THE NATURE OF UNSUCCESSFUL ACTS AND THEIR ORDER OF ELIMINATION IN ANIMAL LEARNING[1]

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The so-called unsuccessful movements in animal or human learning may be of two general types; they may be either ill-adaptive acts or merely excessive acts. By an ill-adaptive act is meant one that will either result in physical punishment or tend to check or disrupt the activity or the progress of the animal toward a consummatory reaction, such as food, or relief from confinement. By an excessive act is meant one that will neither do an injury to the organism nor will prevent it from reaching its goal, but that will, nevertheless, delay or prolong the process of consummatory reaction. Ill-adaptive acts as well as excessive acts may be of various degrees.

Our assumption is (1) that under normal conditions animals will eliminate ill-adaptive movements sooner than they will excessive movements, (2) that the order of elimination of ill-adaptive movements will be according to the degree of ill-adaptiveness, and (3) that the merely excessive movements may sometimes not be eliminated at all.

NATURE OF THE EXPERIMENT

To test out the above assumption an experiment was performed with 13 black and white rats. A "multiple choice" apparatus was used containing four compartments. One of these led the animal to the food box by a short path; another, by a longer path; another confined the animal for a period of time, and a fourth provided an electric shock punishment. For convenience of discussion we shall hereafter call these four compartments

[1] Invaluable suggestions and assistance were received from Dr. Edward C. Tolman. Read in part before the Western Psychological Association, August, 1921.

short-path compartment, long-path compartment, confinement compartment and electric-shock compartment, respectively.

It was assumed that both electric shock and confinement were to be classed as "ill-adaptive." And, further, it was assumed that the electric shock was more ill-adaptive than confinement in that the former gives physical pain while the latter simply checks the animal's progress in getting food. And, finally, it was supposed that the entrance into the long-path compartment would be merely an excessive act when compared with the entrance into the short-path compartment. If, then, our original assumptions hold good, we would expect:

1. That the animal would eliminate the confinement compartment sooner than the long-path compartment.

2. That it would eliminate the electric-shock compartment more readily than the confinement compartment.

3. That on the whole rats would prefer the short-path compartment to the long-path compartment.

The figure shows the ground plan of the apparatus. The outside rectangular box, *R.S.T.U.*, is 38 inches in length and 36 inches in width; the inside rectangular box, $R.^1S.^1T.^1U.^1$, is 30 inches in length and 28 inches in width; the runways between the two boxes are 4 inches in width. *E* is the entrance door; D^1, D^2, D^3, and D^4 are spring doors. The inside box consists of four compartments (numbered *1*, *2*, *3*, and *4* in the figure).

The length of the compartment is one-half of the length of the inside box. Each compartment has two doors, one in the front and the other in the back. All the doors, including the entrance door and other spring doors, are tied with string so that the experimenter can close or open these doors by manipulating the strings. On the floor of all four compartments there are punishment grills connected with an induction coil outside the maze, The entire maze is constructed of unpainted $\frac{3}{4}$ inch redwood, 7 inches high, and is covered with wire mesh.

During the "preliminary" the animal is fed at *O*. During the actual experiment food is put either at F^1 or F^2. *P* is the position of the experimenter. By means of the spring doors the experimenter was enabled at will to make the animal go to the food box either by a long path or by a short path. For instance, if the food box was at F^2 and if the animal chose the long path compartment, the experimenter then opened doors D^1, D^3, and D^4, and the animal was obliged to go around the maze in order to get food. If, on the other hand, it chose the short-

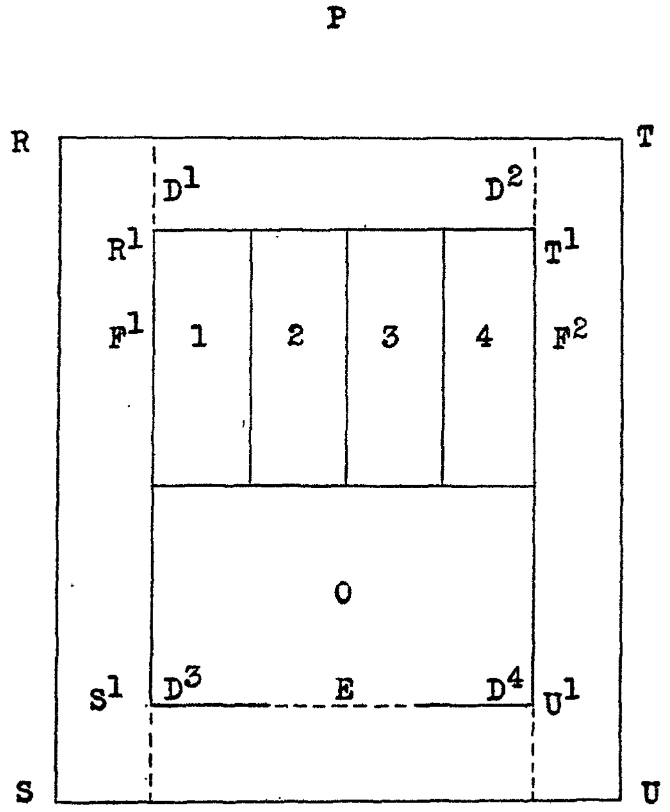

FIG. 1

path compartment, door D^2 was opened and it would immediately get food by turning to the right.

