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THE LAW OF EFFECT

By EDWARD L. THORNDIKE, Teachers College, Columbia University

The alleged law of effect, that what comes after a connection acts upon it to alter its strength, has suffered disfavor from psychologists and neglect from physiologists. It is, compared with apparently more mechanical forces like frequency and intensity, indefinite and troublesome to think with. It has been even more odious to philosophers and educational theorists who find it a dangerous antagonist to, or an inferior substitute for, their explanations of behavior by purposes, relief from tensions, and other teleological or quasi-teleological factors.

It was invented as a purely empirical hypothesis to explain the facts of learning or modifiability in animals which frequency could not explain. It was extended as a fundamental law to assist in explaining the general potency of wants, interests, purposes and desires in education and elsewhere. The chief justification of it in the past has been the fact that when 'annoyingness' is attached to a frequent connection and 'satisfyingness' to a rare connection, the latter gains and the former loses until the latter becomes the habitual response. Recent experiments[1] have shown that the frequent will not, by its frequency alone, gain at the expense of the rare, so that when a frequent response grows more and more frequent, some law of effect is needed as truly as when the rare displaces the frequent. So now, more than ever, the law of effect deserves a more thorough-going investigation.

I report here what I hope may be one step in such a thorough investigation. The experiments to be reported here were designed to be, and I think are, a crucial test of whether the after-effects of a connection do in fact strengthen or weaken it.

The effects which have practically monopolized what little discussion there has been are satisfyingness and annoyingness, or states of affairs considered according to the amount of satisfyingness or annoyingness which they possess. It would probably be profitable to study also excitement and calm, sensory pains and sensory pleasures,

[1] A preliminary report of these was made in *Proc. Nat. Acad. Sci.*, Jan., 1927.

muscular tension and muscular relaxation, restlessness and quiescence, and other effects of the action of connections; but we shall limit ourselves to the effects to which primary importance has been attached by the adherents of the doctrine.

The actual effects used in the experiments were the words "right" and "wrong" spoken by the experimenter about 2 sec. after the *S*'s response.

EXPERIMENT A

A series of 50 strips of paper, two of every unit length between 3 and 27 cm., and alike in every respect except length, was presented on a fixed background in a random order. The *S*, who had before him a strip 10 cm. long and known by him to be 10, estimated the length of each strip in integral numbers. The 10-standard was kept fixed in a spot to the right of the lengths to be judged. The *S* knew nothing concerning the constitution of the series of strips, save that they were all integral multiples of one-tenth of the standard. He never saw the strips except one at a time during the experiment.

After 50 judgments had been made with no aid save that which the *S* could derive from the standard, and with no statement to him of any sort about the results, the series was presented in the following manner. A strip was placed before *S*. As soon as *S* announced his estimate, the strip was withdrawn, placed behind a screen and turned over; and the experimenter said "right" or "wrong," according as the estimate was right or wrong. No statement was made of the amount or direction of the error. The experimenter then recorded the estimate, and presented another strip. The statement of "right" or "wrong" came approximately 2 sec. after *S*'s announcement of his estimate, and approximately $1\frac{1}{4}$ secs. after the strip was removed from his sight. After a number of such presentations of the 50 strips (usually seven, two or three a day for three or four days), the series was presented with no aid, save the presence of the standard 10, as in the first trial.

The results of these experiments are like those where animals are rewarded by food or freedom or the like, after certain connections act; and are punished, or at least not rewarded, after certain other connections act. The satisfying connections are strengthened and the curve of successes rises indubitably and rapidly. The results are in striking contrast to those of experiments of similar nature in which no "right" and "wrong" consequences are attached to the connections.

Table I shows the essential facts for 5 *S*s in the case of whom the connections produced the effects of "right" and "wrong." All *S*s improved greatly. The average percent of reduction in the error was 61 with a probable error of ±4.

TABLE I

THE INFLUENCE OF EFFECT: The accuracy of estimates of lengths 3 cm. to 27 cm., a 10-cm. line being shown.

S	Test before training	Sums of deviations from the true lengths; training with "right" and "wrong"									
		Training periods								Test after training	Percent of reduction
		1	2	3	4	5	6	7	8		
A	33	47	32	31	27	22	22	13	14*	12	64
Le	68	59	46	49	43	37	26	26	41	35	49
Li	70	47	19	29	25	27	25	25		20	71
S	112	117	106	96	61	49	30	34		26	77
Wi	36	28	38	24	25	13	29	16		20	44
Sum	319	298	241	229	181	148	132	114		113	

Average, 61 ± 4 Median, 64

*Estimate from 25 judgments.

