THE EFFECT OF VARYING EXTERNAL CONDITIONS

ON

LEARNING, RETENTION, AND REPRODUCTION

by

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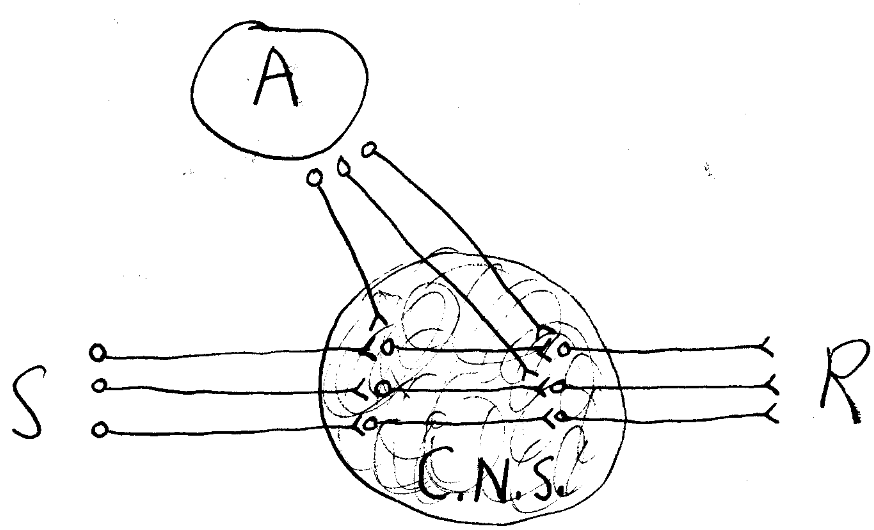
Section 1.

INTRODUCTION

It would be superfluous to discuss the importance of studying the psychology of learning. This field has lately attracted more and more attention from competent psychologists and rightly so. For applied and theoretical psychology, and for educational psychology the problem of learning is a central one. As a natural consequence, the work in this field has become more and more exact and detailed. It is to just this sort of problem that this report is addressed.

The problem is not a new one. The effect of external conditions on learning has been investigated to some extent in the past. Some such study as Bills' investigation (2) of the effects of muscular tension on learning would be one example. He found that muscular tension exerts a facilitating effect on learning.

The purpose of the present study was to determine the influence of varying external conditions on learning, retention, and reproduction, and the following diagram will illustrate what is meant.



We may think of the learning arc as the S-cns-R (see diagram). In this diagram S represents Stimulus, CNS represents Central Nervous System, R represents Response, and A represents an external condition. We may then think of condition A as either inhibiting or facilitating the bonds in CNS. That is, A might either facilitate or inhibit the formation (learning) of these bonds; might hasten or retard the wearing out of these bonds with time (retention); or might facilitate or inhibit impulses discharging through the bonds (reproduction).

We may see the problem in its practical aspects if we remember that the problem is one with which we come in contact in our every day life. If the favorite pipe is not ready to hand when wanted, learning, studying, or reading may be halted until it is found, and if it is not found, studying may be given up altogether. Henry (9, p.158) reports several cases of famous men who illustrate this phenomenon, in too bizarre a fashion perhaps, but still acceptably. Ampere, for instance, could not do his thinking unless he was walking. Descartes, on the other hand, found that he did his best work lying in bed, and he recommended this method to would-be philosophers.

We hear of various other writers sitting down to write only when dressed in formal evening dress. Schiller, peculiarly enough, found that in order to think, he had to have his feet on ice and sniff the odor of fermenting apples. This, of course, is a ridiculous extreme. The phenomenon illustrates the same principle, however. The stimulus-response arc can not function unless the background condition is present.

Bostock (3) tells us that we may observe the same phenomenon in circus animals. He reports the case of the tigers who always went through their tricks in the arena while the band was playing. One day the band went out on strike and so there was no music that day. It was found impossible to make the animals perform.

Burnham (4) reports a similar incident which illustrates the same principle. An elephant went wild. He ran about tearing, killing, and destroying. Apparently nothing could stop his rampage. Suddenly he found himself in the arena where he customarily went through his routine. At once his wild impulses were short-circuited, and there in the middle of the deserted arena he went through his tricks one after the other. And when he was done he took up his rampage where he had left off and went on crashing through the tents once more.

