Journal of Experimental Psychology

VOL. 38, NO. 5 OCTOBER, 1948

POSTREMITY, RECENCY, AND FREQUENCY AS BASES FOR PREDICTION IN THE MAZE SITUATION [1]

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INTRODUCTION

A central problem in psychology is the determination of bases for accurate prediction of behavior, with the necessity thus arising of ascertaining what factors determine the response an organism will make to any given situation. There have been postulated a variety of such factors, the present investigation being conducted to determine the significance of one of these: namely, the factor of recency in the Guthrian sense of the term (cf. **3**, pp. 417 and 420, **4**, p. 457, **5**, **6**, p. 527, **7**, p. 26, **8**, p. 111). The following is a brief statement of this principle of recency: In a recurring situation, such as repeated trials in a puzzle-box or maze, the most probable response on any trial is the one last made to the stimuli present on that trial. If some transitory cause alters the response, this new response is the one predicted for the next trial on which that stimulus pattern occurs. This advantage of the last-made response holds even when some other response has had indefinitely greater frequency.

Although there have been many studies of 'recency,' most of these were concerned with principles other than the present one. For example, a great number centered around the effect of differences in the length of time interval between presentation of a situation and re-presentation of that situation, or the effect of differences in position of a pair of nonsense syllables in a list. None of this work has any direct bearing on the present problem of recency. However, because of the duplication in terms, conclusions regarding 'recency'

[1] This paper is taken from a dissertation presented to the faculty of the University of Washington in partial fulfillment of the requirements for the Master of Science degree.

reached by those experimenters have been widely quoted by others discussing the newer 'recency' principle, even though the studies and conclusions were not about the same principle and the experimental data on those principles show nothing about the present principle of recency. Partly because of a tendency to ignore differences in meaning and implication, and partly because of other related factors, considerable confusion has resulted from using the same term to cover a variety of meanings.[2] To help preclude further confusion, it would be well to introduce a new term for at least one of these principles of recency. Accordingly in the present paper, the term 'postremity' (from the Latin *postremo*, superlative of 'late') will be used when referring to the Guthrian principle, and the term 'recency' when referring to the more traditional principles.

As previously mentioned, most of the experimental work on recency has no significance regarding postremity; but some experiments have been done to investigate this latter principle. In 1937, Guthrie and Horton (9) observed the behavior of cats in a puzzle-box, release from which was effected by tilting a pole. Having a semispherical base, this pole could be tilted easily by any one of a great variety of responses. A photograph was taken automatically of each escape movement, and it was found that "although no two cats used the same method, the successive escapes of any individual cat showed an unexpected number of final movements substantially identical." A detailed account of this experiment is presented in the 1946 book by these co-workers. A further study by Horton and Guthrie (11) of cats in a puzzle-box of considerably different construction revealed again a marked tendency toward stereotyped escape movements. As the principle of postremity would lead one to predict, the cats tended strongly to do in this situation what they had last done in that situation.

For the maze situation, Peterson is the only experimenter who has made an effort to test the validity of the principle of postremity. (He called it 'recency.') Two experiments were performed. In the first (17), 17 rats were divided into three groups, each group learning one of three differently patterned mazes. For every rat, a record was kept of the specific blinds entered on any given trial; but the results for the first three trials only were published. It is unfortunate that only the first three trials were analyzed, for during the beginning trials especially the situation is changing rapidly and rather markedly as the internal pattern of stimuli is often greatly modified by, for example, the dispersion of initial excitement, curiosity, or tension. Thus on the first few trials the possible validity of the principle of postremity is somewhat obscured.

The conclusion drawn by Peterson from this study was that while "the effects of recency and frequency are obvious in any detailed study" (p. 360), they are not of any great importance. Nonetheless, it is to be noted that for each group of rats, and for 12 of the 17 individuals, the predictions made

[2] For various meanings of 'recency,' see the usages of Brown, Hunter, Jersild, McGeoch, Warden and Cummings, Watson.

on the basis of postremity were more often correct than incorrect. Such results would occur by chance about five times in 100. The lack of greater statistical significance may be attributable to the small number of rats being used and the first trials only being analyzed.

