STUDIES IN INDIVIDUAL DIFFERENCES IN MAZE ABILITY

VIII. PREDICTION VALIDITY OF THE PSYCHOLOGICAL COMPONENTS OF MAZE ABILITY[1]

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In the preceding paper of this series (4), I presented the hypothesis that ten specific types of psychological components were the determinants of performance of rats on successive stages of their running through our 17 T-unit Maze X. The existence of these components was inferred from observations on 1,085 rats who ran this maze. The claim was made that these components satisfied our first two criteria of validity of such inferences, namely, that the logic of the components was applied to the maze performance with internal consistency, and that the theoretical difficulties of the blinds, based on the logic, fitted accurately the actual experimental difficulties shown in the rats' performance.

There remains for treatment in this paper the question of the degree to which these components meet our third and fourth prediction criteria of validity. The third criterion, called *prediction in situ,* states that the components should show a fit with other behaviors *in situ,* behaviors which one should reasonably expect them to influence, but behaviors not directly studied, however, at the time the components were originally inferred. These other behaviors *in situ* which are studied

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here, but which were not quantitatively analyzed when I originally postulated the existence of these maze components, are full and partial entrances into blind alleys, retracings into blinds and into stems of the T-units, and speed of running in the true paths.

The fourth criterion, called *external prediction*, states that one should be able to predict, from the theory of components, behavior to be observed in a *new* situation, provided, of course, that the new behavior is of the sort one would reasonably expect the components to influence. This paper will present my attempts to predict the experimental difficulties of blinds at successive stages of learning of a second 20 T-unit Maze Y. These predictions were made *before* the data of this second maze were analyzed. And these predictions were based on our conception of components and of their properties as developed in our study of Maze X.

As an important rider to these prediction criteria, the reservation must be kept in mind that prediction of other behaviors, *in situ* or external, will *necessarily* depart from perfection to the degree that the components, conceived in the study of the original behavior, manifest different properties, or weights, in the predicted behaviors, and to the degree that new special components emerge. To the extent in which we fail of perfect prediction, confidence in our components may be jeopardized. A saving circumstance will be our ability to "explain away" our degree of failure by showing *specifically* just how the weighting of the components has changed in the predicted behaviors, and just what the new components may be. Such "explanations" must, however, be applied with internal consistency, and should improve the fit.

I. PREDICTION IN SITU (MAZE X)

The maze components. In the preceding study, the *experimental difficulties* of the blind alleys, as measured by the per cent of rats who entered them, were shown quantitatively to be described exactly by the hypothesis that blind entrances in Maze X were determined by the following *cognitive* components:

direction-sets, food-pointing, counter tendency, centrifugal swing, short-cut, and by the *noncognitive* components: adaptation, lassitude, inertia, exit gradient, and conflict. A schematic diagram of Maze X is reproduced in figure 1. For each of the components a theoretical weight was assigned to each blind indicating the degree to which the component determined entrance into it, and a total *theoretical difficulty* value resulting from the operation of all components was then calculated for each blind. The theoretical difficulty values, x', for the first trial performance (4, table 2), and y', for the plateau trials 12–19 (4, table 3), fitted rigorously their respective experimental values, and a linear combination, z', of x' and y' fitted well the experimental difficulties at all intervening stages. Our present problem, therefore, is to discover the degree to which the theo-

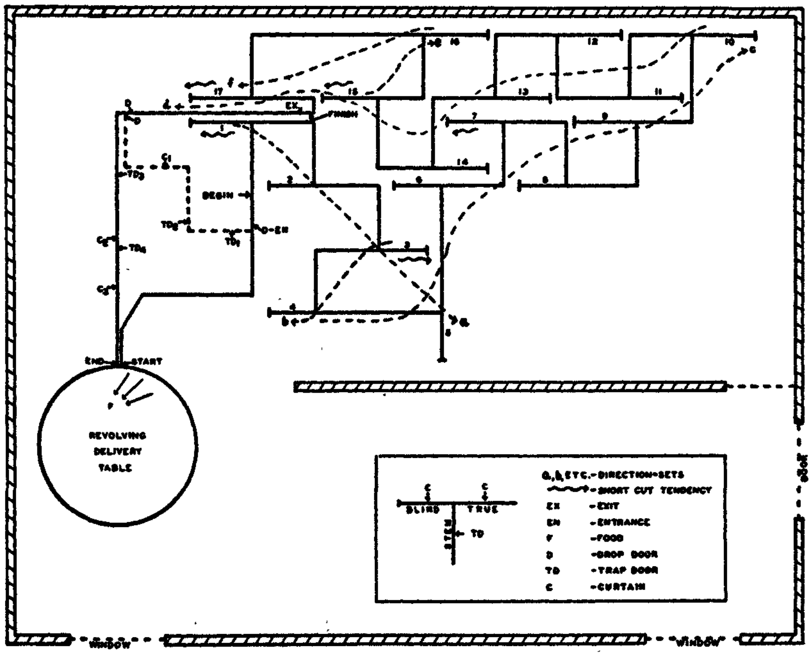


FIG. 1. SCHEMATIC PLAN OF MAZE X SHOWING INFERRED DIRECTION-SETS
The preliminary practice path begins at "Start" and turns left at "En" proceeding along dashed line and around to "End." Electric recording of maze run starts at "Begin," ends at "Finish."

retical values, x', y', and z' fit other behaviors in the Maze X situation, and if possible to account for the degree to which these components do not exactly fit these performances.

A. Full and partial entrances into blind alleys

As the rat steps into a blind alley, he depresses the floor, and thus registers an electrical contact below it, but as he proceeds to the end of the blind, the floor rides free of the contact; on coming out of the blind, he again depresses the floor and makes a second contact. A *partial* entrance occurs, therefore, when the rat merely steps into the blind, making one contact, but leaves without proceeding further. A *full* entrance occurs when he goes to the end of the blind and returns, thus making two contacts. In the preceding paper, the blind difficulty was defined as the per cent of rats who made either full or partial entrances, and the components inferred there pertain to these total entrances, to which we may give the symbol, E. If we use the symbol, F, for the per cent of rats making full entrances, and P for the per cent making partial, then $E = F + P$.

Do the components which rigorously fit the composite score, E, equally well fit the two behaviors, F and P, which constitute it? Let us consider the reasonable hypothesis that, when the rats are *strongly* controlled by the components which make for errors, they make full entrances into blinds, but when these components are *weakened* by learning the rats would tend to make partial entrances. This hypothesis assumes that the components are exactly the same for full and partial errors. Were we to make up tables for F and P, like tables 2 and 3 of the preceding paper, we would, on this hypothesis, have exactly the same configuration of weights per component as there shown, but the magnitudes of the weights for partial errors would be a constant fraction of those for full.

In table 10 of the appendix the per cents of rats making full and partial entrances per stage of learning are given. A statistical summary of the facts relevant to our question is presented in table 1. Sections (3) and (4) of this table give the degree of fit with full and partial entrances of the x' and y' components shown to fit total entrances, E, on the first trial and on the plateau, respectively. Analogous data for E were given in table 4 of the preceding paper. If, as before, we define z as the experimentally determined per cent of rats making full entrances at any given stage of learning, then $r_{zx'}$ [third row of section (3)] shows the fit of the first trial components, x', with the experimental values. Note that $r_{zx'}$ for trial 1 is .99, signifying that the components which fit total entrances, E, fit rigorously full entrances, F. The $r_{zy'}$ values give the fit of the plateau components. Note that $r_{zy'}$ is also .99 for plateau trials 12–19, showing that these components fit exactly full and total errors at this stage. The fit of a *combination* of these components to the F values of each stage is given in the $r_{zz'}$ values in the first row of section (3), where z' equals $(1x' + ky')$,

TABLE 1

Average and variability of full (F) and partial (P) per cent entrances (z) into the 17 blinds at successive stages of learning Maze X, and goodness of fit of components z', x', y', with such entrances

	TRIALS						
	1	2–3	4–5	6–7	8–9	10–11	12–19
(1) Mean:							
F	.47	.38	.22	.16	.14	.12	.10
P	.09	.06	.07	.06	.06	.06	.05
(2) Sigma:							
F	.22	.21	.15	.11	.09	.08	.07
P	.03	.02	.04	.04	.04	.04	.03
(3) Fit of z', x', y' components with F:							
$r_{zz'}$	.99	.95	.93	.95	.96	.97	.99
k	.0	.5	2.1	4.8	9.9	48.1	78.8
$r_{zx'}$	.99	.89	.66	.56	.50	.45	.45
$r_{zy'}$	.40	.68	.88	.93	.96	.97	.99
(4) Fit of z', x', y' components with P:							
$r_{zz'}$	.51	.65	.88	.95	.95	.94	.93
k	1.4*	.8	1.0	2.9	10.0	57.2	29.0*
$r_{zx'}$	−.14	.58	.75	.63	.49	.43	.39
$r_{zy'}$	.37	.52	.74	.92	.94	.94	.93

* Weight of x' is -1.0 instead of $+1.0$.

k being the critical weight of the plateau components which makes $r_{ss'}$ a maximum. Note that $r_{ss'}$ is .93 or above for all stages. The components therefore fit with high accuracy the full entrance in blinds at all intervening stages. Comparing the data of section (3) of table 1 with the analogous statistics for the total entrances, E, of the preceding study, one finds them to be almost exactly the same throughout. We therefore conclude that the components which determine total entrances are the same as those that determine full entrances. This conclusion is not surprising when we look at the values of the sigmas in section (2) of table 1, for there we see that the sigmas of full entrances are in general considerably larger than those for partial entrances at each stage, and since total entrances are a mere summation of F and P, the statistical findings on E should therefore closely match those of the element, F.

The really interesting findings pertain to the partial entrances, summarized in section (4) of table 1. The important statistics are the $r_{ss'}$ values of the first row, where it may be noticed that the magnitudes are close to or above .90 from trials 4–5 on. Indeed, the data from trials 4–5 on closely resemble the findings for full and total entrances. The only serious discrepancies are in trials 1 and 2–3. Observe that the first trial components, x', fit partial errors on trial 1 to the degree, $-.14$. One would at first conclude that the components controlling full entrances on the first trial were utterly independent of those determining partial entrances. But the reason for this bizarre finding is readily apparent. The blinds, 3, 4, 10, 15, 16, 17 are exceedingly difficult for the rats on trial 1, so much so that about 70 per cent of the rats make full entrances into them (see figure 1 of the preceding paper). Not more than 30 per cent could therefore make partial errors, and indeed less than this amount, for these blinds are in the areas of conflict, a component which occasions some true path entrances by chance. When the per cent of full entrances in blinds, F, exceeds about 60 per cent, the partial entrances, P, tend necessarily to be small, a statistical phenomenon which in this case depresses the value of correlation between F and P. Our findings for partial errors on the first three trials are therefore ambiguous.