Four groups of black and white rats were used as subjects. Group four consisted of four rats, the other three groups consisted of three rats each. All of these rats were young adult males, approximately three months old at the beginning of the

TABLE 1

Individual records of thirteen rats

TRIAL NUMBER	GROUP I			GROUP II			GROUP III			GROUP IV			
	Setting: Compartment 1—Long path; Compartment 2—Electric shock; Compartment 3—Confinement; Compartment 4—Short path			Setting: Compartment 1—Confinement; Compartment 2—Short path; Compartment 3—Long path; Compartment 4—Electric shock			Setting: Compartment 1—Short path; Compartment 2—Long path; Compartment 3—Electric shock; Compartment 4—Confinement			Setting: Compartment 1—Electric shock; Compartment 2—Confinement; Compartment 3—Short path; Compartment 4—Long path			
	Rat 1	Rat 2	Rat 3	Rat 4	Rat 5	Rat 6	Rat 7	Rat 8	Rat 9	Rat 10	Rat 11	Rat 12	Rat 13
	Compartment entered	Compartment entered	Compartment entered	Compartment entered	Compartment entered	Compartment entered	Compartment entered	Compartment entered	Compartment entered	Compartment entered	Compartment entered	Compartment entered	Compartment entered
1	3.1	1	2.4	2	1.4.2	4.1.2	4.3.2	1	4.2	4	3	3	4
2	2.4	2.1	2.4	1.4.3	1.2	4.2	4.3.2	4.1	3.2	1.3	2.3	1.4	1.4
3	2.4	2.4	2.2.3.4	1.3	4.3	2	2	3.1	3.1	2.3	4	4	3
4	2.1	2.2.2.1	1	4.3	4.1.2	4.2	1	1	2	3	1.4	2.4	2.4
5	2.4	1	2.2.1	3	1.3	2	1	1	2	4	4	1.2.4	1.4
6	3.1	2.3.3.4	3.2.4	3	2	1.3	2	2	3.2	4	4	4	2.1.4
7	2.4	3.2.4	3.4	4.3	1.1.2	3	2	2	1	4	3	4	3
8	4	2.1	4	3	2	4.3	2	2	1	4	4	4	3
9	4	1	2.4	2	3	3	2	3.4.2	1	4	3	4	3
10	3.2.3.2.1.	2.2.1	4	1.2	1.3	3	1	2	1	4	3	4	3
11	3.1	3.4	4	3	2	2	2	3.1	1	4	3	4	3
12	3.4	3.4	1	3	3	2	2	1	1	4	2.4	4	2.3
13	4	3.3.2.3.1	1	2	1.2	2	1	1	1	2.4	3	2.4	2.3
14	3.1	2.1	2.3.1	3	2	2	1	1	1	4	4	4	3
15	4	1	3.4	3	3	2	2	1	1	4	4	4	4
16	1	1	4	3	3	2	2	1	1	4	3	4	2.4
17	3.4	1	4	1.3	2	2	4.1	1	1	4	4	4	3
18	1	3.4	4	3	2	2	1	1	1	4	4	4	3
19	4	4	3.4	2	2	2	2	1	1	4	3	4	3
20	4	4	1	2	3	2	2	1	1	4	3	4	3

21	4	1	4	3	3	2	2	1	1	4	4	4	3
22	1	1	4	3	2	2	2	1		4	3	4	3
23	3.4	1	4	3	3	2	2	1		4	3	4	3
24	4	1	4	1.2	3	3	3	1		4	4	4	3
25	1	1	4	3	3	2	1	1		4	3	4	3
26	4	1	4	3	3		1			4	3	4	3
27	1	4	4	1.2	3		2			4	3	4	3
28	1	1	4	2	3		2			4	3	4	3
29	4	1	4	2	2		2			4	3	4	3
30	3.4	1	4	3	3		2			4	3	4	3
31	1	1	4	2	3		2			4	3	4	3
32	1	4	4	3	2		2			4	3	4	
33	4	4	4	2	3		1			4	3	4	
34	1	4	4	2	3		2			4	3	4	
35	3.1.4	1	4	2	2		1			4	3	4	
36	4	4		3	3		1			4	3	4	
37	1	4		2	3		1			4	3	4	
38	4	4		2	3		1			4	3	4	
39	3.4	1		2	3		2			4	3	4	
40	4	4		2	2		1			4		4	
41	4	1		2	3		1						
42	4	4		3	3		1						
43	4	1		3	1.2		1						
44	4	4		2	2		1						
45	3.1	4		2	3		1						
46	1	4		2	3		1						
47	1	4		2	3		1						
48	1	4		2	2		1						
49	3.4	4		2	2		1						
50	4	4		2	2		1						
51	1	4		2	2		1						
52	1	4		2	2		1						

TABLE 1—*Continued*

TRIAL NUMBER	GROUP I			GROUP II			GROUP III			GROUP IV			
	Setting: Compartment 1—Long path; Compartment 2—Electric shock; Compartment 3—Confinement; Compartment 4—Short path			*Setting:* Compartment 1—Confinement; Compartment 2—Short path; Compartment 3—Long path; Compartment 4—Electric shock			*Setting:* Compartment 1—Short path; Compartment 2—Long path; Compartment 3—Electric shock; Compartment 4—Confinement			*Setting:* Compartment 1—Electric shock; Compartment 2—Confinement; Compartment 3—Short path; Compartment 4—Long path			
	Rat 1	Rat 2	Rat 3	Rat 4	Rat 5	Rat 6	Rat 7	Rat 8	Rat 9	Rat 10	Rat 11	Rat 12	Rat 13
	Compartment entered	Compartment entered	Compartment entered	Compartment entered	Compartment entered	Compartment entered	Compartment entered	Compartment entered	Compartment entered	Compartment entered	Compartment entered	Compartment entered	Compartment entered
53	4	4		2	2		1						
54	1	4		2	2		1						
55	4	4		2	2								
56	1	4		2	2								
57	1	4		2	2								
58	1	4		2	2								
59	4				2								
60	4				2								
61	4				2								
62	4				2								
63	4												
64	4												
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66	4												
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68	4												
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70	4												
71	4												
72	4												
73	4												

experiment. They were in good health throughout. Great care was exercised in selecting subjects. Many rats were rejected on account of their not being docile; that is, being wild or excitable. We shall, in a later section, justify such procedure of selection. No rat selected had any training previous to the experiment.