It is unnecessary to multiply incidents. We see, in short, that the stimulus-reponse arc, which is customarily conceived of as a discrete entity is nothing of the sort. It is influenced by other arcs of responses and stimuli. Conditions, circumstances, and positions can facilitate or inhibit. It was to study the effects of variations of simple conditions that this experiment was carried out.

Section 2.
HISTORICAL

I. Observations on animals.

Small (18a)*, one of the first to work with the maze, made some incidental observances that are interesting. He reports that his rats learned the maze in the dark and reproduced in the light without any loss

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* Quoted from Watson (20).

in efficiency. Of course it must be remembered that any changes that might occur because of varying external conditions would be of no great magnitude, as the cues in learning were not affected. This observation of Small and most of the others following would be subjected to this criticism, namely, that they were looking for changes and disturbances of some magnitude and thus may have neglected to report more minute changes. Small also had the rats learn the maze with the lights shining from one side. They then reproduced with the lights shining from the other side. There were no effects. He tried the effects of putting red posts in the middle of the right path a few inches beyond the dividing of the ways. When the path was learned these posts were removed. There was no effect on either the original learning or the reproduction. Yerkes* (22) found on the contrary that changing the coloring of the walls of the maze did markedly affect the frog's learning of the maze.

Allen (1) put colored cards at one of the critical turns in the maze which a guinea pig was learning. There was no effect on either learning or reproduction. She also tried changing many of the conditions after the maze was learned. Light was excluded. Cardboard walls were substituted for the original wire ones. A black cloth covered the floor of the experimental cage. No difference in time was found.

Rouse* (18) had pigeons learn a maze in the light. Reproduction in the dark had a disturbing effect. We must here distinguish between light as a background condition and as a bearer of visual cues. Turning off the light and making the room dark would disturb ones reading. This

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* Quoted from Watson (20).

** Watson (20) describes these experiments, at the time unpublished.

is because the visual stimuli are removed and not because of background conditions primarily. The S-R arc is disturbed not because of any effects of outward conditions, but because of the removal of the stimulus part of the arc.

Carr** had rats learn the maze in the light and reproduce in the dark and reports no observable difference in time.

The criticism made in connection with Small's study would apply here also. This result was an incidental observation, made while investigating a different problem. We may suggest that a procedure better calculated to arrive at truth would be some such scheme as the following. Four groups of animals would learn and reproduce the maze under the following set of conditions:

Group One - learn in dark, reproduce in dark.
Group Two - learn in dark, reproduce in light.
Group Three - learn in light, reproduce in light.
Group Four - learn in light, reproduce in dark.

The results that would be obtained in such a procedure would be much more significant.

Watson (2) carried out an extensive series of experiments on rat learning. Rats learned the maze in the light. Their eyes were enucleated and they were then again run through the maze. He reports that there was no difference in the performance of the two groups of rats. In another experiment, anosmic rats learned in the light and reproduced in the dark. Learning and reproduction were equally efficient in the two cases. Deaf rats also performed normally in the maze. Removal of all auditory conditions was without effect. The removal of the rats vibris-

** Watson (20) describes these experiments, at the time unpublished.

sae had no effect after a short rest. Changes in temperature, air currents, and cutaneous factors also made no difference. One change of condition which had a marked and unexpected influence on learning and reproduction was rotating the maze. When Watson did this he obtained marked disturbances. These were not due to a change in environment or external cues becamse no disturbance resulted when the maze was carried twelve feet straight south, maintaining the original orientation. Apparently a change in respect to compass direction was the only type of change that had this effect.

Watson's experiment on rotating the maze was repeated and confirmed by Porter (17) on sparrows, and by Hunter (10) on pigeons. Dashiell (7) also investigated the influence of rotating the maze on rats and he attributed the effects produced to disturbed bodily orientation. Lashley (13) and Lashley and Hubbert (14) noticed and reported bodily orientation of the rats towards the goal. Lashley found that if the roof was taken off the alleys of the maze, the rats could run straight for the food box over the tops of the alleys.