We conclude, however, that from trials 4–5 on to the end, the components which we inferred for total entrances are substantially the same as those which determine both full and partial entrances into blinds, and thus the hypothesis that full and partial entrances are respectively strong and weak manifestations of our one set of inferred components is supported.

B. Retracings in blinds and stems

Granting that the rat is motivated to get on through the maze to food, one is forced to conclude that retracings are, in general, noncognitive, unadjusted movements. To return to a blind which he has just come out of, and to retrace into a stem which has just delivered him from a preceding unit are reactions of the rat difficult to explain as produced directly by components which describe his attempts to cognize the maze path. I would believe such behavior to be largely caused by emotional upset, conflict, lassitude and inertia. On this hypothesis, I would expect our inferred components which account for *E*, the first entrances into the blinds, to fit these retracings only reasonably well and only to the extent expected from the fact that first entrances in blinds are themselves partially determined by these noncognitive components.

For the same 1,085 rats, I worked out the per cent per trial that retraced into blinds, which we may call retracings of type *B*, and the analogous per cent that retraced into stems, called type *S*. These values are given in table 11 of the appendix. I scored the rat as making a blind retracing, *B*, if on entering a given unit his movements were stem-blind-blind, or stem-blind-stem-blind. A stem retracing, *S*, was scored when his movements were stem-stem, or stem-blind-stem. The relevant data on these *B*, *S* retracings are given in table 2.

As the blinds constitute barriers in the rats' path to the goal, we might expect the rats to "attack" them more persistently than the stems through which they come but which are *not* barriers. But this is not the case, as the mean per cent retracings given in section (1) of table 2 shows. On the first trial only .06 of the rats reentered the average blind, whereas .19 retraced the average stem, and this relation tends to persist throughout learning. This difference suggests that retracings are not cognitively generated movements as assumed by the barrier-attacking hypothesis.

TABLE 2

Average and variability of per cent retracings (z) into the 17 blinds (B) and stems (S) at successive stages of learning Maze X, goodness of fit of components, z', x', y', with such retracings, and relation between B, S, and blind difficulty (E)

	TRIALS						
	1	2–3	4–5	6–7	8–9	10–11	12–19
(1) Mean:							
B	.06	.04	.04	.02	.02	.01	.01
S	.19	.11	.08	.05	.04	.03	.02
(2) Sigma:							
B	.03	.03	.03	.02	.01	.01	.01
S	.08	.08	.07	.04	.04	.03	.02
(3) Fit of z', x', y' components with B:							
$r_{zz'}$	.81	.83	.77	.85	.86	.96	.94
k	.4	2.5	11.8	8.5*	3.8*	3.5*	3.1*
$r_{zx'}$	.77	.57	.39	.29	.17	.16	.13
$r_{zy'}$	.56	.79	.77	.84	.84	.92	.89
(4) Fit of z', x', y' components with S:							
$r_{zz'}$	.82	.84	.83	.91	.90	.94	.91
k	.69	3.2	23.2*	6.3*	8.1	5.0	5.3
$r_{zx'}$	.74	.54	.34	.28	.48	.55	.53
$r_{zy'}$	.64	.81	.82	.90	.89	.93	.90
(5) Relation between B, S, and E:							
r_{BS}	.94	.94	.97	.98	.95	.94	.98
r_{BE}	.75	.80	.85	.87	.88	.93	.94
r_{SE}	.75	.80	.83	.87	.88	.90	.92

* Weight of x' is -1.0 instead of $+1.0$.

Before trying to explain the componential bases of the differences between the units in B and S retracings, we should first be assured that these differences are reliably measured. Though, strictly speaking, I have no reliability coefficients of these measures, the correlations, r_{BS}, given in the first row of section (5) of table 2 indicate that the reliabilities are nearly unity. Be it remembered that in these correlations, the maze units are, as in all of these analyses, the "individuals," and the score is *per cent of rats making B or S retracings.* On trial 1, r_{BS} is, for example, .94. These correlations are between independently derived measures, the lowest value being .94. The reliabilities would certainly be higher.

These high correlations between retracings in blinds and stems at all stages of learning indicate clearly that the two types of retracings are determined by virtually the *same* components, whatever they may be. A pictorial representation of this high relation is shown in figure 2, plots (3) and (6), which present the correlation scatter between the *S* and *B* retracings on trials 1 and on (12–19), respectively. Read the plot as follows: in plot (3), the entry "1" means that in unit 1, 38 per cent of the rats retraced in the stem of the unit, 13.2 per cent in the blind, *etc.*

Corroborating evidence of the identity of the components of *B* and *S* is the fact that they show almost exactly the same magnitudes and "profile" (1) of correlations with other variables. Note that in section (5) of table 2, *B* and *S* have almost exactly the same pattern of correlations with first blind entrances, *E*, throughout the seven stages of learning. Furthermore, in sections (3) and (4), *B* and *S* respectively show in corresponding rows nearly an identical pattern of correlations with the x', y' and z' components. Our conclusion from these data is that the components which *S* and *B* have in common with these other variables are identical throughout learning.

If the cognitive components which in part influence *first* entrances in blinds, *B*, namely, direction-sets, food-pointing, counter tendency, centrifugal swing, and short-cut, also determine to some degree the differences between maze units in the *retracings* into blinds, *B*, then one would certainly expect *B* to correlate higher with *E*, than would stem retracings, *S*, for these components should be absent from *S*. The forward or lateral orienting nature of these cognitive components precludes their causing the rat to move *backward* into the stems.

The reasoning seems straight-forward: since the cognitive components cannot determine stem retracings, and since blind retracings, B, correlate nearly unity with S, and to no higher degree with E and with the x', y', z' components, than does S, these components are absent from blind retracings. They are therefore absent from all retracings.

Being thus forced to the conclusion that retracings are not produced by cognitive components, we require *positive* evidence that they are produced by the noncognitive components: adaptation, lassitude, inertia, exit gradient, and conflict. Figure 2 provides the evidence. Consider plot (3), the relation between B and S for the first trial. The respective and increasing frequencies of retracings into the maze units are to be seen if one scans the plotted entries from lower left to upper right. Can we explain why in units 9, 13, 14 retracings are rare on trial 1,

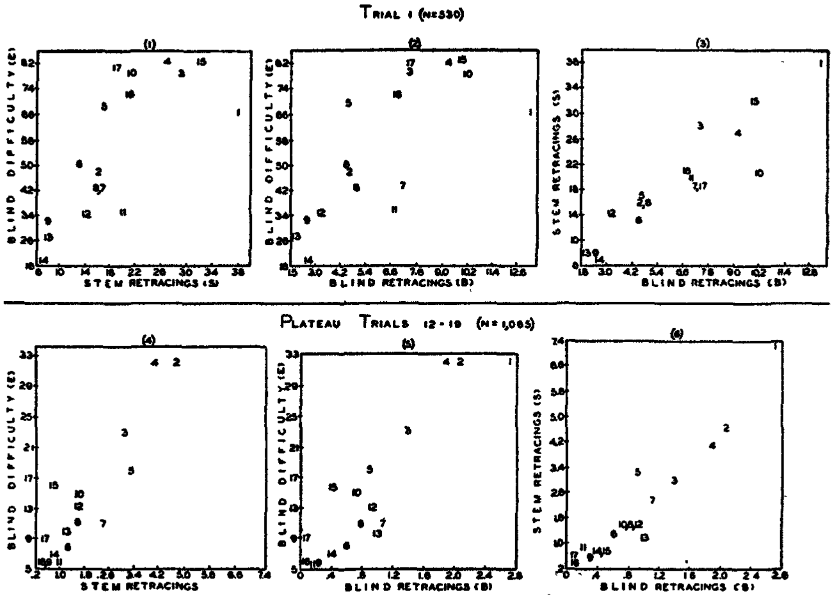


FIG. 2. RELATION BETWEEN BLIND DIFFICULTY (E), BLIND RETRACING (B), AND STEM RETRACING (S) IN MAZE X

The entries are unit numbers, and the ordinates and abscissae are per cent entrances.

but frequent in 1, 15, 4, 3, 10,—and solely in terms of the noncognitive determiners? It is to be recalled from the preceding paper that the components, adaptation, lassitude, and conflict, affect trial 1 performance in the manner of producing aimless wandering movements in the units. Adaptation refers to emotional upset, which would make for retracings in units 1, 2, 3, 4. Lassitude appears as the rats approach unit 10, and towards the end, in units 15, 16, 17. Conflict arises when the rat is pulled and pushed by conflicting components, occurring notably in the first units 1, 2, 3, 4, 5, and when he blunders into blind 10, and into 15, 16, 17. And these are just the units which in plot (3) suffer the most retracing. Though these statements do here lack quantitative elegance, the facts could, if we wished, be closely reproduced by assigning appropriate and internally consistent weight values to each component.

In the plateau period, the frequency of retracings as seen in the diagonal of plot (6) presents a striking order, for as one proceeds from upper right to lower left one sees that, with minor inversions, retracings decrease as the rat proceeds through the maze. This fact fairly clinches the point, for it may be remembered from the preceding paper that the heavily weighted noncognitive components in the plateau are the inertia and exit gradients which would, by hypothesis, produce just this observed order. It looks, however, as if in the plateau, the exit (or goal) gradient plays a minor role, for as it is assumed to have a logarithmic effect, the jamming together of the terminal maze units at the lower left of plot (6) is difficult to fit with this goal gradient hypothesis.

If retracings are noncognitively produced, whereas first blind entrances, *E*, are generated by both cognitive and noncognitive determinants, then a study of the correlation plots between retracings and *E* should reveal the fact. These plots are (1), (2), (4) and (5) of figure 2. Look at plot (2). Following the logic of the preceding paper, a straight line through the swarm of points would be a line of equal relative difficulty, that is, if all units fell upon it, then for any given unit, the rats would, relatively speaking, show an equal propensity to enter its blind initially as to retrace later into it. The units which lay *above* this imaginary line would be those in which the rats had a relatively greater tendency to enter the blind initially than to retrace into it. By our reasoning, we would expect to find above the line those units which are highly charged with the cognitive components that affect E alone. Now the most potent cognitive determiners are the direction-sets which make the blinds at their termini very difficult. These blinds are 3, 4, 5, 10, 15, 16, 17. In plots (1) and (2), these blinds do in fact not only lie above such an imaginary straight line (which the reader can fit by eye), but they are those which are excessively difficult in E. In the plateau, plots (4) and (5), though these blinds are still, as expected, properly located with respect to the line, since the cognitive components are reduced in weight relative to the noncognitive (to be shown later), the divergences are not as great.