In a second experiment (18), 16 human *Ss* learned a 10-blind, mental maze, the results of all trials being published in this work. Peterson concluded that postremity is not a factor in learning, and stated further that it is "negative in its effects, tending to fix the erroneous response rather than the correct one" (p. 290). These conclusions, although widely quoted, lack statistical justification. The data show that of 4,518 predictions based upon postremity, 68.4 percent were correct. This degree of accuracy differs from 50.0 percent by 26.1 times the standard error of 50.0 percent (SE = .74 percent). From this rough analysis it would seem that postremity of a response is a sound basis for prediction of behavior.[3]

Furthermore, upon analysis of the data, postremity is not found to be negative in its effect, but on the contrary, is found to fix apparently the right responses more than the erroneous ones. Of those occasions when the postreme response had been the 'right' response, 73.0 percent of the time it was made on the next trial. Of those occasions when the postreme response had been the 'wrong' response, only 63.9 percent of the time was it made on the next trial. Therefore, it appears that if postremity tends more toward preserving one set of responses rather than another, it tends more toward preserving the correct responses rather than the incorrect. (Actually, by the present hypothesis, postremity itself is neutral, having no differential effect on the correct and incorrect responses.) Thus it is found that contrary to Peterson's conclusion, his data indicate that postremity may be a significantly accurate basis for prediction and is not negative in its effect.

Yoshioka (23) used 21 rats in a three-legged maze, each of these legs making an angle of 120° with the others. The rat was started at the end of one, and was fed at the end of the next leg to which he went. He then was started from the end of that leg, and fed at the end of that to which he next went. After this he was removed from the maze. For each rat, a record was kept of the responses on each set of trials. Yoshioka concluded that "preferential pattern may be one of the dominant factors in maze learning" (p. 197), but that frequency and recency are negligible. It should be noted that Yoshioka was not using 'recency' in the sense of postremity. In fact, he meant by 'pattern' what partially is meant herein by postremity. If, for example, a rat went from the end of one of the legs, turned right at the central choice point, and proceeded to the end of that second leg, Yoshioka would predict on the basis of 'preferred pattern' that when the rat went from the end of that leg and arrived next at the central choice point, he would again turn right. This is precisely what would be predicted on the basis of postremity. The rat, having run down a straight path and having then found two other paths extending at a certain angle toward the right and toward the left, last responded by turning toward the right. There-

[3] This statistical analysis is not strictly correct. For example, it in no way takes into account individual differences, nor does it equally weight the results from each subject. As the data for individuals were not published, it was impossible to overcome these and other difficulties.

fore, when next the rat runs down a straight path and is again at the central choice point with a path extending at the same angle toward the right and one toward the left, it would be predicted from postremity (if the other stimuli are similar) that he will turn right, for his postreme response to such a stimulus pattern was turning toward the right. The empirical findings strongly indicate the validity of this basis for prediction, the number of times the responses accorded with predictions based upon 'preferential pattern' or postremity being significant at the one percent level of confidence.

Hudson (12) also performed an experiment in which one-trial learning clearly was demonstrated. Using 14 rats, he once shocked the animals as they ate from a metallic food-holder fastened to a star design. After one month, he again put the animals in that situation and found that 13 of the 14 made conditioned responses of withdrawal to that stimulus pattern. According to our calculations based on the binomial expansion, this result would occur by chance less than one time in a thousand.

Other experiments could be analyzed to determine the significance (or non-significance) of the principle of postremity; but the data from most of these were lumped, all errors for a given trial being grouped or data from all subjects being grouped, and thus the possibility of such an analysis of these data is precluded.

Statement of the Problem

The present experiment was designed to aid in answering these specific questions: (1) Can postremity be used as a basis for accurate predictions of behavior? (2) If the postreme response is one which had been made *less* frequently in the past than some other response, is postremity an accurate basis for prediction? (3) What is the relative accuracy of postremity and frequency as bases for prediction?

Apparatus and Procedure

In order to have a fairly adequate indication of the generality of any results which might be obtained, three parallel experiments were conducted, in each of which different subjects with different apparatus and procedures were used. The experiments were conducted in a quiet and relatively isolated, but unfortunately not soundproof, room.