May and Larson (15) found it possible to teach a dog not to accept food until his hind legs were extended by the experimenter. This was done by Kälischer's "Dressur" method (12).

Carr (5) carried out an extensive series of investigations that are summarized in Table I reproduced from Shuh Pan (16). It will be seen that he confirmed Watson's results and added to them.

II. Observations on humans.

Jones reports (11) that visual memory and auditory memory are better when subjects are lying in the horizontal position. Adding in this

Table I

A Summary of Carr's Experimental Results

Alteration of Conditions during Recall (after Learning)	Effects
1. Covering maze with canvas top after it was learned	No effect
2. Uncovering maze after learning. Change from poor daylight illumination to normal daylight illumination.	No effect
3. Uncovering maze. Change from artificial illumination to daylight illumination.	5 out of 10 rats affected. Average error for those affected increased from 0.20 to 1.07
4. Increase of illumination	7 out of 10 rats affected. Average error increased from 0.51 to 1.35
5. Decrease of illumination	7 out of 10 rats affected. Average error increased from 0.21 to 3.18
6. Change of position of experimenter	All rats affected. Average error increased from 0.11 to 2.50
7. Rotation of uniform environment (canvas top)	No effect
8. Rotation of heterogeneous environment (canvas top with one side open)	5 out of 7 rats affected. Average error, 1.90
9. Change of position of maze in the room	4 out of 6 rats affected. Average error, 2.08
10. Rotation of maze. 5 experiments with various conditions	All showed disturbance. Results in harmony with those secured by Watson
11. Rotation of maze and environment	On average 8 out of 10 rats disturbed. Average error, 1.40

Alteration of Conditions during Learning	Effects
1. Maze rotated 90 degrees for each day's test	Average number of trials required for mastering the maze, 30. Group zero error record first obtained on

Table I (continued)

	36th trial. Average error, 196. The corresponding values for a group learning the same maze while it is stationary were 18, 22, and 144 respectively. A comparison between two other groups with previous experience upon different types of problems showed similar results.
2. Maze covered by canvas top.	Average number of trials, 26; average number errors, 282. The corresponding numbers for the control-group were 18 and 144 respectively.

position is more accurate and more rapid. However, pitch discrimination is greater in the ordinary vertical position as is the strength of grip and rate of tapping.

Wilson's experiment, which was reported by Smith and Guthrie (19, p.112) also bears directly on our problem. He had a group of subjects learn in a laboratory room. A second group learned in this room and reproduced out in the open. A third group learned in the open and reproduced in the open. And a fourth group learned in the open and reproduced in the laboratory. He found that the group that learned and reproduced in the same surroundings did better than those that learned and reproduced under different conditions. He repeated the experiment using the odor of peppermint as the variable condition, and obtained similar results.

Wong and Brown (21) studied the effects of surroundings on mental work as measured by Yerkes' multiple choice method. They found that the group which worked in a disordered, dusty attic room did not do as well as a group working in a neat, sunny office.

Shuh Pan (16) found that learning and recall of paired associates were influenced by contextual conditions. The nature and amount of effect varied with the nature of the condition. A word-context logically related to the response word exerted a beneficial effect on the learning. Its removal during the recall was highly detrimental to the learning. When the context was varied during the learning, the effects were lessened. A word-context logically unrelated to both the stimulus and response words was detrimental to learning. Its removal during the recall was beneficial. The presence of a number-context during learning was slightly detrimental and its removal in recall exerted a similar effect.

Bills (2) found that a condition of tension during learning helped this learning as measured by speed, accuracy, and relearning. Tension during recall was also beneficial. All of the experiments described above were concerned with the effects of varying a background condition on the efficiency of learning, retaining, and reproducing. In the present experiment, the background condition that was varied was the sound of a bell.

Section 3.

PROCEDURE AND APPARATUS

A table top partition, painted black, was located between the experimenter and the subject. This partition was placed vertically along the central line of the table. Its dimensions were 26" x 48". Exactly in the center of this partition was a slit-like window, 1" x 5", which framed the card which the subject was to see. From his side the experimenter was able to control a simple slide mechanism similar to that used in moving and replacing slides in a projection lantern. This enabled the experimenter to put one card in place while the other card was being shown.