To sum up, in line with our aim to test the validity of the components initially inferred as determinants of first entrances into blinds, E, we have entertained the hypothesis that other sorts of behavior *in situ*, namely, retracings into blinds, B, and stems, S, are determined by emotional and motivational dispositions. I have therefore examined these latter behaviors with the eye to discovering whether only the noncognitive types operate in these behaviors. The findings here do, in fact, clearly support this hypothesis, thus contributing to our assurance of the validity of the initial components. Additional evidence, not mentioned above, is the fact that a best weighted composite of the initial components fits such retracings to a significant degree, as the $r_{ss'}$ values of table 2, first rows of sections (3) and (4), show, findings to be expected from the fact that the initial components are, in part, also composed of noncognitive determinants, and increasingly so as learning proceeds.

C. Speed of running in the true paths

An aspect of the rat's maze performance quite different from his movements into blinds and stems is his speed, or rate of running in the pathways. And yet the components I have inferred for entrances into blinds should, by their psychological nature, influence speed of movement. I shall analyze here the speed of the rats' running in the true paths of each unit (see figure 1). One would certainly expect that the components which drive rats into a blind alley should, to some degree at least, influence their speed of running directly away from it into the opposing true path, whether the movement away from the blind be that of avoiding the blind in the first place, or on entering it, that of leaving it.

As we shall see, rats as a group vary in running speed in the different units of the maze. These differences between running speeds of the various units, I have called the *speed pattern.* If our components have validity, they should in large part account for the speed pattern. To fit this pattern, we might have to change the weight and gradient values of some of these components from the values they took in fitting the blind difficulty pattern, for it would indeed be surprising if speed of movement were determined in exactly the same way as is the spot behavior of critical entrances into alleys. We might also anticipate the presence of a few new components affecting speed only, but any revolutionary changes or additions might jeopardize the validity of the initial set inferred for the blinds.

A perennial difficulty in measuring the rat's speed of movement is that of removing from such a measure the effects of, and actual time elapsed during, his movements into blinds and stems of the units. Fortunately, our electrical recording system permits our getting a relatively pure measure of speed. We are able to measure the time elapsed during his movement from the choice-point of one unit (after he leaves the stem or blind) to the choice point of the next. This area includes the true path of the unit and, normally, the turn around an elbow into the stem of the next unit and up to its choice point. I have termed this area the *true path* of a unit, though it does in fact include the stem of the following unit.

Specifically, on each rat's daily tape record, I counted the number of millimeters of tape that had moved, at constant rate, through the recorder while the rat had traversed the true path area in each unit. If the rat had made an entrance in the blind, the reading was taken from the point where the blind alley floor contact was broken, to the "make" of the stem at the next choice-point; if he made no blind entrance, the reading was from the point where the stem floor contact was broken to the "make" of the following stem. The distances from these two points of origin are equal. It happens that in several of the units this true path segment is longer than the standard of three feet. Obviously, we cannot compare the time record of different units if the space traversed differs. I therefore measured the length, C, of the true path in the units, calculated the factor, $3/C$, and then multiplied each rat's *mm.* measurement by this factor for the unit in question. The record for each unit then finally read: *mm.* of tape per three foot length. Our final measure of speed in each unit is this: for N rats the average number of *mm.* of tape per three foot run in the true path. These values are given in table 12 of the appendix. As 2.56 *mm.* corresponds to one second of time, these values are comparable *speed rates*, being time, measured in *mm.*, per constant distance. A high time value thus refers to slow rate, a low value, to a fast rate.

The sample. The analysis was performed on the records of 234 rats on whom we made a special effort to secure a complete time record for each rat for every trial, including trial 1. The sample was drawn from the Bright (B) and Dull (D) stocks of the F_{13} generation of our selective breeding experiment, from a Dull backcross (Bk) stock, and from a Median (Md) group which was the F_2 of a cross of $B \times D$ and theoretically constituted a random sample. The 121 males consisted of 27B, 25D, 9Bk, and 60Md; the 113 females, of 23B, 25D, 12Bk, and 53Md. The group is therefore slightly more variable than a truly random sample.

Reliability. As our sample is somewhat smaller than that of the preceding groups, it is all the more important that we discover the degree of reliability of the differences between units in running speed. The ideal procedure would have been to split our sample into random halves, determine the speed pattern for each half, then correlate the two series for each stage of learning, and finally apply the Spearman-Brown correction. As I worked up the data for males and females separately, I have used them in lieu of the ideal split. The reliability coefficient, r_{11}, for each stage is given in table 5, row (1), where it may be seen that the coefficient for the first trial is .81, rising sharply to .95 by trial 4–5, and reaching a magnitude of .98 at plateau trials 12–19. Thus the mean speeds of running in the true paths are highly reliably different in the various units for all stages, excepting possibly trials 1 and 2–3.

Change in speed pattern with learning. Though the above high reliabilities indicate that on each stage of learning some systematic coalition of components is at work determining the differences in speed in the various units, the coalition is certainly not the same throughout all stages. The intercorrelations between the speed patterns of the seven successive stages of learning, given in table 5, section (4), do not approach the reliabilities as they should were the coalition the same throughout.

Especially interesting are the correlations between the speed pattern of trial 1 and that of each of the succeeding stages [first row of section (4)]. It appears that speed pattern on trial 1 has very little in common with any other stage. On the other hand, trials 2–3, whose reliability of .81 is no higher than that of trial 1, shows considerable positive relation to the speed pattern on the trials which follow it. The trial 1 speed pattern appears therefore to be unique. The reason, I believe, is not difficult to find. It appears that on trial 1, the rats are uniformly slow in nearly all units. It may be seen in table 12 that 14 of the 17 units show time scores closely similar, from 12 *mm.* to 16 *mm.* Units 8, 15, 17 differ from these 14 units by being much slower. This fact is pictorially shown in figure 3, the plot for trial 1, in which one should ignore the ordinate axis. Furthermore, I find that the correlation between the speed patterns of males and females for the 14 units alone approaches zero, but when I include units 8, 15, 17 the *r* rises to .81. This fact means that as a group the rats show a hesitant and constant pace through the other 14 units.

Following trial 1 the speed pattern changes rapidly. On trials 2–3, the 17 units now spread rather evenly through a range of from 7 *mm.* to 15 *mm.*—the rats run consistently slowly in some units, rapidly in others. The reliability of .81 for these trials is not due only to the excessive slowness of three units, but in general the units spread throughout the range on the *mm.* scale. This consistent array means that a coalition of components has now entered as determiners of speed—a coalition which, reasoning from the *r*'s between trials 2–3 and the later stages [see table 5, section (4), row 2], persists to some degree through following stages. The speed pattern continues to change as learning proceeds, but by trials 6–7 it has become relatively stable, for the inter-r's between these and the later trials are very high.

The components of speed. Our major task now is to discover the components which determine the speed pattern that emerges clearly on trials 2–3, but which changes gradually to stability at the plateau trials 12–19. Our expectation is that the components inferred for the blind difficulty pattern will be substantially similar to those determining the speed pattern. The componential bases would be considered to be identical if the blind and speed patterns were identical. But this is not the case, as the correlation plots of figure 3 show. In the plot for trial 1 (to the left in the figure), we see the degree of relation between the blind and speed patterns. Read the plot as follows: on trial 1, the entry "17" stands for unit 17 in which 81 per cent of all blind entrances (the ordinate) were in blind 17, and in the true path of this unit the mean time was 24.8 *mm.* (the abscissa). There is obviously little similarity between the blind and speed patterns on trial 1. This fact is, however, not disturbing, for we saw above that trial 1 is unique in its speed pattern, and would therefore show no relation with any other variable. On the other hand, in the plot for the plateau trials 12–19 (to the right in figure 3) an obvious positive relation appears between the two patterns.

In view of the fact that a discrepancy appears between the blind difficulty and the speed patterns, the most fruitful procedure would be to set up componential weight tables for speed, similar to tables 2 and 3 for blind difficulty pattern in the preceding paper, preserving in the main the components postulated for the blind difficulty pattern, but making such modifications as seem psychologically reasonable and proper. The case for the validity of the component originally postulated will rest on whether the modifications are reasonable, and at the same time we may gain insight into the special componential bases of the speed pattern, which is an interesting phenomenon in its own right.

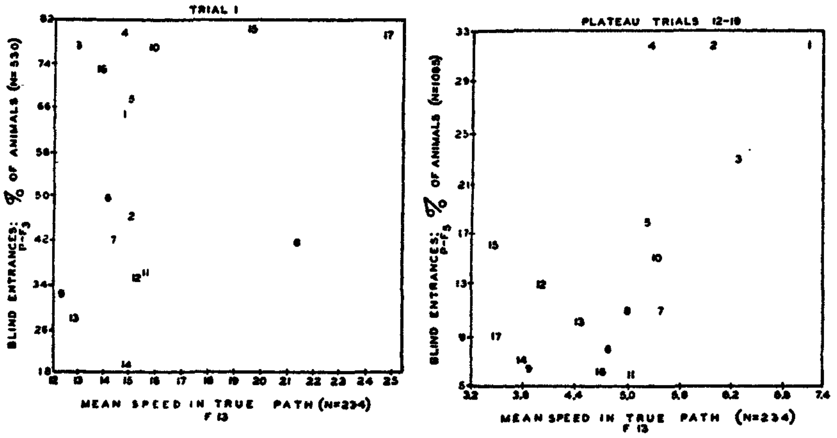


FIG. 3. RELATION BETWEEN ERRORS IN BLINDS AND SPEED IN TRUE PATHS IN MAZE X

Entries are unit numbers, the ordinates are difficulties of blinds, and the abscissae are mean times in true paths measured in *mm.* of tape.