Hunger was the primary motive used in the experiment. Other reaction tendencies such as curiosity, anger, and the like, were eliminated to a maximum degree either by the selection of subjects or by controlling the experimental conditions. Before the experiment was started the rats were given abundant food. Two days before the "preliminary" the food was reduced to a minimum and the same amount of food was given daily at the same hour throughout the experiment. No rat was fed outside the maze either during the preliminary or during the actual experiment.

During the preliminary period the rats were allowed to explore the runways of the maze while both the front and back doors of all the compartments were kept closed. This preliminary training usually lasted from five to six days. Great care was taken to look for any habitual disposition to enter one compartment rather than another before the training was begun, but no such preferential tendency was discovered.

The four compartments were so arranged that each of them could be used interchangeably as electric-shock compartment for one group of rats, as confinement compartment for another group, as long-path compartment for the third group, and as short-path compartment for the fourth group. Thus, no compartment was used the same way for two groups (for example, the same compartment was never used as confinement compartment for more than one group). The arrangements for settings of the four compartments for the four groups of rats will be seen on the top of each of the four main columns of table 1. The numbers 1, 2, 3, 4, in the "setting" column designate the compartment numbers as shown in the drawing of the apparatus.

When the animal was admitted by the entrance door *E*, he had to choose one of the four compartments in order to get food.

All the front doors were open while the back doors were closed. If the animal chose the short-path compartment the experimenter immediately lifted the back door and permitted him to go to the food box by a short path. If he chose the long-path compartment the experimenter lifted the back door and made the animal go to the food box by a round trip. If the electric-shock or the confinement compartment were chosen the experimenter immediately lowered the front door and in the former case pressed the key outside the maze thus giving the animal a shock, or, in the latter case confining him in the compartment for *twenty seconds*. The electric shock was strong enough to make the animal squeal every time and immediately jump back from the compartment after the shock was given. Great care was taken to prevent any injury to the animal's tissue. No rat seemed to have displayed any excitement or refused to work after the punishment, although hesitation to reenter the electric-shock compartment after the shock had been given was observed in many rats.

Each rat was given five trials per day. After the rat had learned to go to any given compartment consecutively for fifteen trials, without any error, the habit was considered as perfect and the experiment was discontinued.

RESULTS

Table 1 gives the detailed records of the four groups of rats. The figures in the first column represent the trial numbers. The figures in the other columns designate the compartment numbers entered by the rats on each trial; for instance, Rat 1 entered compartments *3* and *1* on the first which were set as confinement compartment and long-path compartment, respectively, for group I (rats 1–3). Rat 4 entered compartments *1*, *4*, and *3*, on the second trial which were set for group II (rats 4–6) as confinement compartment, electric-shock compartment, and long-path compartment, respectively.

Table 2 gives the number of the trial on which electric-shock, confinement and long-path compartments were last entered by each of the thirteen rats. *E.S.* designates electric-shock compartment; *C.F.* confinement compartment; and *L.P.* long-path compartment. Figures with parentheses represent the cases that do not follow the rule of the order of elimination found in this experiment.

The results show several important features:

1. *The electric-shock compartment was eliminated sooner than the confinement compartment.* On the average the last entrance into the former compartment occurred on the 7th trial (median,

TABLE 2

RAT	E. S.	C. F.	L. P.	TOTAL TRIALS
1	10th	49th	58th	73
2	14th	18th	43d	58
3	14th	19th	20th	35
4	7th	27th	43d	58
5	4th	43d	47th	62
6	(8th)	(6th)	10th	25
7	2nd	17th	39th	54
8	(11th)	(9th)	(10th)	25
9	(6th)	(1st)	(6th)	21
10	2nd	13th		40
11	4th	12th	24th	39
12	5th	13th		40
13	6th	(16th)	(16th)	31
Average	7th	18th	28th	43
Median	6th	16th	24th	40

6th trial), while the last entrance into the latter occurred between the 18th and 19th trials (median, 16th trial). For no rat did the last entrance into the electric-shock compartment occur after the 14th trial. The majority of the rats eliminated this compartment before the 10th trial. On the other hand, in rats 1 and 5 the tendency to enter the confinement compartment did not entirely disappear until after the 49th and 43d trials, respectively.

2. *On the whole, the confinement compartment was eliminated sooner than the long-path compartment.* On the average the last entrance into the long path compartment occurred between the 28th and the 29th trials (median, 24th trial). In rat 1 the

tendency to enter this compartment did not entirely disappear until after the 58th trial. On the other hand, the averaged last entrance into the confinement compartment was the 18th trial (median, 16th trial).