The material that was used was a list of nine meaningless words with as little interassociation as possible. The words were picked by chance from the list of "Familiar Words in Learning Experiments" in Cason's article on backward association (6). This list was constructed by him from a list of most common 3-letter words in Thorndike's "Teachers Word Book" (1921).

Although these words were chosen by chance, certain rules for improving the list were used. All words with obvious associations were eliminated. Words beginning with the same letters were never put near each other. Meaningful groups of words were split up, and every attempt was made to have the words and the series equal to each other in memory value.

A total of 100 series, of nine words each, were made up in this way; and the lists were typewritten on cards just large enough to fit into the apparatus. What the subject saw was a 1" x 5" aperture, and a white cardboard on which was typewritten a series of nine meaningful words in meaningless order. Each word in Cason's list was used three times, but always in different series.

Each card was exposed ten seconds, and the subject just had enough time to read the series twice. Thus the learning was of the memory span type. The card was removed from view and the subject gazed at a blank white card in the window (for five seconds in the first experiment and fifteen in the second). This was the period of retention. At a given signal the subject repeated as many words as he remembered. (Fifteen seconds was allowed in Experiment I; 10 seconds in Experiment II.) Only correct reproductions of words were scored. The entire procedure was repeated several times. In Experiment I the pause between the two series was a variable length of time, from 5 to 15 seconds. It was noticed that the sooner one series followed another, the poorer were the results. In Experiment II this variable was controlled. Exactly ten seconds elapsed between the end of the reproduction period and the presentation of the next card. Series were presented in this fashion for about an hour.

The sound of a bell was chosen as the variable external factor because of its simplicity and convenience. The two conditions that we used were (1) presence of the bell stimulus, and (2) absence of the bell (silence); and all possible combinations of the three periods and the two conditions which we used are as follows:

	Learning	Retention	Reproduction
Series S	silence	silence	silence
" T	"	"	bell
" U	"	bell	silence
" W	bell	bell	bell
" V	silence	"	"
" X	bell	bell	silence
" Y	bell	silence	bell
" Z	bell	silence	silence

These series were presented in such a way as to eliminate the factors of position, serial association, and similarity of series. The word cards were presented so that each card was learned under each and all of the eight series of conditions.

It was noticed that there was a marked practice effect, and in order to partially eliminate this factor, each subject learned eight practice lists and these results were not used.

Two separate experiments were carried out. In the first, the period of learning was 10 seconds, of retention 5 seconds, and of reproduction 15 seconds. In the second experiment, the periods were 10 seconds for learning, 15 for retention, and 10 for reproduction. The principal difference between the procedure in the two experiments was in the time intervals. The number of subjects in the first experiment was 28. The results from six of these subjects were discarded because of changes in procedure at the beginning of the experiment. The number of subjects whose results were used was, for the first experiment 22, and for the second experiment 35.

Section 4.

RESULTS

The results for Experiment I and Experiment II will be presented separately and then compared with each other. The frequency of the scores in Experiment I is given in Table 2. The Condition-Series (S,T, etc.) are shown in the second row, and the numbers of words reproduced are shown in the second column. For example, in condition S, 19 subjects reproduced three words out of a possible nine. The mean scores for each of the eight conditions are given in the last row. The order of efficiency for the various conditions was as follows:

	Learning	Retention	Reproduction
W - 5.339 ± .08	bell	bell	bell
U - 5.241 ± .07	silence	bell	silence
S - 5.215 ± .09	silence	silence	silence
T - 5.160 ± .08	silence	silence	bell
Z - 5.096 ± .08	bell	silence	silence
V - 5.090 ± .08	silence	bell	bell
Y - 5.080 ± .08	bell	silence	bell
X - 5.040 ± .08	bell	bell	silence