TABLE II

THE INFLUENCE OF MERE REPETITION: The accuracy of estimates of lengths 3 cm. to 27 cm., a 10-cm. line being shown.

S	Test before training	Sums of deviations from the true lengths; training with mere repetition								
		Training periods							Test after training	Percent of reduction
		1	2	3	4	5	6	7		
T	34	21	27	24	24	18	37	20	36	−6
K	61	73	41	50	55	48	60	58	40	34
R	50	38	52	42	38	40	37	33	49	2
H	54	38	48	34	33	25	52	35	35	35
M	99	126	125	128	126	89	79	93	89	10
C	91	70	84	107	66	85	77	93	116	−27
F	43	55	70	53	54	55	78	72	86	−100
Sum	432	421	447	438	396	360	420	404	451	

Average, −7 Median, 2

The gain came partly by a reduction in constant errors for Le, Li, and S, and partly by a reduction in the variable error for all. In the test before training Le had a total of 52 units too low and 16 too high; Li judged the lengths 15 or below too low in 19 cases out of 26, and judged the lengths 16 or above too high in 19 cases out of 24; S had a total of 111 units too low and 1 too high. In the final test Le's constant error was such as to produce 23 minus and 12 plus errors; Li's had been reduced to a slight tendency to estimate all lengths too low; S's had changed to a slight error in the opposite direction.

The reduction in the variable error may be measured by the differences between the two early estimates and the differences between the two later estimates for the same lengths. The sums of these differences were:

S	Before Training	After Training
A	19	8
Le	36	21
Li	37	10
S	30	12
Wi	25	12

With Table I we may contrast Table II, which presents similar measurements in the case of subjects of similar general intelligence and initial ability in estimating the lengths in the case of whom the same number of experiences occurred, but with no effects in the shape of announcements of "right" and "wrong."

As a general check on the universality of the facts, and as a special check on the remote possibility that some personal influence of the experimenter might have in some way distorted the facts, Mr. Abelson did me the favor of repeating the experiment with 6 *S*s, but with five instead of seven presentations with "right" and "wrong" as effects. The control *S*s similarly had five presentations with no aid. The results, shown in Table III, are closely similar to those of the first experiment. The average percent of reduction in error is 50, with a probable error of ± 5. The average percent of reduction for the control group is 6 with a probable error of ± 12.

These experiments are crucial as a demonstration that the consequences of a connection work back upon it to influence it. There is no difference between the 'aided' and 'no aid' experiences save in the consequences of the connections. It is also evident that the

consequences probably act on the connection directly, and not by leading the *S* to repeat it, or something like it, to himself. Strictly speaking, he could not repeat *it*, but at most could hold in mind some sort of image or illusion of the strip and repeat the approved estimate as a response to this image or illusion. He had little time to do this because a new length was presented about a second after the "right" or "wrong" announcement was made. It is improbable that such images would be sufficiently accurate to serve as substitutes for the real strips. We hope later to carry out special experiments to settle this question.

TABLE III

THE INFLUENCE OF EFFECT: The accuracy of estimates of lengths, 3 cm. to 27 cm., a 10-cm. line being shown. Data by Abelson. Sums of deviations from the true lengths

Tests before and after 5 periods of training with "right" and "wrong"				Tests before and after 5 periods of training by mere repetition			
S	Before	After	Percent of reduction	*S*	Before	After	Percent of reduction
A	53	37	32	G	70	61	13
B	72	13	82	H	56	104	−86
C	57	40	30	I	60	54	10
D	34	14	59	J	66	46	30
E	106	67	37	K	82	59	28
F	128	49	62	L	136	80	41
Sum	450	220			470	404	
Average			50±5	Average			6±12
Median			48	Median			21