To this end I present tables 3 and 4 showing the weights per maze unit of each component for the speed patterns in trials 2–3 and in the plateau trials 12–19, respectively. Let us compare table 3 here with table 2 of the preceding paper which showed the componential weights for the blind difficulty pattern on trial 1. These two tables are virtually identical as far as the *types* of components eliciting the error and speed pattern are concerned. Only two changes have been introduced. Cen-

TABLE 3

Weights per maze unit of each component—trials 2–3—speed in true path, Maze X

BLIND	DIRECTION-SETS							FOOD PT	COUNTER TP	ADAPT	LASS	CONFLICT	S'_s THEOR.*	S_s EXP.†
	a	b	c	d	e	f	Prel							
1	−1						2	3	−1	2		1	12	11.8
2	−3						2	3		2		2	12	13.6
3	6	−1						−3	−5	2		4	9	11.3
4	−3	2						3	−5	1		2	6	9.3
5	2		−1						−3		1	1	6	9.6
6	−1		−2					2			2		7	9.4
7			−2					2			5		11	14.9
8			−4					2			7		11	14.7
9			−6								4		4	7.7
10			7						−7		3		9	12.8
11			1	−1							1	1	8	10.3
12				−1							1		6	11.1
13				−3							1		4	9.6
14				−5				−1			2		2	8.5
15				7	−2			1	−7		3		8	10.5
16				−1	3			−1	−4		4	2	9	12.8
17				2		1		1	−5		1	1	7	11.7

* Sum of weights plus 6.

† Mean mm. of tape.

TABLE 4

Weights per maze unit of each component—plateau trials 12–19—speed in true path, Maze X

BLIND	DIRECTION-SETS						SHORT CUT	COUNTER		INERTIA	EXIT GRAD	CONFLICT	LASS	S'_s THEOR.†	S_s EXP.‡
	a	b	c	d	e	f		B1	TP						
1	−.5						1			13.3*	−.9	2		25	7.1
2	−1									10.0*	−1.0	3		21	6.0
3	3	−1.5					1		−2*	8.5*	−1.2	3		21	6.3
4	−1	2						1	−1*	5.0	−1.3	3		18	5.3
5	.5		−1							4.0	−1.5	1	1*	14	5.2
6	−1		−2							3.6	−1.7		2*	11	4.8
7			−2				1			3.3	−1.9		3*	13	5.4
8			−2							3.0	−2.1		3*	12	5.0
9			−3							2.7	−2.3		3*	10	3.9
10			4	−1					−4*	2.3	−2.7		2*	11	5.3
11			1	−1				−1		2.1	−3.0		2*	10	5.1
12			2	−1						1.9	−3.3			10	4.0
13			1	−1						1.7	−3.6			8	4.5
14				−1.5						1.5	−4.0			6	3.8
15				3	−1		1		−4*	1.4	−5.5*	1		6	3.4
16				−2	2	−1		1	−1*	1.2	−7.2*	1		4	4.7
17				1		2	.5		−1*	1.0	−12.3*			1	3.5

* Change from error difficulty weights; food-pointing deleted in speed.

† Sum of weights plus 10, rounded.

‡ Mean mm. of tape.

trifugal swing is dropped, being considered not a factor in speed. As this component is believed to be a purely local orienting determinant within a unit, generating no *general* momentum over *several* units, it is believed not to be a factor in speed on trial 1. A second change is in the counter tendency. It may be recalled that this tendency arises when a strong direction-set culminates in a blind, resulting in the generating of movement in the counter direction. This counter set, called *TP*, is felt at once in the opposing true path of the unit whose blind constituted the thwart, and it is considered to have a weight roughly proportional to the direction-set which is thwarted. Thus it should appear in table 3 in blinds 1, 3, 4, 5, 10, 15, 16, 17. This logic is obviously consistent with that employed for this same component in the explanation of blind difficulties.

As for the other components they are the same as used in the earlier table which accounted for the error pattern of trial 1. But differences in weight have been introduced in some cases. Consider the direction-sets: for example, *set a*. The weights, of course, carry the same sign as in the table for blind entrances, for when *set a*, for example, strongly pushes the rat into blind 3, giving a plus weight for blind difficulty, it should, for psychological consistency, exert a counter pull out of the true path of 3, slowing up his movement there, giving a plus weight for speed, that is, in terms of our *mm.* measurement, making the latter increase. Note that in this speed table, the weights for *set a* spread over more units than when they determined the trial 1 error pattern. But this is consistent with our original formulation of the properties of direction-sets, namely, that as learning proceeds, they become more dynamically generalized, thus producing a spreading of the influence of the direction-sets over more units, as in trials 2–3 considered here. A real difference occurs in the *magnitude* of the weights for the direction-sets. I have made them slightly larger than before, on the grounds that these sets determine speed more strongly than blind entrances.

Food-pointing, adaptation, conflict have been preserved in speed substantially as in errors. But lassitude I have introduced as a more potent component. In this I believe most rat-runners would support me, for whereas this tendency to "give up" would only to a minor degree determine differential *errors*, it should affect differential speed in the units. It has been my irksome observation that as the rats proceed away from the focus of the maze, i.e., the starting and food chambers, and progress toward unit 10 they tend to give up and wander, but after they turn the corner at 10, they pick up a bit on the return trip and then slow up again at the end.

When we turn to the components which determine the speed pattern of the plateau, given in table 4, we find fewer changes (the starred entries) from those that determine blind difficulty, as given in table 3 of the preceding paper. In modifying the *types* of components, I have necessarily introduced the *TP* counter tendency mentioned above and have kept the blind counter tendency as a possible factor in the later stages when the rats are running faster. Lassitude has also been introduced, for observation leads me to believe that, among the dull animals, especially, the tendency to flag at the task seems to continue into the plateau. The weight of this component increases as the rats move farther from the starting and food box locus, disappearing, however, on the return trip from unit 10. Food-pointing creates a problem, for I find that leaving it in disturbs the fit of the coalition of components with the speed pattern. It does not appear therefore as a component in table 4. The two general gradients, inertia and exit, are augmented at the points in the maze where their influence is most heavily felt. Thus, on the hypothesis that inertia occasions an inordinate slowing-up of speed of movement at the beginning of the maze in contrast to its influence on blind entrances, I have increased its weight here. Likewise with the exit gradient; its weight has been increased at the terminus of the maze.

Goodness of fit. Assuming these components to be properly considered, psychologically, the question naturally arises: how well do they fit the experimentally determined speed pattern? In table 3, the experimental *mm.* values per unit are represented by the symbol, x_2, in the last column, and the theoretical values, x'_2, consisting of the sum of the weights plus 10, are in the next to last column. For the plateau, the analogous series y_2 and y'_2 are shown in the terminal columns of table 4.

The tabled values denoting goodness of fit of the theoretical values with the experimental are given in table 5, section (5). If we let z stand for the experimentally determined speed pattern of the seven stages of learning taken in turn, then the $r_{zx'_2}$ values of row 3 of section (5) give the correlations, or degrees of fit, of the coalition of table 3, namely, x'_2, with the successive speed patterns as learning proceeds. The second of these values, .85, is the fit with the speed pattern on trials 2–3. This is about as good a fit as we could expect, in view of the fact that the reliability coefficient of this speed pattern is only .81. We would not wish a fit greater than the square root of the reliability, for this value would be the amount that the experimental series would correlate with a true coalition which fitted rigor-

TABLE 5

Reliability, average, and variability of speed in true paths, z, at successive stages of learning Maze X, and goodness of fit of z', x'_2, y'_2 with speed

	TRIALS						
	1	2–3	4–5	6–7	8–9	10–11	12–19
(1) r_{II}	.81	.81	.95	.98	.95	.88	.98
(2) M	15.8	11.2	8.2	6.7	6.0	5.7	4.9
(3) Sigma	3.1	2.0	1.7	1.6	1.4	1.1	.9
(4) Inter-r (trials):							
1		.34	−.17	−.34	−.19	−.18	−.33
2–3	.34		.74	.60	.53	.45	.37
4–5	−.17	.74		.91	.83	.79	.76
6–7	−.34	.60	.91		.93	.86	.87
8–9	−.19	.53	.83	.93		.90	.88
10–11	−.18	.45	.79	.86	.90		.92
12–19	−.33	.37	.76	.87	.88	.92	
(5) Fit:							
$r_{zz'}$	.69	.90	.84	.84	.92	.88	.96
k	−1.1	.3*	.3	.9	.9	1.3	2.7
$r_{zx'_2}$	.30	.85	.81	.74	.81	.73	.69
$r_{zy'_2}$	−.38	.19	.59	.73	.79	.79	.93

* Weight of x'_2 is −1.0 instead of +1.0.

ously the experimental pattern based on a total universe of rats. Following, now, the $r_{sx'_2}$ values along the row, one sees that our components of table 3 fit very well the speed patterns on succeeding trials.

The degrees of fit of the plateau components of table 4 with the speed patterns of the successive stages are shown in the bottom row of section (5). The last value, .93, shows the fit with the plateau speed pattern, and indicates an excellent fit, though an ideal one would be the square root of .98, the reliability.

The conclusive description of fit is best given by the $r_{ss'}$ values of the first row of section (5), for these values, it may be remembered, show the fit of a linear combination of the x'_2 and y'_2 coalitions with the speed pattern of each stage. For the stages which intervene between trials 2–3 and the plateau, the fit varies from .84 to .92. Though good, it could be better, for the reliabilities of these stages in general approach unity. It would be fair to say, I believe, that our components account for most of the variance between true paths in the speeds with which rats move through them, though we may have neglected some components of minor importance, or the weights assigned to those that we have postulated have not been as properly valued as they could be.

To sum up, our argument for the validity of the components inferred for blind entrances has been bolstered by the fact that another behavior *in situ*, speed of running in true paths, has been accounted for by essentially the same coalition of components. Minor alterations in the coalition and in the weights of the initial components have been introduced, changes which it is believed have been made in a reasonable and consistent fashion. These changes have been instituted not only with an eye to effecting a good fit with the experimental speed pattern, but also to giving additional insight into the psychological determination of speed. In any event, the resulting coalitions, being hypothetical substructures of performance, do fit the major portion of the reliable variance of true path speed.

II. EXTERNAL PREDICTION (MAZE Y)

We turn now to the more crucial test of the validity of the types of components we believe to determine maze performance. Though I have shown that our conception of them has led to an accurate fit with the actual performance of rats on Maze X, nevertheless this conception may be criticized as a case of being wise after the event. However, having made a detailed analysis of the performance, we have molded our conception to fit the complex facts—no mean task in its own right.

The nicest check on the validity of our theory is to see if we can predict from it what rats do in another maze situation, this prediction to be made before the detailed analysis of their performance in this other situation is seen.