In the first experiment, a high-relief, 18 choice-point, multiple-T, finger maze was used in which the end of each blind was marked by a small brad, and the end of each correct alley was marked by a slight hump in the wire immediately preceding the choice point. This was patterned after a maze designed by Spence (19), with the modifications introduced by Granneberg (2). With a practice maze of this type before him, the procedure was explained to each *S* and he was told that he would be required to reach a criterion of three successive perfect trials on the regular maze. Detailed instructions were given for *S*'s counting of alleys (*S* paused after his finger dropped down from the hump and announced the number of the choice point *before* that choice was made), for the position of the hand and fingers, and for the complete procedure. The instructions were accompanied by a demonstration by *E*, and were followed by *S*'s closing his eyes and going through the practice maze once. He was then blindfolded, the maze to be learned was placed before him, and some of the directions were repeated for emphasis and for the purpose of giving him an opportunity to become accustomed to the blindfold. Care was taken in all cases to have the subject feel at ease before the experiment was begun.

For the second experiment, a punch-board stylus maze was used. This maze had 30 pairs of holes in a figure 'S' pattern identical to that of the maze introduced by Muenzinger and Vine (16).

A chime sounded if the S chose the correct hole of a pair; a buzzer, if he chose the incorrect one. The pattern of correct and incorrect holes was reversed at the end of each S's trials, so that the holes which had been correct for the last S were incorrect for the next S and those which had been incorrect were correct. These Ss were instructed also to stop and say aloud the number of each pair before making their choice, if an error was made to notice it carefully but not to correct it at that time, to continue working on the maze until the criterion of three perfect successive trials was reached, and to "go at a moderate rate; do *not* rush through the maze, but do not make long stops in any part of it—don't, for example, when you get to number 4, try to rehearse your moves that far as that will cause you to do more poorly."[4]

In the third experiment, one change only was made: The Ss were given a threaded stylus which necessitated the screwing of the stylus into the holes and out again after every choice, whereas in the second experiment the stylus was merely pushed in.

The 57 Ss were volunteers from classes in Elementary Psychology at the University of Washington. For the first experiment, 25 Ss were used (Group 1); for the second, 16 (Group 2); and for the third, 16 (Group 3).

Method of Recording Data and Making Predictions

For each individual, a record of responses was kept on graph paper, the response made on each trial at each choice point being recorded in the proper square for that trial and choice point. For each response after trial 1, two predictions were made: One prediction was made on the basis of postremity—the response recorded for the preceding trial and that choice point being the response predicted for the present trial. The other prediction was made on the basis of frequency—the response recorded most often on all preceding trials for that choice point being the one predicted for the present trial. If the two opposing responses had been made an equal number of times at that point, either of the two would be predicted by frequency. For such cases, one-half the time the 'correct' response was recorded for the prediction and one-half the time the 'incorrect,' the predictions being alternated for those points.

Results and Interpretation

A. Analysis of all predictions made by postremity.

Considering the data as a whole, predictions based upon postremity were found to agree extremely well with observed behavior. For Group 1, the mean of the percentage correct for each S is 88.7 percent; for Group 2, 82.3 percent; for Group 3, 83.1 percent

TABLE I

Total Predictions by Postremity for Groups

	Number of Subjects	Mean % Correct Predictions	Sigma of		CR
			Dist.	Mean	
Group 1	25	88.74	2.97	0.606	63.9
Group 2	16	82.30	4.09	1.06	30.4
Group 3	16	83.05	4.45	1.15	28.7

* In Tables I and II, N is taken as the number of Ss; the means are obtained by adding the percentage correct for each S in the group and dividing by the number of Ss; sigmas of the mean equal sigma of the distribution of scores divided by $\sqrt{N-1}$; the critical ratio equals the mean minus 50 percent divided by the sigma of the mean.

[4] Much implicit practice was avoided by permitting no pauses between trials, nor any pauses of more than three sec. during the trials.

(Table I). The critical ratios of these means to their standard errors are 63.9, 30.4, and 28.7 respectively.