While the rule that the electric-shock compartment is eliminated sooner than the confinement compartment, and that these two compartments are eliminated more readily than the long-path compartment, holds good in the four groups of rats as a whole; there are some exceptions. In rat 6 the last entrance into the electric-shock compartment occurred on the 8th trial, while the confinement compartment was dropped out two trials earlier. Rat 8 did not eliminate the electric-shock compartment until the 11th trial, but on the 9th trial he made his last entrance into the confinement compartment, and on the 10th trial his last entrance into the long-path compartment. The last entrance into the electric-shock compartment and into the long-path compartment occurred on the same trial (6th) for rat 9, but this rat had ceased to enter the confinement compartment after the first trial. In rat 13, the entrance into the confinement compartment and long path compartment were eliminated simultaneously on the 16th trial. The deviation of the results of these four rats from the rule found for the experiment as a whole can be easily explained. We note that rats 6, 8, 9, and 13, are the quickest learners among the thirteen. Rat 9 masters the maze in 21 trials; Rats 6 and 8 in 25 trials, and rat 13 in 31 trials. This necessarily implies an earlier elimination of the long path compartment by these rats than that by others, although not necessarily an earlier elimination of the electric shock and confinement compartments. Table I shows that in every case the trial on which the entrance by these exceptional rats into the long path compartment last occurred is far below the median trial of the last entrance into this compartment for the group as a whole, and this is also true of their last entrance into the confinement compartment, with the exception of Rat 13, whose last entrance into the confinement compartment occurred on the median trial (16th trial) On the other hand, it will be noted that the rate of the elimination of the electric shock compartment was not accelerated by these rats. The earlier elimination of the confinement compartment and especially of the long path compartment by these rats tends to distort the order of the elimination of the three compartments commonly found in other rats.

3. All but two of the thirteen rats (10 and 12) finally chose the short path compartment (see table 1). And in many cases the shifting from the long path compartment to the short path compartment came about suddenly and in spite of frequency. After entering these two compartments alternately for a number of trials a rat might suddenly cease going to the long path compartment entirely and persevere in entering the short path compartment. The *suddenness* of the shifting from the long path compartment to the short path compartment is especially marked in rats 5, 6, 8, and 9. And the occurrence of the shift in spite of a greater accumulated frequency for the long path compartment is especially notable in rats 2, 4, 5, 7, and 9. In rats 6, 8, and 11 the number of times of entrance into both compartments was equal when they began to cease entering the long path compartment.

4. Two rats (10 and 12) never made the shift from the long path compartment to the short path compartment. Rat 10 never went to the short path compartment after the fourth trial while rat 12 never went to it after the first trial. The number of trials in these two rats was extended to 40 (see table 1), but there was no indication that they would chance to enter the short path compartment since the habit of going to the long path compartment seemed to be fixed. Such cases must not, however, be interpreted as altogether of the nature of a failure on the part of these rats. The records of the other rats indicate that they tended to enter both the short path compartment and the long path compartment alternately, for some time, after which they eventually chose the former and discarded the latter. But since rat 12 never entered the short path compartment after the first trial, and rat 10 never after the fourth trial, in their case there was little opportunity for this shift.

We may now present a more detailed analysis of the frequencies of the different compartments and the shift from compartment to compartment.

Table 3 shows the total number of the entrances by thirteen rats into each of the four compartments in each *trial period.* The first twenty trials are divided into four *trial periods,* thus making five trials to a period; the next twenty trials (from the 21st to the 40th trial) are divided into two periods, (ten trials in each period) and from the 41st trial up all trials are grouped in one trial period.

Considering the results for each compartment individually and in comparison with the others the following points appear:

TABLE 3

	TRIAL PERIODS						
	1–5	6–10	11–15	16–20	21–30	31–40	41 up
Entrances into the E. S. compartment	34	15	4	0	0	0	0
Entrances into the C. F. compartment	18	15	16	6	4	2	3
Entrances into the L. P. compartment	34	38	31	26	57	41	19
Entrances into the S. P. compartment	31	27	34	39	55	44	86
Total	117	95	85	71	116	87	108

a. The electric shock compartment

The total number of entrances by the 13 rats into the electric shock compartment in the first trial period is equal to their total number of entrances into the long path compartment, but greater than their total number of entrances into the confinement compartment or into the short path compartment. But in the second trial period their total number of entrances into this compartment is greatly decreased. In the third period (from trial 11th to trial 15th) the total number of entrances into this compartment is still further decreased.[2] The number of entrances into the compartment in the fourth period is nil, and no recurrence of entrance into it took place thereafter.

[2] The individual record not presented here shows that ten rats never entered it in this trial period.

b. The confinement compartment

The total number of entrances by all rats into the confinement compartment in the first trial period is smaller than their total number of entrances into any other compartment in the same period. In the second period the total number of entrances by all rats into the confinement compartment is slightly decreased; in the third period the total number is a little greater than that in the second period. From the fourth period on the total number is gradually decreased. Seven rats eliminated the compartment after the third period; and twelve after the fifth period.

It is interesting to note that the tendency to enter the electric shock compartment disappears not only very early but very suddenly, whereas the tendency to enter the confinement compartment dies out rather gradually and slowly. Furthermore, the individual record shows that the entrance into the former never recurs after the tendency has been inhibited, whereas in some rats the tendency to enter the latter may occasionally recur after a period of disappearance.

c. The long path compartment

The total number of entrances by all rats into the long path compartment is greater than that of entrances into the short path compartment in the first trial period. From the second period to the sixth period the situation is rather fluctuating. The total number of entrances into the long path compartment may be increased in one period and decreased in another; the number of entrances into the compartment by all the rats is greater in the second and fifth periods but smaller in the third, fourth, and sixth periods than the number of entrances into the short path compartment. In the last period the total number of entrances by all rats into the long path compartment is greatly decreased, while that of entrance into the short path compartment is greatly increased. This is due to the fact that all rats had chosen the latter compartment during this period.

We conclude that frequency and recency as such have very little to do with the matter of elimination in this experiment. This can be easily seen from table 1.

THEORIES OF LEARNING IN ANIMALS

The results of our study immediately raise the mooted question in animal behavior; namely, "Why an animal learns, or why the so-called unsuccessful acts are rejected and the successful ones are selected; or, to put it more specifically, why ill-adaptive acts are eliminated sooner than the excessive ones, and why the excessive acts may not always be eliminated? Before we state our own point of view with regard to this question we shall make a critical examination of the theories that have been suggested by various writers for the explanation of learning in animals.