My data provided just such an opportunity. After running 140 rats of the original *P* generation on Maze X, I moved these animals to another room and ran them through Maze Y, another T-maze but having 20 blinds and a radically different design from that of Maze X. This experiment was performed in 1927, at which time I was only interested in the degree to which the individual differences in learning Maze X were correlated with those in Maze Y (3). The data had lain fallow for seven years, when in 1934, having just made the blind analysis presented in the preceding paper, it occurred to me to resurrect the Maze Y materials. Before looking at these data, however, I studied the design of Maze Y, and on the hypothesis that the same types of components I had inferred for Maze X also operated in Maze Y, I laid out a table of components for trial 1 and the plateau period, entered weights for each blind according to the principles developed from Maze X, and by summation finally had before me the "predicted" difficulties of the blinds of Maze Y for trial 1 and for the plateau. The question now was whether these predicted values did in fact fit the experimental values as shown by the 140 rats. At this point the actual data of Maze Y were worked up, and the fit measured.

A palpably reasonable objection may at once be raised that, as I personally had run and scored the rats in 1927, I would remember in 1934 the relative order of difficulty of the blinds. The prediction would thus not be a clean one, as I had seen the performance seven years before. There are several reasons why this objection is not valid. In the first place, I can and do claim complete obliviscence of the blind difficulties after these years—though it is possible that this information lurked dormant in my unconscious. Second, as I was originally *set* to study individual differences and not blind differences, the psychological conditions were not fulfilled for remembrance of the latter. Third, as my prediction was to be of blind difficulties at the different stages of learning, such remembrance would be masterful indeed in view of the fact that on a given experimental day different groups were running at different stages of learning.

But these personal rationalizations are of little moment compared with another point. It must be remembered that the predicted difficulties of blinds are *final* theoretical values deriving from a sum of specific weights given the components. In performing the operations, one begins by taking the first component, e.g., a direction-set, assigning weights to the blinds according to the principles earlier laid down; then one proceeds to the next component, performing like operations; and then proceeds in like fashion to the end of the list of components. After this, one finally figures the sum of weights for each blind, thus arriving at its predicted theoretical difficulty. One does not know what this final difficulty value will be until the end of these operations. Any "inside" information the analyst has regarding the experimental difficulties could only operate on the final theoretical values, but the analyst does not know what these are to be until after all the weights have been assigned. Stated another way, what the analyst predicts are the weights of individual components, based on consistent execution of principles—he does not predict the final theoretical values as such, and this series is the only statistic that knowledge of the data could affect.

Maze, procedure, and rats. A description of Maze Y and the procedure of running the animals in it is given elsewhere

(2, 157 ff.). Briefly, it is an alley floor maze, made up of 20 T-units, having the design schematically shown in figure 4. The rats run one trial a day to food. Each rat is given all the food he can eat at the end of the run, being removed from the food box when he loses interest in the food tin and starts wandering around the chamber. Before running the maze proper each rat runs five trials a day for two days through the preliminary path, which, as shown in figure 4, requires two left turns through unit 20 to the end box. The rats therefore know the position of food when they start the maze proper on the third day.

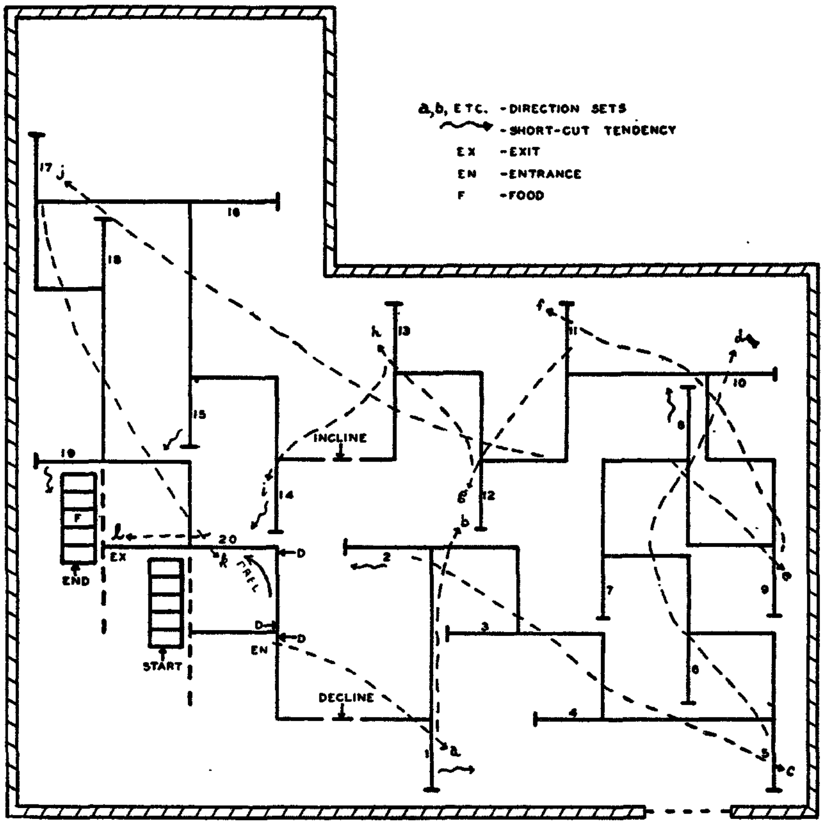


FIG. 4. SCHEMATIC PLAN OF MAZE Y SHOWING INFERRED DIRECTION-SETS

Having run Maze X, the rats were moved in batches of about 15 rats each to Maze Y, where several batches were run at the same time, though starting on different days. The sample of rats was the *P* generation of the selective breeding experiment and consisted of a random sample of 88 males and 52 females (2, 161 ff.).

The predicted components. The technique of prediction is, first, to study carefully the maze design as presented in figure 4, then, keeping in mind the procedure and the fact that the rats, having run Maze X, are maze-wise, to enter in tables 6 and 7 a column for each component believed to be elicited in this maze according to the theory of components developed from Maze X, and finally to enter weights comparable to those in the earlier analysis. The weights not closed in parentheses in tables 6 and 7 are those that I postulated.

The first components considered are the direction-sets, shown by dashed lines in figure 4. There are thirteen of these, including the one generated by the preliminary path. In conformity with the properties of these sets as presented in the preceding paper, those elicited on the first trial, table 6, have very localized effects; but in the plateau, becoming more dynamically generalized, they spread over more units. As with Maze X, food-pointing increases in weight in the plateau. Short-cut emerges in the plateau, and is given slightly more weight here than in Maze X, because the rats, being maze-wise, should more readily evolve the higher-direction configurations which determine short-cut. Counter tendency is again introduced, being given less weight here, for it is reasonable to believe that the maze-wise rats would have learned to some degree from Maze X that this localized reaction is unfruitful, a belief consistent with our principle of reducing the weight of counter tendency as learning proceeds. Centrifugal swing appears on trial 1, disappears in the plateau. Anticipation, considered for Maze X but not utilized there, is here introduced only in blind 19, which is homologous with the final correct turn in unit 20.

The noncognitive components are the same as before. Adap-

TABLE 6

Predicted and revised weights per blind of each component—1st trial—Maze Y errors

Revised magnitudes of weights in parenthesis

BLIND	DIRECTION-SETS													FOOD PT	COUNTER	CENT SWNG	ADAPT	LASS	CONFLICT	x'_p PRED.*	x'_1 REV.*	x EXP.†
	a	b	c	d	e	f	g	h	i	j	k	l	Prel									
1	3(4)												−2	−2			2		1	7	8	75
2	−1(2)												3(2)	3(2)			2			12	9	56
3			−2											2		−1	1			5	5	44
4			−3											1		−1				2	2	30
5			5(6)																	10	11	77
6				−2											−2(1)	−1				0	1	31
7				−3												−1				1	1	24
8				5(6)												1		1(0)	1	13	13	89
9				−1(5)	2										2(1)	1		1(0)	1	11	5	34
10						−1										−1		1(0)		4	3	47
11						3(2)														8	7	50
12							2								1	1				9	9	71
13								2							1	1				9	9	63
14									2					1	1	1				10	10	86
15										−2(1)				1	−1	−1				2	3	40
16										−3(2)								1(0)		3	3	50
17										5(3)				−1				2(1)		11	8	65
18											−2			−1	−2	−1		2(1)		1	0	15
19											−2			1(2)				1		5	6	67
20											4(3)			−2(4)		1		1		9	6	54

* Sum of weights plus 5, rounded.

† Per cent entrances.

TABLE 7

Predicted and revised weights per blind of each component—plateau trials 12-19—Maze Y errors

Revised magnitudes of weights in parenthesis; in revision, exit gradient deleted

BLIND	DIRECTION-SETS												FOOD PT	SHORT CUT	COUNTER	ANTIC	INERTIA	EXIT GRAD	CONFLICT	y'_p PRED.*	y_1' REV.†	y EXP.‡
	a	b	c	d	e	f	g	h	i	j	k	l										
1	2(4)	−1	.5(1)										−3(2)	0(2)			8.3	−.7	1	20	18	24
2			−1										6(4)	2			8.0	−.8		27	18	18
3			−2										3				7.5	−.9		21	13	13
4			−2(3)										1				5.0	−1.0		16	8	8
5			3(7)	−1													4.0	−1.2		18	15	22
6				−1											−1		3.6	−1.3		13	7	6
7				−2													3.3	−1.5		13	6	5
8				3	−1	.5								2			3.0	−1.6	2	21	15	18
9				−1(4)	2	−1									1		2.7	−1.8	2	17	8	5
10				.5		−2											2.3	−2.1		12	6	8
11				.5		3	−1			.5							2.1	−2.3	1	17	11	11
12							2	−1		−.5			.5		.5		1.9	−2.6	1	15	9	5
13								2	−1	1			−1		.5		1.7	−2.8	1	14	9	8
14									2	−1			3	2	.5		1.5	−3.3	1	19	14	16
15										−2			3	2	−.5		1.4	−3.6		13	9	10
16										−3							1.2	−4.0		7	3	5
17										4	−1		−1				1.0	−4.5		12	8	8
18										1	−1		−2		−1		1.0	−5.2		6	3	2
19											−2	1	4	1		3	1.0	−6.0		15	13	17
20											2	−2	−6(4)				1.0	−7.3		1	2	5

* Sum of predicted weights plus 13, rounded.

† Sum of revised weights plus 5, rounded.

‡ Per cent entrances.

tation and lassitude appear here, though they are slightly reduced in weight because the rats were experienced. Inertia and the exit gradient are included, being parameters necessarily identical to those of Maze X.