Also, examination of the record for each of the 57 individuals separately revealed that *for every S the predictions based upon postremity were highly accurate.*[5] For each of 49 *S*s, more than $\frac{4}{5}$ of the predictions made by postremity were correct. For only two of 57 individuals were less than $\frac{3}{4}$ of the predictions correct, and for only one of these did postremity predict correctly as little as 73.3 percent of the time. The CR of 73.3 percent minus 50.0 percent to the SE of 50.0 percent is 6.2; so it is seen that even for that individual for whom postremity was least accurate, the accuracy was high enough that, for this number of trials, it would not be equalled by chance one time in a million.[6] The results for all other individuals also were significant considerably beyond the 0.1 percent level.

B. Analysis of those Predictions by postremity which were opposed by frequency.

For this analysis, not all the predictions made by postremity were considered, but only those for which the response postremity predicted was not the one that had been more frequently made. It was found that the mean percentages of these predictions which were made correctly by postremity were about 71 percent for the various groups, with the CR's being about 8 (see Table II).

TABLE II

PREDICTIONS BT POSTREMITY WHEN AT VARIANCE WITH FREQUENCY FOR GROUPS

	Number of Subjects	Mean % Correct Predictions	Sigma of		CR
			Dist.	Mean	
Group 1	25	68.91	11.9	2.43	7.8
Group 2	16	68.10	5.58	1.44	12.6
Group 3	16	76.56	7.89	2.04	8.2

An analysis was made also of the results for each individual. In the cases of 24 of the 25 members of Group 1, even though postremity was predicting the response which had been made less frequently in the past, its predictions were correct the major part of the time. Such a result would occur by chance about three times in a million.

[5] Tabulations of these data for each individual and other individual data mentioned in sections A, B, and C (number of responses predicted correctly, number predicted incorrectly, standard errors, critical rations, *P*-values, etc.) were omitted to conserve space. They may be obtained from the writer.

[6] The formula used for this and each of the other standard errors for individuals in sections A and B is: $\sqrt{50\,(50)/N}$, in which N is the number of predictions made for that individual.

Similarly in Group 2, postremity predicted correctly more often than incorrectly in the case of each of the 16 *S*s. If the null hypothesis were correct, all 16 cases would fall in the same direction about three times in 100,000. The same results were obtained for Group 3, 100 percent of those 16 cases also being in the same direction.

Moreover, even for these instances in which postremity predicted the less frequent response, it predicted correctly more than $\frac{2}{3}$ of the time in the cases of each of 41 *S*s and more than $\frac{3}{4}$ of the time for 23 *S*s. The predictions by postremity were significant beyond the five percent level of confidence for 46 *S*s, beyond the one percent level for 37 *S*s, and beyond the 0.1 percent level for 29 *S*s.

It is apparent that for the great majority of individuals and for all groups in this experiment, postremity is a statistically reliable basis for prediction of responses, *even when frequency is favoring an opposed response.*

C. Comparison of the predictions by postremity and those by frequency when at variance.

The final analysis was a study of the relative accuracy of postremity and frequency as bases for predictions when the two are at variance. As can be seen from Table II, for Group 1, 68.91 is the mean percentage of postremity's predictions which were correct when an opposed response had been more frequent; whereas only 31.09 percent of frequency's predictions were correct on the average when it predicted a response other than the postreme response. Similar results were found for Groups 2 and 3, predictions based upon frequency having a mean accuracy of only 31.90 and 23.44 percent when postremity was opposed.

If, instead of grouping the data, each *S*'s record is examined separately, the findings are comparable. When at variance with postremity, for only seven *S*'s out of 57 were predictions by frequency correct as much as 40 percent of the time; and for 41 *S*s they were correct *less* than $\frac{1}{3}$ of the time. A statistical analysis showed that for each of 47 individuals, the greater accuracy of postremity's predictions over those of frequency would not occur five times in 100 by chance; for 37, not once in 1,000.[7]

Also, for 56 of the 57 individuals used in all groups, when opposed by postremity, frequency predicted with less accuracy than postremity, and with less than 50 percent accuracy. If the principle of postremity held with no consistently greater accuracy than that of frequency, these results would not occur once in 10 million groups of 57 individuals.

[7] The formula used for the SE of the differences followed Treloar (20, p. 227).

Thus we find that in this experiment frequency is an accurate basis of prediction only as long as predictions based upon it agree with predictions based upon postremity. When the more frequent response is not the postreme response, then frequency is a highly inaccurate basis of prediction, less accurate than chance.