The pleasure-pain theory is perhaps the oldest. There is little need for any outline of the theory here. The opponents of the theory have charged its advocates with being subjectivistic and interactionistic. The charge is so far well grounded; indeed many of the exponents of the pleasure-pain theory have been committed to a mentalization of animal behavior.

The fact that a painful stimulus tends to cause avoidance and a pleasurable stimulus tends to encourage approaching, I think no one will deny. But the pleasure-pain theory does no more than state this empirical fact. It does not tell us why the pleasureable acts are selected and the unpleasurable ones rejected. In other words, the theory is simply a restatement of the problem rather than a solution of it. Furthermore, as Carr[3] and others have pointed out, not all rejected acts are unpleasant, neither are all selected acts pleasant.

Primarily in order to avoid the interactionist implications of the pleasure-pain theory, Hobhouse[4] suggests the theory of confirmation and inhibition for explaining animal learning. Reviewing this theory Holmes says "It is essentially a theory of how behavior comes to be adaptively modified through the formation of association. It makes no attempt to explain why pleasure is associated with certain experiences and pain with others."[5]

[3] Principles of Selection in Animal Learning, Psychol. Rev., xxi, 169. 1914.
[4] Mind in Evolution, 1915.
[5] Studies in Animal Behavior, 1916, pp. 134–135.

Holmes here seems to have clearly pointed out that what we need to explain is the question "why certain responses tend to be repeated and others tend to be inhibited." But neither has Holmes been successful in answering the question which he has well raised in his criticism of Hobhouse's theory. According to him, "A response which results in setting into action a strong instinctive proclivity is reenforced or inhibited, as the case may be, according to its congruity or incongruity with the proclivity thus aroused."[6]

Nothing is gained by Holmes' theory except that he substitutes a pair of terms "congruous" and "incongruous" for "successful" and "unsuccessful." He here also falls back to the mere description of the nature of the rejected acts and selected acts. Acts are selected or rejected because they are "congruous" or "incongruous." But why are congruous acts selected and incongruous ones rejected? To this question Holmes gives us no answer. He has attempted to explain the selective agency in animal learning but he got nowhere! Moreover, just as not all selected acts are pleasant and not all rejected acts are unpleasant, so not all the former are congruous and not all the latter incongruous; many trivial or superfluous acts that are neither congruous nor incongruous may be selected or rejected.

J. Peterson proposes the principle of 'completeness of response' as an explanation of learning.[7] "In the case of the maze problem the animal on entering a *cul de sac,* or any other path in fact, responds at first more or less incompletely because all the subordinate activities cannot take place at once. If the animal's progress is soon checked in a blind alley the animal is not seriously nonplussed, certain elements of the general response are tending to drain into other alleys that recently have been passed, thus partially dividing the animal's activity. These elements now prevail when the others are checked. Let us suppose that the correct path A has just been passed when the animal suddenly comes to the end of the *cul de sac* B. The tendencies to respond to A are still surviving and now direct

[6] Op. cit., pp. 148–149.

[7] Completeness of Response, etc., Psychol. Rev., xxiii, 153–162. 1919.

the impeded activity into this the successful path. If, on the other hand, the correct path had been chosen the first time the distracting impulses toward B would have become fainter and fainter as the animal proceeded into A and would finally fade away."[8]

Peterson's theory has several difficulties. In the first place, is it necessary that the impulses toward the correct path A should be actually present when the animal enters the blind alley B or *vice versa?* I think it is highly probable that in many instances the animal would go straight ahead to one path without the presence of some antagonistic tendencies which tend to drain into other paths. Secondly, why is it that when the animal enters the correct path A the first time the tendencies to go to the blind alley B become fainter and fainter and would finally die out, whereas the tendency to go to the correct path A still persists even when the animal begins by choosing the blind alley B? This is a very crucial point which Peterson does not explain. Third, if the animal turns back to A after he comes out of B because the tendencies toward A were already present and still persist during his entrance into B, rather than because these tendencies are aroused by the new sensory situation which results from the very act of the entrance into B, it will be difficult to understand "how, on the grounds alleged the tendencies along the true path, which were not strong enough to keep the animal from entering the blind alley, could gain sufficient strength, once the animal had been in and come out of the blind alley, to prevent its reentering it."[9] And, finally, if completeness of response *per se* is responsible for selection and elimination, we should have no right to expect the animal to prefer a short path to a longer one—which is a fact which has been confirmed by the writer in the experiment reported in this paper and also by De Camp.[10] Surely the tendency to go through a long path is at least as completely expressed or performed, as far as

[8] Psychol. Rev., Op. cit., pp. 155–156

[9] R. T. Wiltbank, The Principles of Series and Completeness of Response as Applied to Learning. Psychol. Rev., xxvi, 281, 1919.

[10] Psychobiology, ii, 245–254. 1920.

the discharge of nervous energy is concerned, as is the tendency to go through the short path.

In contrast to the above views there is a second type of theory for the explanation of learning offered by another group of students in animal behavior. This new type of explanation is based upon the prinicple of the conditioned reflex. But this principle, as other views stated above, is a description rather than an explanation of learning.

Let us turn now to another theory, that of Watson. Watson would have us believe that frequency and recency are the chief factors in selection and elimination in animal learning. As is well known, his chief argument is based upon the law of chance. He contends that simply as a matter of chance and the mechanics of the situation at the beginning of any new trial the successful act is the most recent act and has occurred the most frequently. Our own experimental data, however, do not seem to support this contention. Many rats learned to select a correct path not only *not* because of recency or frequency, or both, but in spite of them. As has been pointed out, recency has very little to do with the elimination of errors in the experiment reported in this paper. The findings of our experiment are sufficient to refute Watson's theory; we need not point to the empirical fallacy of his application of the mathematical law of probability to which he has committed himself.[11]

Carr would add to the principles of frequency and recency the principle of sensory intensity.[12] The same criticism which was raised against the views of Hobhouse, Holmes and Peterson may be applied to Carr's theory of sensory intensity; that is, he merely describes in his own fashion the nature of the successful and unsuccessful acts.