It is of course true that a continued success with some one strip, say 3, may influence the estimates of other strips. The 25 strips form to some extent one experiment, not 25 absolutely independent experiments. Being sure that you would know that a short-looking strip was 3 if it really was 3, and thinking that it is not 3, you are profitably led to call it 4. Such facts do not, however, deny that fundamentally the consequences act directly on the connections. And quantitatively, these indirect secondary aids are of relatively little consequence. They often teach the *S*s that 3 is probably the smallest strip that will be presented to them, but 2, 3, and 4 are easily learned, apart from this probability. No *S* gained any surety about the probable upper limit of the series. The greatest aid from this in-

direct ratiocinative use of the consequences seems to be gained when a *S*, feeling fairly sure that certain strips are, say, either 13 or 14, either 16 or 17, either 20 or 21, observes that his lower (or higher) estimates are right and thereafter deliberately favors the lower (or higher) estimate in such cases. Such ratiocinations may, however, be prepared for and based on direct strengthening of certain connections by the "right" and "wrong" consequences. They are also themselves in part constituted by the attachment of "right" to the connection: "My lower estimates are better than my higher." And they do not account for the reduction of variable errors.

Experiment B

In experiment B,[2] the connections were between the commands, "Draw a 3-inch line," "Draw a 4-inch line," "Draw a 5-inch line," "Draw a 6-inch line," and the response of drawing under conditions described below. The effects were "right," said by the *E* when the line drawn was within $\frac{1}{8}$ in. of the correct length in the case of 3-in. lines, or $\frac{1}{4}$ in. of the correct length in the case of the other 3 lengths, and "wrong" said in other cases.

The procedure in learning to draw lines of stated lengths with eyes closed was as follows:

The *S* was seated, blindfolded, at a table opposite the *E*, and in front of a drawing-board, along the left-hand edge of which a strip of veneer, about 2 in. wide, had been fastened in such a way that a large sheet of cross-section paper (16 x 21 in.) could be slipped between it and the board and fastened to the board by means of two or three carpet tacks. The strip of veneer served as a fixed starting edge for all lines. The cross-section paper itself was so ruled, in pencil, as to make it possible for the experimenter to tell readily the length of any line drawn from the strip as a zero point.

The *S* was instructed to draw lines of a given length, starting always from the strip of veneer at the left, and to wait after each line until hearing the score called, before drawing the next line. He was required to draw each line with one continuous, quick movement.

The *S*s were trained to draw 3-, 4-, 5-, and 6-inch lines at a single sitting, and were instructed to draw lines of a given length, waiting

[2]The writer is responsible for the general plan of experiment B and for the treatment of the results, but the credit for the details of its execution belongs to Dr. Elsie O. Bregman. With the assistance of members of the staff of the Institute of Educational Research, she conducted all the tests and training and supervised the scoring and tabulating of results.

after each line to hear its score, until directed to draw lines of a different length. The number of successive repetitions of a single length varied between 4 and 8, and the lengths followed each other, not numerically, but in a random order, according to a prearranged scheme. This scheme, which we shall call the 600 series, since it is made up of a series of 600 lines, 150 of each of the four lengths, was followed at each test period and training period.

Twenty-four *S*s were tested with this series with no announcement of "right" or "wrong," before and after seven training periods at least a day apart, in which "right" or "wrong" was announced about one second after each response. From start to finish no *S* ever saw any line that he drew, or had any practice other than that described above.

The percent of "right" responses in each training period and the percent which would have been "right" (if announcement had been made) in the early and late tests are reported in Table IV. Every *S* improved during the training, though the gain of *S* 41 was so small as to be uncertain.

The percent right rose from a median of 13 in the early test to a median of $34\frac{1}{2}$ in the first training period, and a median of $54\frac{1}{2}$ in the seventh. In the late test, when the *S*s were without any guidance and connection from the announcements of "right" and "wrong," the percent fell back to a median of $26\frac{1}{2}$, but was twice as large as in the early test. Sixteen of the 24 *S*s had more right in the late than the early test. The average gain was 12, with a probable error of 2.2.

A more accurate estimate of the influence of the "right and wrong" conceptions of the connections may be had by measuring each line drawn and computing the average errors in the early and late test for the four lengths. This we have done with the results shown in Table V. There is a reduction in the error for each length and for 18 of the 24 *S*s. The average reduction is nearly eight times its probable error.