Further Discussion

From the foregoing analysis, it is apparent that to a marked degree in at least some maze situations, predictions based upon the principle of postremity correspond to observed behavior. There remain, however, a number of questions in the literature concerning its interpretation and implications.

A. Variations in response.

One of the main questions is this: If the principle of postremity is valid, why does an animal not continue forever to make the same response at any given choice point?

Part of the answer is that for a large proportion of its training, the animal does do precisely that: If he once happens to make the correct response, he then makes the correct response repeatedly; if he once makes an error at a choice point, he continues to make that same error repeatedly. In the present experiment, more than $\frac{4}{5}$ of the responses were of this nature, were repetitions of the response last made.

But the *S* does not always make the same response when at the same choice point. Why is this? One of the fundamental factors causing a change in response at a given point is that there are marked changes from trial to trial in the pattern of stimuli present—even at the 'same' choice point.

In the first place, there are changes from one trial to the next in the internal stimulus pattern. Especially is this so during the first few trials, for during them the *S*, rat or human, may be quite emotional and excited, and the resultant pattern of internal stimuli may change fairly rapidly. But later in training also, the internal stimuli may change considerably from trial to trial: for example, human *S*s may develop feelings of elation, depression, impatience, or anxiety as the trials progress, thus changing the visceral stimuli. Likewise, there are changes in energy level and muscle tonus, and changes as the result of fatigue.

Moreover, as the result of imperfect control, there are further shifts in stimulation. A rat, for instance, may be placed in the maze in slightly varying fashions, thus receiving different tactual, proprioceptive, and visual cues; and he may therefore make a response at the first choice point different from that which he had made there previously. This in turn changes partially the stimulus pattern operating at the next choice point, and so a different response may be made there also. Similarly, the human *S* may radically shift his position, thus changing from one trial to the next his whole pattern of proprioceptive cues. In addition, there may be differences in the external stimuli present on different trials: changes in lighting or olfactory cues, noises outside the laboratory, motions by the experimenter, or any one of many other accidental stimuli. Occasionally therefore, the stimulus pattern is quite different from that present the last time the subject was at this choice point. Consequently, at this point a different response may be made to this different stimulus pattern; and the prediction (based upon the last behavior to a different stimulus pattern at the choice point) will be incorrect.

This does not mean necessarily that the principle of postremity is not completely valid. It may be. The principle states what response is to be expected when the same situation is re-encountered. However, for practical reasons, the principle is used to predict behavior when only a part of the situation is re-encountered (namely: the 'same' choice point). This then is the first reason why predictions based upon postremity, though remarkably accurate, are not perfect; and this is also the first reason why the *S* does not repeat forever the same response to any given choice point: The *S* is not the same *S*, and the choice point is not the same choice point from trial to trial.

B. Elimination of errors.

So far we have been concerned only with why, if the principle of postremity has a consistent effect, there are variations in responses. Going beyond that problem is the question of why errors to a great extent are eliminated.

The factor just discussed is a part of the answer to this question—changes in the internal and external stimulus patterns bring variations in response at the 'same' choice point. However, if this were the only factor operating and if these changes in the stimulus patterns occurred in a perfectly random fashion, errors would not be eliminated; for there would be (within the limits of chance) as many changes in stimulus pattern at times when the right response had been made as when the wrong response had occurred. Thus there would be, on the average, as large a proportion of shifts from making the correct response to making an error as from making an error to making the correct response at a choice point.[8] So the animal would not make the same error always; but neither would this error be eliminated.

If, on the other hand, these changes in the situation do not occur in a perfectly random fashion, errors could tend to be eliminated. It seems highly probable that this is the case, that there are indeed greater variations in the stimulus pattern when errors, than when correct responses, are made. It seems probable, for example, that preceding and accompanying errors

[8] More precisely, the ratio of (a) number of shifts (from one trial to the next) from 'right' to 'wrong' responses to (b) number of 'rights' would be equal on the average for all trials to the ratio of (a) number of shifts from errors to 'right' responses to (b) number of errors.