TABLE 2

Frequency of Scores in Experiment I

Number of Words Reproduced Out of a Possible Nine	Condition-Series							
	S	T	U	V	W	X	Y	X
0	1	2	1	0	1	3	2	1
1	3	0	1	1	1	2	0	3
2	5	4	7	6	5	5	7	5
3	19	14	11	22	10	20	13	16
4	27	41	33	37	24	27	27	33
5	48	37	40	42	60	47	54	52
6	43	48	34	38	46	44	33	37
7	20	19	27	19	21	18	20	16
8	7	6	11	9	7	8	8	11
9	8	5	1	4	5	2	0	3
M. ± $P.E._M$	5.216 ±.09	5.160 ±.08	5.241 ±.07	5.090 ±.08	5.340 ±.08	5.040 ±.08	5.080 ±.08	5.096 ±.08

The fact that the W series is the best for learning has no clear cut significance. We might have expected this result from what we know of distraction experiments. However, we are not testing the effect of distraction. On the basis of the distraction idea, we might expect that the more bell, the better the learning. But this interpretation is excluded by the fact that the X and Y series are at the bottom. It will be more profitable to compare the results of the two experiments.

There is one other way of treating the results to get differential effects of the bell during the three periods. We might add for each period the position numbers, as follows (using the table of order of efficiency on page 11.) For example, if we look at this table we see under the head of Learning the condition used in the various series during the learning period. Do we find bell or silence being used at the top of the list, that is, in the most efficient series?

Learning Period		Retention Period		Reproduction Period	
bell	silence	bell	silence	bell	silence
position:					
1	2	1	3	1	2
" 5	3	2	4	4	3
" 7	4	6	5	6	5
" 8	6	8	7	7	8
21	15	17	19	18	18

The only conclusion we can draw from this treatment is thatduring the learning period, it is slightly more advantageous to learn in silence.

There is one deduction that we might legitimately make from the results of Experiment I. We can say that when the conditions for learning and for reproduction are the same, the learning is more efficient. The retention period is not as important so far as varying conditions go. If we take the series that conform to this condition, their position numbers are in order - 1, 2, 3, and 7 or W, U, S, and Y. Why the Y series is so far down is impossible to explain. The position numbers of the series in which conditions for learning and reproduction are different are, 4, 5, 6, and 8 (T, Z, V, X).

This set of observations may be summed up as follows. Learning is more efficient when the conditions of learning are the same as the conditions of reproduction.

This view is substantiated by Wilson's experiment (19), referred to above. Gates (8) also believed that this similarity of conditions during learning and recall are more conducive to learning. The results of Experiment II do not substantiate the tentative theory, however.

If we examine Table 3 we find that there are no reliable differences between any of the means of the series. The only differences that approach reliability are those between series W (at the top of the list) and the series X, V, Y, and Z at the bottom of the list. These differences have critical ratios of more than two.

Experiment II

In general, this experiment was exactly the same as Experiment I except for changes in the time of the various periods. The retention period now is given 15 seconds, instead of 5 as in Experiment I, and the reproduction period is now 10 seconds instead of 15.

Table 3

Differences between Efficiency of Series - Experiment I - n = 22

T	U	V	W	X	Y	Z	
0.055 ± .12	0.026 ± .04	0.126 ± .12	0.123 ± .11	0.176 ± .12	0.136 ± .12	0.120 ± .12	S
	0.081 ± .11	0.070 ± .11	0.179 ± .11	0.120 ± .12	0.080 ± .11	0.064 ± .12	T
		0.151 ± .11	0.098 ± .11	0.201 ± .11	0.161 ± .11	0.145 ± .11	U
			0.249 ± .11	0.050 ± .12	0.010 ± .11	0.006 ± .11	V
				0.299 ± .11	0.259 ± .11	0.243 ± .11	W
					0.040 ± .11	0.056 ± .12	X
						0.016 ± .11	Y

Our results in Experiment II are more reliable than those in Experiment I. The order of efficiency was:

			Learning	Retention	Reproduction
W	5.235	± .05	Bell	Bell	Bell
T	5.128	± .07	Silence	Bell	Bell
Y	5.022	± .07	Bell	Silence	Bell
S	5.016	± .08	Silence	Silence	Silence
V	4.926	± .07	Silence	Bell	Bell
Z	4.855	± .07	Bell	Silence	Silence
X	4.850	± .08	Bell	Bell	Silence
U	4.826	± .08	Silence	Bell	Silence

Here again we have the W series at the top. The order of the series (except for interchange of U and Y) is approximately the same as the order for Experiment I. If we put them side by side we can see this more readily.