The experimental difficulties. Having completed these theoretical weights, based on the above reasoning, I summed them, securing thus the theoretical difficulties in the columns marked x'_p and y'_p of tables 6 and 7, respectively. The next step was to work up the actual experimental data, and to discover the goodness of fit of the predicted values with the experimental. The total number of animals who entered each blind per stage of learning is given in table 13 of the appendix. Defining difficulty again as the per cent of rats entering each blind per stage, I present a graph of these difficulties in figure 5. As before, we see on trial 1 a large variation among blinds in difficulty, signifying at once the existence of systematic components at work. There is *not* a chance distribution around 50 per cent, to be expected if the rats run in a random "trial and error" fashion on this first trial when they are ignorant of the maze path. In contrast with the analogous curves of the blinds in Maze X (q.v.), those of figure 5 show in general a more rapid fall in blind difficulties and fewer critical changes in relative difficulties of some of the blinds. This improvement of performance in Maze Y is probably due to the fact that the rats were experienced, but, even so, it is surprising in view of the fact that Maze Y is more complex in design than Maze X.

Before we turn to the results on prediction, it is necessary to examine certain quantitative properties of these difficulties. In the first place, we must know the reliability of these values, for we cannot expect to find correlations between predicted and experimental difficulties higher than the square root of the reliabilities of the latter. As before, I have estimated reliability from the correlation between the experimental difficulties of males and females, the value of which, after S-B correction, is shown for each stage of learning in row (1) of table 8. These values are doubtless a little low. The experimental difficulties have therefore a negligible error at all stages, for the reliabilities are high.

A second matter has to do with the change of relative difficulty. If we are to predict plateau difficulties we must know that a plateau exists. From figure 5 it is evident that the

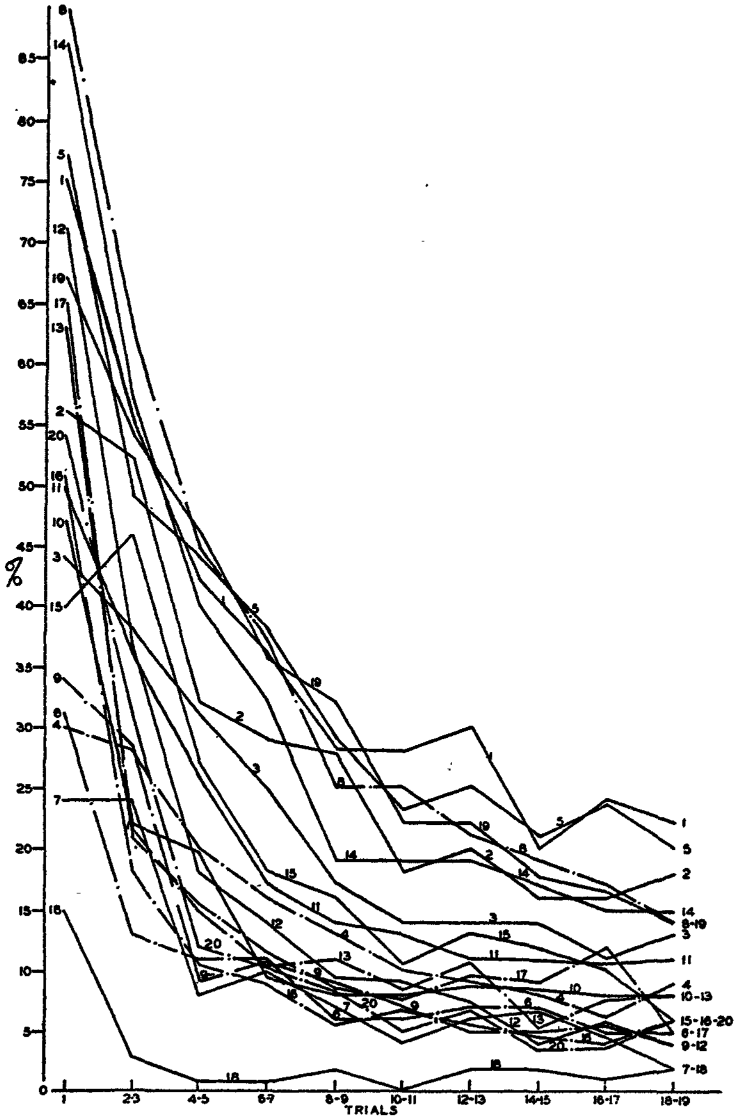


FIG. 5. PER CENT OF RATS ENTERING EACH BLIND PER TRIAL IN MAZE Y
Each graph refers to a given blind, as numbered. N is 140 rats

blind difficulties have reached an approximate level by trial 12. But a better source of information is the correlation between the stages, presented in table 8, section (4). It is to be seen that blind difficulties of trial 1 show *r*'s of the order .7 with those of subsequent stages, whereas the difficulties of trials 12–19 show *r*'s which approach unity with those of the stages which precede it. Note that as one goes into the lower right corner of the table the coefficients rise toward unity. These facts mean that the coalition of components which determine the difficulties on trial 1 is altered as learning proceeds, rapidly becoming a stable coalition in a very few trials. In comparing this table with the analogous table for Maze X (table 1 of the preceding paper), one sees that the transition from the first trial coalition to the plateau coalition occurs more rapidly than in Maze X. Furthermore, for Maze Y, the first trial coalition more closely resembles the plateau coalition, for the correlation between these two stages is higher than in Maze X. These facts suggest that in Maze Y the rats more rapidly reach

TABLE 8

Reliability, average and variability of blind difficulties, z, at successive stages of learning Maze Y, and goodness of fit of z', x'_1, y'_1, with such difficulties

	TRIALS						
	1	2–3	4–5	6–7	8–9	10–11	12–19
(1) r_{II}	.96	.95	.94	.93	.93	.96	.96
(2) *M*	.53	.35	.24	.19	.15	.12	.11
(3) Sigma	.20	.16	.14	.11	.09	.08	.06
(4) Inter-r (trials):							
1		.74	.74	.72	.64	.76	.69
2–3	.74		.92	.93	.90	.89	.85
4–5	.74	.92		.97	.94	.96	.94
6–7	.72	.93	.97		.96	.96	.96
8–9	.64	.90	.94	.96		.94	.96
10–11	.76	.89	.96	.96	.94		.98
12–19	.69	.85	.94	.96	.96	.98	
(5) Fit (rev. comp.):							
$r_{zz'}$	.92	.86	.87	.90	.90	.91	.92
k	.0	2.5	5.5	6.8	43.0	4.8	19.00
$r_{zx'}$	.92	.72	.67	.67	.62	.70	.65
$r_{zy'_1}$	.63	.84	.87	.90	.90	.90	.92

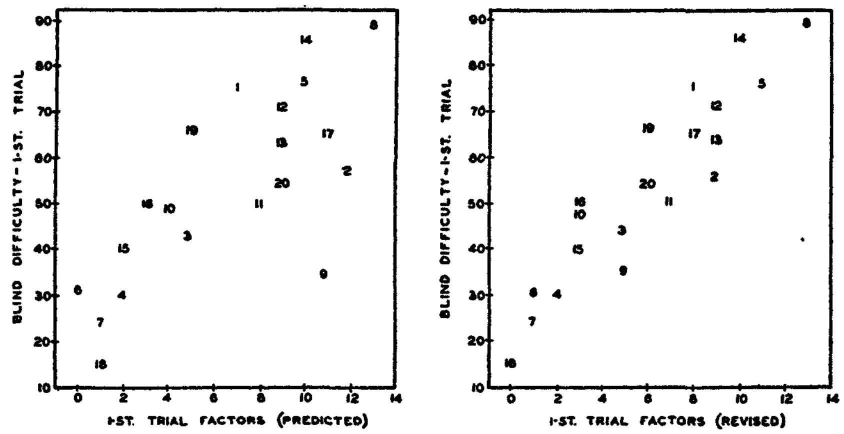
the plateau because they learn faster, having had maze training. The facts also suggest that the components *unique* to trial 1 and to the plateau are reduced in weight. These components, that are present in the first trial but absent in the plateau, are just those that would less readily appear in maze-wise rats, namely, centrifugal swing, adaptation, and lassitude. The components *common* to the two stages are thus more heavily weighted in Maze Y than in Maze X. Later, when we shall attempt to improve the fit by revising the predicted values, we shall see that it is by the reduction in weight of some of these unique components that the fit is improved.

Goodness of prediction. The relation between the predicted and the experimental difficulties is shown in figure 6. The upper left plot shows the relationship for trial 1. Read the graph as follows: the entry "8" stands for blind 8, the experimental difficulty of which is 90 per cent (the ordinate), meaning that 90 per cent of the rats enter this blind, and the predicted difficulty, from table 6, is 13 (the abscissa). It should be apparent that in general the prediction is very good indeed. We did, however, pull bloomers on blinds 2 and 9 which lie well off an imaginary straight line of hypothetical perfect prediction. The correlation between experimental and predicted difficulties, $r_{x'_p x}$ is .73, but on deleting blinds 2 and 9 *it is .92* for the remaining blinds.

The lower left plot shows the relation between predicted and experimental values for the plateau. The fit is pretty good, giving an $r_{y'_p y}$ of .70. As the swarm of points is curvilinear, *eta* would be higher. A study of the points in this plot will show at once what prevented our prediction from being better. Note that blinds 20, 19, 18, 17, 16, 15, are off the imaginary line of exact prediction, and depart from it in magnitude in general in that order. And these discrepancies are due to our making these blinds too easy. Now there is just one component which has this unique effect, the exit or goal gradient. Had we deleted this component from the coalition, the fit would have been excellent, as we shall see later.