there is greater uncertainty and anxiety aroused by the stimuli present at those choice points and more emotion as the result of making errors (being blocked); hence, as these emotional response patterns characteristically involve varying tensions, there are greater changes in stimulation at those times. Similarly, it has been observed that many human beings tend to withdraw from a situation in which they are not being 'successful.' This would result in fluctuations of attention—i.e., involve many of the stimulus patterns being present for the *S* sometimes and not being present other times, and also would result in introduction of new stimuli by the *S*'s talking to himself about various changing matters. Thus, there would be, for this reason too, more variability of stimuli when errors are made than when the correct responses are made. It follows from these considerations that correct responses to choice points would have a greater tendency to be repeated on subsequent trials (because those stimulus patterns are more nearly constant from trial to trial); and the errors would tend less strongly to be repeated (because the stimulus patterns are more variable).

In addition to this, there is a second factor which, if the principle of postremity is valid, would result in the elimination of errors. The factor is this: Following a correct response to a choice point, usually no stimulus is given eliciting a different response at that choice point; whereas, in sharp contrast to this, following an incorrect response, frequently a stimulus *is* given which causes the animal to make some other response while many of the choice point stimuli are present. Thus at a choice point where the correct response was made on the last trial, the correct response usually is the postreme response to all stimuli present at that choice point. But where an error was made on the last trial, the error—although it is the postreme response to some of the stimuli—often is *not* the postreme response to many of the other stimuli present at that choice point.

For example, in a multiple-T maze, when the correct response is made at a choice point, there is usually no retracing; the subject goes on to the the next. Therefore, the last response that was made to all stimuli at that point was to go down the correct alley.

In contrast to this, when an error is made at a choice point the animal is faced by a wall or some sort of block, in response to which he comes back out of the blind and then goes down the correct alley. This is not, of course, identical to making the correct response to that choice point stimulus pattern which just elicited the wrong response. (And therefore, 'wrong' is predicted as the response which will be made the next time the animal arrives at that choice point.) Nonetheless, the stimulus-pattern-response-pattern of going down the correct alley after coming out of the blind has some components identical to that of going down the correct alley without going into the blind (e.g., sight of correct alley accompanies running down right alley in either case); and so even on those trials when the wrong response is made, some of the stimuli become cues for making the correct response. Also, many of the stimuli that accompanied and elicited the wrong response are present when the incompatible response later is made of turning around and coming out of the blind; and so these stimuli are detached from the response of continuing down the blind. Since these stimuli are then cues for coming out of the blind and no longer cues for continuing to go down it, they indirectly are cues for going down the correct alley (if there are but two ways to go at a choice point).

In spite of this detachment of some of the choice point stimuli from the wrong response, as was previously mentioned there still are many stimuli at this choice point which are cues for making the wrong response (e.g., the stimuli from whatever responses were made at preceding points, of approaching this point, of the sight of the blind and other alley extending at certain angles from the approach point, etc.) Not until the animal approaches this point, and without first starting down the wrong alley, makes the correct response, can all stimuli of that choice point become cues for the correct response.

Thus it is seen that the choice point situation which has elicited a *wrong* response *becomes ambiguous* when the animal comes back out of the blind and goes down the correct alley—some of the stimuli are still cues for the wrong response but others now have become cues for the right response; whereas the choice point situation which last elicited a *correct* response usually is *not ambiguous*—all of the stimuli remain cues for the right response. Hence, in accordance with the present theory, right responses will tend more strongly to be repeated than will wrong.

Another example of how this second factor may operate toward facilitating elimination of errors is found in the consideration of behavior to the punch-board maze. The factor, it will be recalled, is this: Following a response which is an error, in many experiments a stimulus is given which may cause the animal to make some other response in the presence of much of the stimulus compound which had elicited the error. Now, in the learning of the punch-board maze, *S* may insert his stylus into the wrong hole of a pair, e.g., pair 8. A stimulus then is presented (the sound of the buzzer in our experiment, *E* saying 'wrong' in others, etc.) which may cause *S* to withdraw his stylus and make additional responses on that trial to that choice point. These responses may involve, for instance, the *S*'s saying to himself "Eight, not this hole, that one is right," or even making incipient or possibly overt movements toward the other correct hole while looking at the pair. If this has been the case, the next time the *S* comes to that pair of holes, he will say "Eight" (as instructed), and it is expected he will start toward the incorrect hole, draw his stylus back, say "No, not this hole; that one is right," and then make the previously established conditioned response to the stimulus "that-is-right,", i.e., the response of inserting his stylus into the hole at which he just looked and said "That is right." Thus another error may be eliminated. This again is in accordance with the principle of postremity: The *S*, when he previously approached that pair, made an error. This response was then followed by presentation of a stimulus which in this case caused *S* to make some other response to a large part of the stimulus pattern to which he had made the error (such parts would be the stimulus of the sight of the pair of holes, saying the number of the pair, etc.). Thus this 'other response' becomes cued to those parts of the stimulus pattern and the error is detached from them. The next time *S* came to the pair, he made the response which was his postreme response to most of the stimulus pattern.