While the pleasure-pain theory, the theories of confirmation and inhibition, of congruousness and incongruousness, and of completeness of response, of conditioned reflex and of sensory intensity have described more or less adequately the nature of the

[11] See Dashiell's article, The Need for Analytic Study of the Maze Problem. Psychobiology, ii, 181–186. 1920.

[12] Principles of Selection, etc., Op. cit., pp 157–165.

selected and rejected acts, and have explained rather nicely how certain sensory-motor associations are formed, and while the principle of recency and particularly of frequency have explained how a habit is fixated, they have all failed entirely to give an adequate account for a selective agency, "which preserves or repeats certain activities and rejects others on the basis of their results,"[13] to use Holmes's own expression again. We do not mean here, however, to reject all these theories as wholly ungrounded, but rather to call attention to the fact that further analysis of the situation should be made so that a more adequate account for the selective agency can be given which will in no way contradict any of the above theories. Such an analysis will consist (1) of a distinction between the fixation of habit and elimination of errors; (2) the nature of the principal response and its relation to the subordinate acts, and (3) the determination and control of the principal response in the laboratory. Let us first take up the distinction between the fixation of habit and elimination of errors.

1. By fixation of habit is meant the *becoming automatic* of an act. By elimination of errors we mean the *selection and rejection* of acts. Acts may be selected or rejected by the animal at the early period of learning and yet they may not at once reach the automatic stage. It is only after a number of repetitions that they gradually become automatic; that is, fixated. That frequency is chiefly responsible for fixation of habit no one will deny. But frequency *per se* has very little to do with elimination of errors. Observations of the behavior of rats in a maze shows that in choosing a correct path a second time they do not go at it blindly, that is to say, they do not choose it as a result of mere previous frequency. In my experience after they have been disappointed a number of times in getting food by an incorrect compartment, they hesitated to enter that compartment when they happened again to go before its door, and after hesitating turned to the right compartment. Some of them half entered the wrong compartment but hastily withdrew

[13] Jour. of Compt. Neurol. and Psychol., Op. cit., p. 147.

and then went immediately into the right compartment; others passed by the incorrect compartment without even paying any attention to it. Such tentative non-automatic seeming choices were observed only during the beginning of the experiment; they disappeared after a correct compartment had been chosen and repeatedly entered for a number of trials; i.e., after fixation had set in.

That 'accuracy' which is, of course, the result of the elimination of errors, is something quite distinct from 'automaticity' which is the result of frequency, has been demonstrated by Miss Vincent's experiment on visual control in rats.[14] In this experiment she found that at the beginning of learning, before the rat's attention was freed, the choice of a correct path largely depended upon visual control, but after the problem had been learned kineasthetic functions gradually took the place of visual function and the act became automatic. She found also that in times of momentary distraction vision resumed its potency and the result was "a less perfect automatism and a slower speed." This shows clearly that accurate movement and automaticity (fixation) do not necessarily go together. So long as accurate movement is dependent upon visual control it indicates that 'fixation' has not set in or is momentarily disrupted.

In the case of human learning the distinction can be more readily seen. In the acquisition of a new skill a person may, through imitation or verbal instruction, be able at the beginning of learning to execute the performance as accurately as might be desired. But this can only be accomplished by great effort of attention. Here again, as in the case of the rats used in Miss Vincent's experiment, visual control plays a very important part in making correct movements. It is obvious that when attention is high or effort is great the act is not "fixated" and the speed of the performance is slow. Automaticity or fixation of habit is characterized by the decrease of effort or lessening of attention, by the gain in speed, and by the fact that the act is taken care of more by kinaesthetic and tactual function than

[14] Jour. of Animal Behavior, v, 1–24.

by vision. Of course, such an automatic stage can be reached only after numerous repetitions.

The distinction between fixation of habit and elimination of errors might perhaps have been very obvious to every one were it not for the fact that Watson insists on making frequency and accuracy alone responsible for elimination in maze learning,[15] for in so doing he obscures this distinction. Since our experimental findings and observations of the rats' behavior have clearly shown that frequency has very little to do with elimination, we are obliged to draw such a distinction and to seek for a more fundamental factor which is sufficient to explain learning. What, then, is this fundamental factor? This question leads us to a consideration of our second proposition; namely, the nature of the principal response and its relation to the subordinate acts.

2. The nature of the principal response and its relation to the subordinate acts have recent.y been well discussed by a group of writers (Perry,[16] Tolman,[17] and Woodworth[18]). Although these writers differ from each other in detail, the main motive of their attempt is essentially the same; namely, the desire to allow, in a purely mechanical and objective way, for the purposiveness which they would claim is inherent in and fundamental to learning. According to them the selective agency is a drive[19] (Woodworth), higher propensity (Perry), or determining adjustment (Tolman). This drive sets the organism in a state of readiness—bodily attitude or motor set. "Once aroused and not immediately satisfied" it acts as a determining tendency and excites certain varieties of subordinate responses and inhibits others. The subordinate acts or preparatory reactions are "means"—reactions, which are excitable by the drive and may serve to bring about the consummation of the end—reaction. These subordinate acts are selected or rejected according to their consequences with reference to the consummatory reaction.

[15] Behavior, pp. 267–268.

[16] Docility and Purposiveness. Psychol. Rev., pp. 1–20. 1918.