Experiment I	Experiment II
W	W
U	T
S	Y
T	S
Z	V
V	Z
Y	X
X	U

Except for series U and Y, the rank order of all is the same or approximately the same. The explanation for this interchange of position may be found in the increasing period of retention.

Series U and Y are the converse of each other, one being

U = Silence Bell Silence
Y = Bell Silence Bell

The bell ringing during a long period of retention would undoubtedly explain the relative loss in efficiency in series U, at the same that it would increase the relative advantage of series Y.

If we examine the support for the tentative generalization made as the result of Experiment I, we find that it does not fare quite so well as it did then. If we add up rank numbers for series that have condition, the same for learning and reproduction, we find them in order 1, 3, 4, 8 (W, Y, X, U) as against 2, 5, 6, 7 (T., V, Z, X). Adding them reveals only a slight advantage (16 vs. 20) for the similar series as over against the dissimilar series. This would naturally be expected with the increased importance of the retention period.

If we get the differential effects of the bell on the three periods we find them as follows:

	Learning Period		Retention Period		Reproduction Period	
	bell	silence	bell	silence	bell	silence
Pos.	1	2	1	2	1	4
	3	4	5	3	2	6
	6	5	7	4	3	7
	7	8	8	6	5	8
	17	19	21	15	11	25

We see silence as a slight advantage during the retention period. Introspective reports, after the experiment, of the subjects confirms this finding. Unexpectedly enough we find that the bell during the reproductive period is a great aid to efficiency, whereas in Experiment I there was absolutely no difference. I have no explanation to offer for this phenomenon.

If we examine Table 5 we find that we have differences much more reliable than Experiment I.

If we arrange the series in the order of their efficiency (W, T, Y, S, V, Z, X, U), we find that we have differences that are reliable or that fairly approach reliability, for any series and any other series 2 rank orders removed from it. That is, the difference between S and X, V, and W will be more reliable but the difference between S, Y, and V will not be.

Summary and Conclusion

There is no doubt that varying sets of external conditions influence learning arcs and influence them in a constant way. This is proven by the relative stability of the rank order of the series in the two experiments. A radical change in the retention period affected seriously the rank order of only two series (U and Y). Beyond this change the two experiments confirm each other.

Varying the length of the retention period did affect the relative efficiency of the 2 condition-series, namely, U series (S-B-S) and the Y series (B-S-B).

Table 4

Frequency of Scores in Experiment 2

Number of Words Reproduced out of a Possible Nine	Condition Series S	T	U	V	W	X	Y	Z
0	1	0	0	0	0	1	0	0
1	3	0	3	3	0	2	1	2
2	6	5	10	6	7	14	4	6
3	18	21	27	14	18	24	16	24
4	43	33	40	48	36	34	45	43
5	43	62	45	54	53	45	47	54
6	45	45	42	44	45	51	38	42
7	15	18	13	12	24	15	22	19
8	10	10	5	8	6	5	5	3
9	3	1	5	0	7	3	0	0
M. ± P.E.$_M$	5.016 ±.079	5.128 ±.068	4.826 ±.079	4.926 ±.069	5.235 ±.050	4.851 ±.079	5.023 ±.069	4.855 ±.067

Table 5

Differences between Averages of Series - Experiment 2 n = 35

T	U	V	W	X	Y	Z	
0.112 ± .10	0.190 ± .11	0.090 ± .10	0.219 ± .09	0.166 ± .11	0.007 ± .11	0.161 ± .10	S
	0.302 ± .10	0.202 ± .10	0.107 ± .08	0.278 ± .10	0.106 ± .10	0.273 ± .10	T
		0.0996 ± .10	0.408 ± .09	0.024 ± .11	0.196 ± .11	0.029 ± .10	U
			0.309 ± .08	0.075 ± .10	0.097 ± .10	0.071 ± .10	V
				0.384 ± .09	0.212 ± .09	0.380 ± .08	W
					0.172 ± .10	0.004 ± .10	X
						0.168 ± .10	Y

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