This postreme response, it should be noted, is a response different from that of inserting the stylus into the wrong hole; and therefore the wrong response was not made on this trial.

C. *Imperfect predictions.*

There is one more point which should be noted in connection with the above. Predictions are based upon the last response *recorded;* whereas behavior (according to the principle of postremity) depends upon the last response *made* to a situation. Now if the response to the stimulus pattern of a choice point is correct, the last-recorded response is likely to be the last-made response (because, as previously suggested, the subsequent stimuli indicating that the response is correct usually do not bring additional responses to that choice point differing from that recorded); but if the response is incorrect, the stimuli following that response which indicate its 'incorrectness' often do bring other added responses on that trial to many of the stimuli of that pair, added responses such as movement away from the incorrect hole and toward the correct hole. These responses (which are now the postreme response to some of the stimuli of that choice point situation) are not recorded, however; and they are different from and incompatible with the one that was recorded. Therefore, since the last-made response sometimes does not agree with the last-recorded response (especially in the case of errors), and since predictions are based upon the last-recorded response while future behavior is a function of the last-made response (according to the postremity hypothesis), the predictions will fail sometimes to agree with the behavior even though the theory is sound.

Another main reason, previously mentioned, why predictions fail to have complete accuracy is that the stimulus pattern was changed from that of the preceding trial. As these two factors constitute a part of the conditions assumed to be fulfilled when one uses the principle of postremity in the way followed in this paper, it is imperative that the particular stimulus pattern present now and the particular response last made to these stimuli be noted with extreme care if one is to test the present theory. If they were taken more completely into account, predictions should have an accuracy still higher than that we found—providing the theory including the principle of postremity is valid.

D. *Postremity and frequency.*

The final problems we shall consider are why the postreme response was more apt to be repeated when it had been also the more frequent response than when it had been the less frequent; and why the postreme response was repeated in many instances even though it had been the less frequent response. One interpretation in accordance with the principle of postremity is based in part upon the two following points.

1. For a certain choice point, if the response recorded as the postreme response of trial X was also the more frequent response, this indicates: (a) the stimulus pattern on X was very similar to ones that had occurred at that choice point frequently in the past (for if it were not, a response different from that made on most preceding trials would have occurred on X and also responses different from that which did occur most frequently on the preceding trials would have had to occur on those previous trials), and (b) the response recorded on preceding trials as the postreme response to that choice point generally was the response actually last made at that point.

2. If the response recorded as the postreme response of trial X′ was the response less frequently made in the past, this may indicate: either (a) the stimulus pattern present on X′ was radically different from ones which had most frequently appeared previously at that choice point; or else that (b) the response recorded for trial X′ − 1 was not actually the postreme reponse made at the choice point in question on that trial (trial X′ − 1), and this had not happened often before.

If 2-a is at least as common as 2-b, and if radically different stimulus patterns are apt to be transitory changes in the fundamental stimulus patterns—i.e., if the nature of the future in respect to stimulus patterns is apt to be more like the most common part of the past than like any other one segment of the past, it follows most directly from 1-a and 2-a that in general the stimulus pattern present on trial X will be expected to recur more often on the following trial than will the pattern of trial X′. Because of this, and because recurrence of the stimulus pattern which accompanied a response is essential for that response to be evoked again, those responses indicating that certain similar stimulus patterns have frequently appeared in the past theoretically should be the ones made on subsequent trials more often than those responses which may indicate the presence of stimuli which have but rarely occurred previously. On the basis of this reasoning, we should expect (as was found) that the response of a certain trial would be more apt to be repeated on the next trial when that response was also the one which had been the more frequent than when it had been the less frequent response.