[17] Instinct and Purpose. Psychol. Rev., pp. 217–234. 1920.

[18] Dynamic Psychology. Columbia Univ. Press. 1918.

[19] I am inclined to think that this drive is acquired rather than inherited. See Jour. of Philos., xviii, 645–664, 1921.

Here we seem to have a somewhat adequate view regarding the selective agency in learning, a view which has been partially or wholly overlooked by all of the other writers whose doctrines with regard to the problem have been discussed in the foregoing pages. This mechanical interpretation of purpose does not, I think, necessarily suppose any presence of the ideational process or any psychical elements in the animal. The exponents of this theory, if I mistake not, are willing rather to characterize the "drive" in terms of muscle tension, motor set, and the like.

Unfortunately these writers have made no attempt to analyze the experimental conditions which bring about and intensify the determining tendency so as to make it prepotent in the situation. Such an analysis is of great import from the standpoint of animal experimentation, for the success of an experiment in animal learning depends to a great extent upon our ability to control the incentive of the animal. The reaction tendencies first evoked by the new environment may be undesirable for rather than helpful to learning. The food seeking trend is most frequently looked to to produce learning. Yet it may not necessarily dominate the situation at the beginning of the experiment. Curiosity which results in exploratory movements; fear which often results in excitability or escape movements; anger (as possibly in the case where the cat is confined in a box) which results often in violent reactions or escape movements, and probably some other reaction tendencies, are more likely to be prepotent at the beginning of an experiment. In fact in a great many rats the food seeking tendency is often completely held in abeyance by other reaction tendencies, particularly curiosity and excitability, during the first few days in the maze. In my own observations many rats were at first too much "excited" by the new environment to care for food even though they had not been fed for twenty-four hours. Such a state of excitement often lasted for two or three days—even longer.

But since these exciting tendencies may not be desirable for experimental purposes the attempt is usually made to reduce them to a minimal degree on the one hand, and intensify the food seeking trend on the other. This is attempted by the so-called "preliminary." During the preliminary an animal is put in the maze to make him familar with it so that curiosity, fear, etc., will not be aroused when the actual experiment is begun. Besides, during this period of preliminary the attempt is made to regulate the degree of hunger and the animal is fed in the maze (and nowhere else) so that it will acquire the habit of seeking for food when in the maze. In experiments where there has been no preliminary it is doubtful whether the food seeking trend dominated the situation at the beginning of the experiment. In Thorndike's experiment with kittens it is clear that the tendency to escape which resulted from fear or anger was prepotent at first—or at least mixed with hunger—and it was only after a number of trials that the former tendency gave way to the latter. In short, the purpose of the preliminary should be to make the animal adapt itself to any distracting stimuli so that reaction tendencies which will tend to interfere with learning will not be aroused.

The control of the motivating tendency for learning is not always successful. The animal may have acquired very strong tendencies of curiosity, fear, and the like, which tend to dominate over other trends and which cannot be easily suppressed by the experimental conditions. Animals of this type may be termed 'indocile,' meaning that they are uncontrollable in that the desired tendency for learning cannot be strengthened and the strength of the undesirable tendencies cannot be minimized. This will partially explain why some animals fail to learn at all; these animals are usually "indocile." And it will justify our procedure of selecting subjects for the experiment reported in the foregoing pages where many rats were rejected on account of their extreme excitability. (See above, page 7.) Failing to learn, however, may sometimes be due to lack of efficiency on the part of the experimenter to control the experimental conditions so as to reenforce the desired tendency.

If such an interpretation is correct, we can easily see why some of the rats learn more readily than others. There are three factors for quick learning; (1) controlability on the part of the learner, (2) readiness or plasticity of its nervous system to form associations, and (3) skill on the part of the experimenter in manipulating the experimental conditions which tend to facilitate on the one hand the reaction tendency desired for learning, and inhibit the disturbing tendencies on the other. In our experiment where many rats mastered the problem readily it may be due to the fact that especially great care was taken in selecting subjects, in regulating hunger, and in controlling other sensory stimuli.

In maze learning in addition to the food seeking trend which we utilize as the main motivating tendency in learning, we sometimes arouse in the animal the fear reaction tendency, so that certain alleys which require negative reaction will be eliminated more readily. This is usually accomplished by electric shock punishment. In administering the electric punishment great caution should be taken against the over arousal of the fear response. In some cases, either due to lack of skill in administering punishment or to the excitability of the rat, the fear response is so aroused that the animal displays violent action or is paralyzed and refuses to work so that the experiment has to be abandoned. In such cases the drive has been shifted; the fear response becomes prepotent and the food seeking trend is momentarily suppressed. There is some justification for those who object to the use of electric punishment; for unless it is carefully managed it is likely to result in a shifting of the drive which may tend to interfere with learning.

In some experiments, however, the fear reaction tendency may be used as the sole motive in learning. In Glaser's experiment, quoted by Watson, "where rats were dropped into hot or cold water and allowed to find an entrance, it was shown that the animal formed the habit of turning correctly in the hot or cold water and finally reaching the exit."[20] In such cases the sole drive in learning was "the tendency to escape." Such a tendency was so strong that the animal was "driven" to face an unpleasant experience—hot or cold water—an experience which he would ordinarily avoid.

[20] Op. cit., pp. 256–257.