If we could assume that mere repetition of such line-drawing with no difference in the effect of accurate and inaccurate responses would produce zero reduction in the error, the result of experiment B would be a second proof that the effects of a connection do work back upon it to alter its strength. It seems better, however, to check this assumption by experiment. Unfortunately, it has been possible to date to do this with only 6 *S*s. Each of them drew 5400 lines just as the *S*s of experiment B did, except that no announcement of

"right" or "wrong" was made at all. From the early to the late experiment three of them improved and three got worse. The gains were, however, greater than the losses, so that there was an average total reduction of 75 for these six, compared with 190 for the 24 *Ss* who had the effects of the "right" and "wrong." The probable error of the 75 is ±70. Consequently, the difference of 115 in favor of the

TABLE IV

THE INFLUENCE OF EFFECT UPON DRAWING LINES WHEN BLINDFOLDED: The percent of "right" response in early and late tests and during the training itself.

*S**	Percent Right									Gain: Late over Early
	Early Test	Training Periods							Late Test	
		1	2	3	4	5	6	7		
16	1	38	48	49	52	56	54	61	21	20
17	28	47	56	69	61	65	68	67	21	− 7
18	2	40	47	50	51	58	55	57	33	31
19	13	34	33	47	53	49	35	56	39	26
20	0	25	42	45	40	47	41	44	30	30
21	15	30	47	52	58	58	58	57	37	22
23	13	35	43	42	47	48	52	60	9	− 4
25	1	37	38	44	44	44	55	60	28	27
26	16	46	50	43	49	34	51	54	28	12
27	12	37	43	45	35	45	49	60	36	24
28	12	33	38	39	50	30	46	42	11	− 1
29	24	55	62	75	77	85	88	93	65	41
33	0	32	48	50	24	36	44	47	35	35
34	16	31	34	36	48	48	55	55	31	15
35	11	26	33	32	46	38	46	33	6	− 5
36	0	0	18	41	43	50	46	47	20	20
37	6	41	53	51	54	61	53	65	24	18
40	24	33	34	37	32	37	41	46	28	4
41	28	39	40	40	36	46	40	41	25	− 3
42	31	34	38	41	40	30	48	50	4	−27
43	7	31	34	27	35	41	40	39	21	14
44	24	36	44	51	49	53	60	62	35	11
46	20	36	42	45	52	48	48	53	11	− 9
48	13	26	38	50	53	46	54	48	9	− 4
		1003						1297		

*It may be of interest to know that *Ss* 16 to 29 were from 20 to 25 years old, and *Ss* 33 to 48 were 35 years old or over, averaging 42.

influence of effect has a large probable error (±74). There is one chance in seven that it may in the long run prove to be as low as 0.

From certain other experiments, and certain added facts about these experiments, which I shall not take time to present here, I am

TABLE V

THE INFLUENCE OF EFFECT UPON DRAWING LINES WHEN BLINDFOLDED

S	Average Divergences								Changes				
	3 in.		4 in.		5 in.		6 in.		3 in.	4 in.	5 in.	6 in.	Total
	Bef.	Aft.	Bef.	Aft.	Bef.	Aft.	Bef.	Aft.					
16	98	41	143	47	201	53	232	114	− 57	− 96	−148	−118	−419
17	28	32	44	59	69	61	84	81	+ 4	+ 15	− 8	− 3	+ 8
18	87	27	125	36	130	49	141	47	− 60	− 89	− 81	− 94	−324
19	59	33	96	29	113	37	131	38	− 26	− 67	− 76	− 93	−262
20	129	38	190	38	222	57	250	52	− 91	−152	−165	−198	−606
21	38	42	66	29	78	29	93	34	+ 4	− 37	− 49	− 59	−141
23	64	44	76	65	73	113	99	163	− 20	− 11	+ 40	+ 64	+ 73
25	111	22	150	33	208	64	262	64	− 89	−117	−144	−198	−548
26	80	36	68	35	93	54	84	47	− 44	− 33	− 39	− 37	−153
27	54	35	91	30	97	39	111	46	− 19	− 61	− 58	− 65	−203
28	79	58	79	103	103	89	115	94	− 21	+ 24	− 14	− 21	− 32
29	62	18	71	22	65	25	66	22	− 48	− 49	− 40	− 44	−181
33	212	27	210	23	275	34	336	40	−185	−187	−241	−296	−909
34	84	27	87	34	90	57	101	81	− 57	− 53	− 33	− 20	−163
35	63	56	103	80	126	97	146	116	− 7	− 23	− 29	− 30	− 89
36	94	45	151	65	202	53	279	62	− 49	− 86	−149	−217	−501
37	36	43	83	42	150	69	179	54	+ 7	− 41	− 81	−125	−240
40	50	32	57	48	64	62	76	58	− 18	− 9	− 2	− 18	− 47
41	37	54	45	48	56	51	71	78	+ 17	+ 3	− 5	+ 7	+ 22
42	58	76	56	122	71	165	70	189	+ 18	+ 66	+ 94	+119	+297
43	104	48	112	78	115	54	110	72	− 56	− 34	− 61	− 38	−189
44	76	24	58	45	56	37	55	45	− 52	− 13	− 19	− 10	− 94
46	33	46	45	93	73	93	86	143	+ 13	+ 48	+ 20	+ 57	+138
48	75	80	79	70	101	98	91	106	+ 5	− 9	− 3	+ 15	+ 8
Av.									− 35	− 42	− 54	− 59	−190
P. E. of Av.									± 5	± 7	± 9	± 11	± 25