Before leaving this matter, I should show the goodness of prediction of the plateau difficulties from the more parsimo-

1st Trial – Maze Y



Plateau Trials – Maze Y

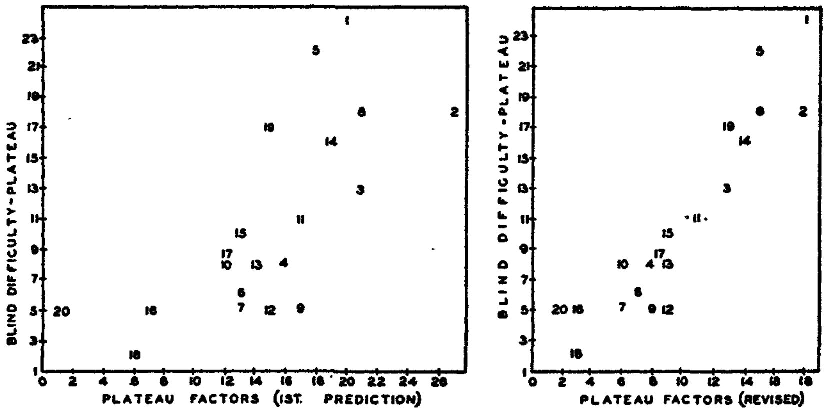


Fig. 6. Relation between Theoretical Difficulty (Predicted and Revised) and Experimental Difficulty of Blinds on Trial 1 and on Plateau Trials 12–19 of Maze Y

Entries are blinds, ordinates are experimental difficulties (per cent entrances), and abscissae are theoretical difficulties.

nious set of components as suggested by Hull and Spence[2], namely, exit or goal gradient, and food-pointing. We should also consider centrifugal swing. Giving blinds a weight of 1 or −1, as does Spence, according as they are food-pointing or not, and keeping our logarithmic gradient for the exit gradient, I found that a coalition of these two gives a correlation of .38 with the experimental difficulties. Adding centrifugal swing raises the r to .44. Though these components have, therefore, a mild predictive value, taken alone they are inadequate. I would consider centrifugal swing of minor significance, especially in the plateau, food-pointing of greater importance, but preferably expressed as a gradient determined by propinquity to food. I believe exit gradient to be negligible in Maze Y, except possibly in the determination of retracings and speed. Retracings were of such low frequency in Maze Y as to preclude analysis, and I did not secure a per unit measurement of speed.

Revision of predicted difficulties. Though our prediction has been good, certainly better than that from a more parsimonious set of components, mistakes were made. We can profit from these errors by noting what kinds of revisions of these components and of their weights result in a more exact fit. Such revision, provided it is consistently applied and is a reasonable alteration

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[2] See the similar treatment in the preceding paper (4). This kind of treatment of a more parsimonious set does not present the best case for such a set. A better method would be to choose the best internally consistent system of weights which would provide a maximal fit with the experimental difficulties.

With respect to the finding of the most parsimonious set of components which would lead to consistency, factor analyses of several sorts could be worked. The most relevant sorts would be the following: the tests (X) and individuals (Y) being, respectively, (1) X-trials, Y-blinds, (2) X-blinds, Y-trials, (3) X-trials, Y-rats, (4) X-blinds, Y-rats. Professor R. J. Wherry has just published several analyses of type (1) (see Factorial analysis of learning dynamics in animals, J. Comp. Psychol., 1939, **28**, 263–272; A test by factorial analysis of Honzik's exteroceptive data, J. Comp. Psychol., 1940, **29**, 75–95). Believing that the psychological meaningfulness of a minimal set of parameters isolated by a factor analysis is questionable (1), I have not made such analyses myself. But I have supplied Professor Wherry with a complete set of the data presented in this and the preceding article, with accompanying manuscripts, and look forward with considerable interest to the publication of his findings.

emanating from a careful consideration of the aspects in which Maze Y differs from Maze X and of the manner in which the rats differ in their history, may give further insight into the nature of how these components control behavior.

The revisions on trial 1 are shown in table 6 by the weight values placed in parentheses after the original weight. The revised values always carry the sign of the original. Any weight not followed by a revised weight stands as it is in the revision. The first kind of change is of the weights of direction-sets. Note that those in the first part of the maze have been increased, especially at the locus of their termini, whereas those toward the end of the maze have been decreased. The rationale of this change is that, since Maze Y is very complex in design, having many direction-sets, the rat is more heavily controlled by these local maze direction features as he proceeds away from the locus (entrance and food box), but on his return from the farthest point (unit 10) from the locus, he is more heavily influenced by orientation to the locus and less by the direction details of the maze design. Our revisions of the weights of the direction-sets are consistent with this theory, as are also the revisions of the weight of food-pointing which have been slightly reduced in the first units but increased in the last. The only other type of revision is in line with a conception held when we made our first predictions, namely that counter tendency and lassitude be reduced in weight because the rats were maze-wise. Hence, these components are further reduced, especially lassitude, which is virtually deleted except in the last units. On this reasoning, centrifugal swing should also be reduced. Further revision could, in fact, have been made, involving the complete deletion of centrifugal swing, counter tendency, adaptation, and lassitude, all components diminished by maze experience and having minor variance, thus leaving the direction-sets and food-pointing to absorb as much of the weights of these deleted components as would be consistent with the principle of revision postulated for these remaining components. The result would not substantially alter the revised final difficulty values from those actually shown in table 6.

In the column headed x'_1 the revised values are given. The relation between these revised difficulties and the experimental values is shown in figure 8, upper right plot. The fit is now excellent, provide an $r_{x'_1 x}$ of .92.

In the plateau, table 7, the revisions of the weights of the direction-sets and of food-pointing are in general consistent with those of the first trial. With short-cut, I had originally made a slip in not noticing that in blind 1 this component would be generated by the rats entering it in the effort to get over into the units beyond.

The important and final revision in the plateau is in the deletion of the exit or goal gradient. As seen before in the lower left plot of figure 8, this is the component which distorted our predicted fit. Deleting this gradient implies that *the exit and food are of negligible differential effect on integration-learning of the path of Maze Y*. In this maze such an implication is reasonable. I would not deny that the food provides a *general* motivation and emotional support for movement through the maze, but would only reject the hypothesis that it differentially affects movement in the various parts of it. Though the rats are in general food-oriented, the orientation is apparently not utilized by them in learning the true pathways. The reasons for this should be evident. The design of Maze Y presents a complex task to the rat, consisting of numerous changes in direction. The rat therefore appears to solve the maze task in its own spacial terms, irrespective of the position of food. By this statement I mean that the cognized goals by which he integrates the direction-sets into higher direction-configurations are the sub-goals in the maze itself. These sub-goals are the direction-sets themselves,—specifically, the particular goal of any given direction-set is its consequence, namely, the direction-set which follows. These sets are integrated into the higher direction-configurations, by means of which the rats cognize the true paths quite without recourse to the general orientation towards the exit. This explanation is consistent with and follows from the theory of maze learning given in the preceding paper (see *Modes of selection*). Be it noted that I am not denying the effects of the goal gradient in *all* mazes. I am merely assuming that when a maze is geographically complex, the goal gradient tends to lack influence.

The relation between the revised difficulties (y'_1 of table 7) and the experimental difficulties is shown in the lower right plot of figure 8. The fit is now excellent, providing an $r_{y'_1 y}$ of .92.

To sum up, our predicted difficulties have given a good fit with the experimental difficulties. The revisions have given one much better, and have involved only such changes in the original set as seem reasonable in the light of the special features of Maze Y. That the difference between the predicted and the revised difficulties is not great is succinctly shown by the correlation between them. This turned out to be .90 for trial 1, and .91 for the plateau.

Goodness of fit with intervening stages. The findings on the degree to which the revised components fit the blind difficulty patterns at *all* stages of learning are given in table 8, section (5). In the third row are shown the degrees of fit of the first trial coalition, x'_1, with the various stages. Note that, whereas the fit with the trial 1 pattern is .92, it drops immediately to .72 on trials 2–3, but changes little thereafter. On the other hand, the fit of the plateau coalition, y'_1, as shown in the fourth row, is .84 with trials 2–3, higher than that of x'_1, and it rises sharply to a maximum within a few trials thereafter. This means that the transition from first trial components to plateau components occurs almost entirely in a few trials, suggesting that adaptation, lassitude and centrifugal swing drop out almost immediately as components of performance and that short-cut, inertia, and conflict emerge in these early trials. The situation is depicted more clearly in the k values which denote the relative importance of the plateau coalition over that of the first trial in providing a maximum fit, $r_{zz'}$, between the error pattern, z, and $(1x'_1 + ky'_1) = z'$. Note that k rises sharply to 2.5 on trials 2–3, signifying that the plateau components have 2.5 times the weight of the first trial in producing the maximum fit of .86 (first row) with the trials that immediately succeed the first.

Of greatest moment is the question whether a linear composite of the two coalitions fits well the difficulty patterns of the intervening stages. The $r_{xx'}$ values of the first row answer this question. These are all of the order .90. With the estimated reliability of these difficulty patterns being of the order .95, the fit approaches fairly close to the upper limit. We may conclude therefore that the revised components, as we have weighted them, do account for the major systematic variance of the difficulty patterns at all stages of learning.

III. THE RELATIVE IMPORTANCE OF DIFFERENT COMPONENTS IN THE COALITION DETERMINING PERFORMANCE

What is the relative weight of the various types of components in determining the blind, speed, and retracing patterns of the maze? Some are obviously more important than others. Of special interest is the relative importance of the cognitive vs. the noncognitive components. This matter is of considerable moment, for most experimenters design mazes in the desire to test some cognitive theory they have in mind, hence the intrusion of noncognitive components into maze performance may be a disturbing feature.

Expressed statistically, the question reduces to finding the degree to which any component contributes variance to the total coalition which determines performance. For example, we may wish to find the percentage of the total variance of a coalition X (e.g., x'_1, the revised first trial coalition of Maze Y), by a given component, A (e.g., the inertia gradient). To simplify the problem, suppose that one assumes that X is determined by only two components, A and B. The variance of X is:

$$\sigma_x^2 = \sigma_a^2 + \sigma_b^2 + 2r_{ab}\sigma_a\sigma_b$$

Note that the variance of the total coalition is augmented over the amount due to the variances of the two components by the addition of two of the terms, $r_{ab}\sigma_a\sigma_b$, sometimes called the "joint effect" of A and B on X. In finding the percentage determination of variance of X by A, if we give one of these joint terms to A (and leave the other for B), adding it to the variance of A, we have as a final value for A:

$$\text{Percentage determination of variance of } X \text{ by } A = \frac{\sigma_a^2 + r_{ab}\sigma_a\sigma_b}{\sigma_x^2}$$

When percentage determination by A is added to the analogous determination by B, the result is unity, or 100 per cent determination of variance of X. When the number of components is n, there will, of course, be $(n - 1)$ joint terms in the numerator of the formula for determination by each component.

To simplify our problem I have worked out the determination of the first trial and plateau coalitions only by the cognitive components, C, and by the noncognitive components, N, each taken as a summed block. The resulting values are given in table 9, where the results for Maze X and Maze Y are separated in subtables. Read the table as follows: in the first row of entries for Maze X, on trial 1 the variance of the coalition giving the theoretical blind difficulties, E, is determined by the cognitive components, C, (symbolized in the table as ds, fp, etc.) to the extent

TABLE 9

Percentage determination (theoretical) of variance in difficulty of blinds and in speed in true paths by cognitive and noncognitive components

Symbols for components are: direction-sets (ds), food-pointing (fp), counter tendency (count), centrifugal swing (cs), short-cut (sh ct), anticipation (ant), adaptation (adpt), lassitude (lass), conflict (cnfl), inertia (iner), exit gradient (ext).