Only after the drive desired for learning has been definitely secured can we divide the subordinate acts into two groups; namely, successful and unsuccessful acts. The successful and unsuccessful acts are referred to only from the standpoint of the consummatory reaction; only when an animal is seeking food can we call an act which will interfere with or prevent the animal from getting food an unsuccessful act. The same subordinate acts may be aroused by fear, curiosity, hunger, or other determining tendencies. But whether or not they are successful acts depends upon the consequences they bring about with reference to the determining tendency. All those terms such as correct or incorrect path, useful and useless movements, and a host of others of similar meaning that are inevitably employed in animal experimentation, refer to the purpose of the experimental conditions which are arranged by the experimenter so as to create or bring about a purposive reaction in the animal; otherwise they are all meaningless. Again, the nature of the sensory consequences of an act can only be understood in the light of the determining tendency. Carr says, "The blind check, thwart, and suppress activity more than does the true path while the latter encourages and facilitates activity more than does a blind alley."[21] Yet this is true only with reference to the food seeking trend. If the animal is well fed and well familiar with the maze the entrance into the blind alley or a confinement compartment may not produce such sensory consequences as Carr here describes; indeed were he not hungry he may lie down in the blind alley or in a confinement compartment and comfortably sleep there. And, furthermore, all the concepts of congruousness or incongruousness, completeness or incompleteness, and annoyance or satisfaction of response will have meaning only when they are interpreted in terms of the principal response. Our chief objection to these concepts lies in the fact that their advocates have failed to explicitly or sufficiently refer them to the purposive conditions of the experiment, or to the determining tendency which is produced by such conditions.

[21] Op. cit., p. 162.

The suppressed tendencies undesirable for learning may occasionally recur. Their recurrence may be due to momentary distraction by new sensory stimuli or by old stimuli to which the animal has not responded for a period of time. It may also be due to some changes taking place in the organism itself, or to some other disturbing factors outside the maze. The recurrence of the suppressed tendencies often tends to momentarily discontinue the process of habit formation which is being gradually built up. Great effort should be made to readjust the experimental conditions in every possible way so that the undesired tendencies will again be put under control.

Let us, now, turn once more to our discussion of the distinction between fixation of habit and elimination of errors, and restate it in the light of our experimental results. We have seen that the drive or determining tendency which moves the organism toward certain consummatory reactions excites a variety of subordinate responses and selects or rejects them on the basis of their results. An important point in this connection which has been brought out by Perry, and particularly emphasized by Tolman, is that there is a great deal of variability among the subordinate responses. These different acts may vary in their sensory effects with reference to the consummatory response; that is, some of them may be ill-adaptive, some irrelevant or excessive, others successful or essential, and, as has been pointed out, all ill-adaptive acts as well as excessive and essential acts vary greatly in degree. Now, if the differences in the degrees of ill-adaptiveness and excessiveness of various subordinate acts are discernible to the animal, (we are not here assuming any presence of consciousness) it will, other things being equal, eliminate these acts accordingly; that is, the ill-adaptive acts will be eliminated sooner than the excessive ones, and the more ill-adaptive ones sooner than the less ill-adaptive ones, and the more essential ones are often preferred. Thus, we have found in our experiment that the electric shock compartment is rejected more rapidly than the confinement compartment, and that these two compartments are eliminated sooner than the long path compartment, and we have confirmed De Camp's findings that within certain limits rats often choose a shorter path.

Here it is obvious that the ill-adaptive acts tend to prevent the organism from, or to disrupt the process of its activity toward, the consumatory response, and hence the muscular tension which is set toward that end-reaction is not released but instead it is likely to be intensified by such a prevention or disruption. And, furthermore, the electric shock, provided it does not produce any violent action or paralyze the animal, gives additional emotional reenforcement which tends to produce in the rat a quicker avoidance reaction (in such case, be it remembered, an additional reaction tendency; namely, fear, is aroused to coöperate with the main tendency; namely, the food seeking trend.[22] On the other hand, the excessive act does not produce any such sensory consequence, there being no disruption of the rat's activity or, in other words, it will eventually bring the animal to the food and hence releases the muscular tension. It is these differences in their consequences with reference to the principal response that account for the order of elimination as found in our experiment.

It must be admitted, though, that the rule of the order of elimination of the unsuccessful acts may be applicable only to such simple conditions as those in our experiment under which the rat is made capable of discriminating the differences between ill-adaptive and excessive acts. On the other hand, if the experimental conditions are so complicated as to throw the animal into confusion, or if the sensory effects of all the unsuccessful acts are equally or nearly equally the same (for instance, the same degree of punishment is given for every wrong choice, or if there is no punishment used in the experiment), the rule may be distorted and the rat may eliminate the errors in a random order or by some other factor such as, for example, recency, frequency, etc. In the case where no punishment

[22] The greater advantage of a combination of the two stimuli has, of course, been previously established by Yerkes and Dodson. Cf. Jour. Comp. Neurol. and Psychol., 1908, xviii, pp. 57–491.

whatever is used for wrong choice,[23] recency, and more particularly frequency, may affect in a negative way; that is, the blind alley which is entered most recently or most frequently is likely to be the most difficult one to be eliminated.[24]

Thus far we have been discussing the process of elimination of errors. Just one word more concerning the fixation of habit. In the early period of learning the rejected acts may occasionally recur or there may appear some new acts and, moreover, the selected acts may not at all times occur in a definite order. During this period of learning rats are more likely to be distracted by new sensory stimuli than they are during the later period. All this is due to the fact that the sensory motor associations have not been fixed and the separate successful acts have not been integrated. Now, after a number of repetitions, the associations are made more and more firm, and the whole series of the successful acts become integrated into a *chain response* and they will appear every time in a more or less definite and fixed order. Such is the process of fixation; it is essentially a process of the integration of the *selected* acts.

[23] In such case any unsuccessful movement must be regarded as excessive rather than ill-adaptive.

[24] Cf. Behavior, p. 288 (footnote) and also Peterson, Learning when Recency and Frequency Factors are Negative, Psychol. Bul., xxviii, 80–18, 1921.