It should be noted that this interpretation of why our predictions from postremity were more accurate when the response of the preceding trial was also the more frequent does *not* attribute this phenomenon to postremity perhaps operating more efficaciously at some times than at others, nor does it attribute the phenomenon to *frequency of the response per se;* but rather it is held as being due fundamentally to the relative frequency with which *certain stimulus patterns* have occurred in the past and therefore may be expected to recur in the future—a matter of which past frequency of the response is taken as an indirect indication. Guthrie has offered another interpretation which also may be applied to the present problem, one which *is* fundamentally in terms of the frequency with which a response has occurred.[9]

We turn now to an interpretation of the final problem stated above. When the occurrence on trial X′ of the response made less frequently on preceding trials is due to stimuli having been applied on trial X′ − 1 which caused *S* to make an additional response at that point different from the one recorded as his postreme response for trial X′ − 1 (i.e., when the response on trial X′ is due probably to factor 2-b rather than 2-a), we should expect, if the present theory of postremity is valid, that for those times the response on trial X′ *would* be the one to occur on X′ + 1—under these conditions, the fact that frequency is opposed is irrelevant. Further, if such additional responses occur appreciably often, we should expect the number of times predictions based upon this hypothecated factor (2-b) and upon postremity (though frequency is opposed) accorded with subsequent behavior to be at least statistically significant. As was pointed out in part B of the preceding section, this was found.[10]

Summary and Conclusions

To determine the accuracy of postremity as a basis for prediction of behavior in the maze situation, the behavior of 57 *S*s was studied, two mazes of radically different type (the raised relief finger maze and the punch-board maze) and two different procedures on the last maze being used, one group of *S*s having to push the stylus in the holes, the other having to screw it in.

It was found that prediction of responses based upon postremity correspond remarkably closely to future observed responses—not only for all groups but for all individuals, the predictions being correct for no individual less than 73 percent of the time and for most individuals more than 85 percent of the time. For each individual, the accuracy was significant considerably beyond the 0.1 percent level of confidence.

High accuracy of predictions based upon postremity also was found even for those times on which it predicted the response opposed to the one most frequently made in the past. For all groups and

[9] This interpretation is that the stimulus pattern changes somewhat from trial to trial and so with added occurrences of the response more stimuli become cues for the response in question. Therefore on future trials, more of the stimuli which may occur have been established as CS's for the response. From this and from the hypothesis that occurrence of a response is positively correlated with the proportion of stimuli present (at the particular time for which prediction is being made) that is composed of CS's for the response, it follows that the more frequently a response has been made the more certain it is to re-appear on the next trial (cf. 5, pp. 99–101).

[10] The number of times postremity was accurate under these conditions and the statistical significance of these results should not be imputed to factor 2-b only; for even if the less frequent response of trial X′ was due to factor 2-a and if this stimulus pattern, though rare in the past, was still present on the next trial (which would at least occasionally be the case in our opinion), then for those trials also the same response would occur on X′ + 1 as on X′, and this also would contribute to the accuracy of postremity as we used it.

most individuals, the accuracy of these predictions exceeded 50 percent by an amount which was significantly greater than would occur by chance.

Predictions based upon frequency did not correspond well with future observed responses *unless these predictions were in accord with those of postremity.* In fact, when frequency and postremity were at variance, predictions based on frequency were less accurate than would be ones based upon chance. For one *S* only were they correct as much as 50 percent of the time. Statistical analyses showed that for the majority of the individuals and for all groups, the accuracy of these predictions from frequency was significantly less than chance and also significantly less than that of those based on postremity.

Suggestions were offered as to the conditions under which variations would occur in the responses made by the same *S* at the 'same' choice point, and under which errors would be eliminated if the principle of postremity were perfectly valid. Interpretations were offered also as to why predictions were imperfect, why the response recorded for the preceding trial was more apt to be repeated when it had also been the more frequent response than when it had been the less frequent, and why it was repeated in many instances even though it had been the less frequent response.

(Manuscript received August 27, 1947)

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