made clear that the summation of such heterogeneous drives as those based on electric stimulation and on hunger takes place. (3) No distinct difference could be recognized between each group in the extinction process. And the summation of anxiety and hunger was not discovered.

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