of the opinion that the extension of experiment B and its control to more individuals and to more than the 4200 lines of training (or mere repetition with the controls) will strengthen the case for effect. This opinion may be somewhat justified to the reader by the fact that the 6 *S*s (of whom only three improved by mere repetition) all improved

when subjected later to experiment B; and improved by an average reduction of 143 ± 27 compared with the 75 ± 70 which repetition had brought.

Assuming that extensions of experiment B confirm our results in favor of a strengthening by "right" or a weakening by "wrong," or both, we have as in the case of the judgments of length, the question whether the influence acts directly on the connections themselves or indirectly by leading the *S*s to repeat some inner counterparts of the connections.

Under the conditions of the experiment, any actual repetition of the successful movement could not occur. The most that the *S* could do was to rehearse the inner "feel," or the cues which led him to make it; and there was little time for this between the execution of one movement and the demand for the next. What could be done was to retain or recall such a feel or such cues after a "right" and abandon or neglect them after a "wrong," and so get what benefit they gave in case the command was for a line of the same length as the previous one (as it was about five times out of six).

It seems probable that such deliberate retention or recall plays a part, but that there is also a more fundamental, general, and direct favoring of the successful connections, for two reasons. First, we have no evidence that a person improves any faster by trying deliberately to retain or recall such cues than by simply drawing line after line as he feels like doing. Second, it seems unlikely that cats, dogs and rats carry on any such deliberate reviews or rehearsals in the bulk of their learning.

By a more fundamental, general, and direct favoring, nothing mysterious need be meant. It may be so simple a thing as a longer duration of the connection, when the *S* hears "right" than when he hears "wrong." Such longer duration would presumably have the same strengthening influence as a larger number of repetitions of equal length.

Two features of the learning to draw lengths blindfold are striking and should be instructive. One is the slow and gradual nature of the process after the very early stage when the subject has (temporarily) got rid of any very pronounced tendency to draw the lines too short or too long. From the second to the seventh practice period, or from the first 150 to the last 150 of 900 lines of each sort, the gain in the number of right responses is only from an average of 42 to an average

of 54. The other is the great discrepancy between the ability under the immediate guidance of the announcements of "right" and "wrong" and the ability after these cease.

Both of these facts seem to me to bear witness to the importance of what may be called identifiability (or, more precisely, 'get-at-ableness') in learning. If the directions had been "Draw a parabola," "Draw a catenary," "Draw a cissoid," "Draw a cardioid," the *S*s, if they succeeded at all, would have probably quickly changed from 0% right to 100% right. They would also have maintained their ability without incessant guidance by "right" and "wrong." When a situation is identifiable so that a person can name it, or place it, or in anyway react to it, distinguished from other situations, and when a response is identifiable in the sense that the person can in any way make it and not any other response than it, the process of connecting any of his repertory of such responses with any of his repertory of such situations usually requires very few repetitions, and takes place very suddenly, suggesting an 'all-or-none' type of action.

The training in experiment B probably was efficacious partly in identifying the responses, more or less temporarily, and partly in strengthening their connections with the four commands. It is reasonable to suppose that the latter influence was much more permanent than the former. It is also reasonable to suppose that the failures of certain *S*s to improve were not due to a failure of the law of effect to act in their case, but to a failure of the response to become sufficiently get-at-able to be connectible with anything.