STAGE	PERFORMANCE	COGN. COMP. (C)	DETER. BY C	NONCOGN. COMP. (N)	DETER. BY N	r_{cn}
		Maze X				
Trial 1.........	Blind diff. (E)	ds, fp, count-B, cs	.81	adpt, lass, cnfl	.19	.51
Trials (2–3)....	Speed in TP (T)	ds, fp, count-TP	.64	adpt, lass, cnfl	.36	−.06
Plateau.......	Blind diff. (E)	ds, fp, sh ct, count-B	.37	iner, ext, cnfl	.63	.18
	Speed in TP (T)	ds, sh ct, count-B-TP	.04	iner, ext, cnfl, lass	.96	−.09
		Maze Y				
Trial 1.........	Blind diff. (E)	ds, fp, count-B, cs	.94	adpt, lass	.06	−.29
Plateau........	Blind diff. (E)	ds, fp, sh ct, count-B, ant	.65	iner, cnfl	.35	.27

.81, by the noncognitive components, *N*, (symbolized as adpt, etc.) to the extent .19, and the correlation between *C* and *N* is .51.

Consider, first, the differences between blinds in difficulty on trial 1. These are more heavily determined by the cognitive components than the noncognitive—.81 vs. .19 in Maze X; .94 vs. .06 in Maze Y. Looking back at the weight tables of the preceding and present paper, one notes that the most important cognitive components of trial 1 (in terms of variability of weights) are the direction-sets, especially, and food-pointing to a lesser degree. And that these should be more important in Maze Y than Maze X is, as we have believed, due to the lessened effects of the noncognitive components, adaptation and lassitude, resulting from the fact that the sample which ran Maze Y was more maze-wise.

At the plateau, which is in general more important since its coalition determines performance very early in learning, the situation is reversed in Maze X, the cognitive components having less weight than the noncognitive—.37 vs. .63. This result doubtless is due to the heavy role of the inertia-exit gradients. But in Maze Y the situation is as it was with the first trial, the cognitive components predominating—.65 vs. .35. In this latter maze, the noncognitive components have nevertheless increased their weight as learning proceeds, for their weight increased from .06 on trial 1 to .36 at the plateau. And this increase is also due largely to the emergence of inertia.

The impressive finding here is the importance of noncognitive components in determing blind entrances after the first trial. The most important of these components is *inertia*. This component appears in both mazes, whereas the exit gradient is lacking from Maze Y. As a parenthetical observation, I must mention that in maze literature great importance has been given to the exit or goal gradient. This gradient has, I suspect, been frequently confused with inertia, the effects on performance of which are substantially the same as those of the goal gradient, producing progressively less difficulty in blinds from start to end. Though the effects on performance are similar, they are conceived as independent psychological radicals, inertia being a "warming-up," "getting-going," "releasing a brake" disposition, goal gradient being a forward-orienting, food-goal-aiming disposition. I would, furthermore, interpret the goal gradient as a special type of direction-set having the exit-food box as a consequence and being itself conditioned, as are all direction-sets, by the spacial design of the maze. When, as in Maze X, the spacial design from unit 10 on consists of a lining up of maze segments in such a fashion that they aim at the exit-goal, the direction-set, which may be named the "goal gradient" may appear; but in Maze Y where such a lining up of segments from units 10 on is prevented by numerous changes in direction, this type of gradient does not appear. This theory leads to a radically different explanation of performance than that given by those who hold to a goal-gradient hypothesis, for we would explain it not as some form of backward conditioning of a food-eating response, but, apart from the effects of inertia, we interpret it as a cognitive *directional* orientation, supported by the configuration of the maze segments, and characterized at its terminus by a spacial locale, which is the exit or food box. The food-goal plays its role by giving an emotive support to this terminal direction-set, that is, by increasing the weight of the set as a determiner of movement at the expense of the weight of other components.

Speed of running, in Maze X, as measured by time in true paths, is also more heavily determined by cognitive than by noncognitive components on the initial trials—.64 vs. .36—but the role of lassitude and conflict is greater than in blind entrances. The plateau coalition, on the other hand, is almost entirely determined by noncognitive factors, especially, inertia, exit gradient, and lassitude, these components, with conflict, contributing 96 per cent of the variance in speed. This finding makes sense, for rat psychologists have, in fact, mistrusted time as a measure of cognitive behavior of the rat in the maze. It must be remembered that we are dealing here with pure speed of running in the true path, and not with the usual time measure which includes time spent in the blinds.

I have not calculated the percentage determinations of the retracing patterns by the various types of components. But it is to be recalled that, in our analysis of retracings in Maze X, the evidence indicated that these are almost exclusively determined by the noncognitive components, the most important of which is inertia.

A final comment should be made on the correlation between the cognitive and noncognitive determiners, r_{cn} in table 9. This correlation would appear to have little psychological significance, for it is in large part generated by the accidents of maze design. For example, if a maze be so designed as to have numerous conflicting direction-sets in the first part of it, less at the end, then the earlier blinds will be in general more difficult than the later, the result being that some positive correlation would appear between the direction-sets and the inertia-exit gradients. But if the later sections be made more difficult, a negative correlation would appear.

Summing up, it would appear that entrances into blind alleys are heavily weighted by the cognitive components—especially the direction-sets and food-pointing. The noncognitive components of inertia and lassitude play a role dependent upon the degree of maze experience of the animals, less if they are wise, more if "green." Inertia and lassitude seem to play the major role in time and retracing. The exit or goal gradient is minimized—when a progressive order of decreasing difficulty of blinds occurs, the component at work is probably inertia. The exit gradient emerges only when the terminal units have a clear exit-aiming alignment.

From a general point of view, we seem to have discovered two major principles at work in the rats' maze learning, so far as Mazes X and Y are concerned. One we may call the *abstract direction principle*, signifying by it that the major cognitive components are the direction-sets and food-pointing, the first being abstracted by the rat from the internal spacial features of the maze segments, the second being a general orientation towards the food box. The other we may call the *effort principle*, signifying by it that on the noncognitive side, the rat's differential movements in various parts of these mazes seem determined largely by inertia and lassitude. Both principles and the components which characterize them have one common feature: the rats' movements are controlled by internal forces which are elicited and conditioned by the general spacial features of the maze, and *not* by specifically presented stimulus cues.

IV. GENERAL SUMMARY

In the preceding paper of this series, a set of components were inferred as the determiners of rats' entrances into the blind alleys of Maze X. These components met the first two criteria of validity of such inferences, namely, they were applied to the performance with consistency, and they were shown to fit the blind difficulties at all stages of learning. In this paper, the intent is to investigate the degree to which these components meet the second two *prediction criteria* of validity.

Prediction *in situ* is studied by noting the degree to which these components fit other behavior in the maze besides total blind entrances. We find, in the first place, that these components show nearly an exact fit with partial as well as full entrances in blind alleys, except for the first trials on which the partial entrances bear a complementary relation to full entrances. Second, the evidence supports the contention that retracing backward into the stems of the units is not determined by the directional cognitive components, for it appears that the noncognitive components alone produce this type of retracing as well as the retracing into blind alleys. Third, the differences between units in the respect of the rats' speed of running in the true paths are described by these components with only minor alterations, which, it is believed, are introduced in a reasonable and consistent fashion.

External prediction is studied by discovering how well the blind difficulties of a second maze, Maze Y, can be predicted from the theory of components shown to be consistent with the findings on Maze X. The theoretical difficulties of the blinds of Maze Y, calculated from a new set of components believed on the theory to be determiners of performance in this new situation, fit the experimental difficulties as indicated by an r of the order, .72, between the two series. Minor revisions of the weights of these components, revisions believed to be consistent with the theory of components, and reasonable in view of the special spacial features of Maze Y and in view of the fact that the rats running Maze Y were maze-wise, raised the fit from .7 to .92. The revised theoretical difficulties are thus found to fit the error patterns almost to the amount permitted by the allowable error. The components inferred for these maze abilities are therefore considered valid in the sense that they satisfactorily meet the two prediction criteria of validity.

The relative importance of the different types of components in determining blind entrances, speed of running, and retracings at different stages of learning is studied. It is discovered that blind entrances are heavily determined by the cognitive components, the direction-sets and food orientation, and by the non-cognitive components, inertia and lassitude, the weights of the latter being sensitive to the degree to which the rats are maze-wise. Speed of running and retracings appears most heavily weighted by inertia and lassitude. The role of the exit or goal gradient in its traditional meaning is minimized. In a broad sense, these findings lead one to describe the rats' running of these mazes as in the main characterized by the abstract direction principle and the effort principle.

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TABLE 10 (APPENDIX)

Per cent of rats per trial making full (F) and partial (P) entrances into each blind for each stage of learning—Maze X

Trial 1 includes rats from P to F_3 generations, later trials from P to F_8. N for each stage of two or more trials includes total rats that ran on those trials.

BLIND	TRIALS						
	1	2–3	4–5	6–7	8–9	10–11	12–19
				Full (F)			
1	53.6	61.0	45.4	32.5	27.8	23.6	22.3
2	33.0	37.7	37.8	32.2	29.8	28.9	20.5
3	68.3	57.8	34.9	25.2	21.5	17.3	16.1
4	75.5	75.3	54.4	40.4	34.8	30.1	24.3
5	57.7	43.4	17.0	12.5	12.7	12.0	12.2
6	39.4	34.0	12.9	9.5	8.1	7.6	5.3
7	38.1	38.5	28.2	18.5	13.9	10.9	7.5
8	33.0	33.6	20.3	13.7	11.5	9.3	7.5
9	21.7	13.9	6.8	6.6	5.4	5.2	3.1
10	69.4	51.1	21.5	14.4	11.4	11.9	10.5
11	27.5	12.4	5.3	4.7	4.4	4.3	4.1
12	25.3	17.1	10.2	9.9	7.6	7.6	7.6
13	19.8	7.0	4.6	5.8	5.2	6.8	6.3
14	15.5	9.5	5.9	6.3	7.1	7.1	4.7
15	80.9	71.4	35.5	23.8	17.4	14.7	10.3
16	65.1	23.4	9.2	5.2	4.1	4.0	2.9
17	74.0	59.6	28.4	16.5	12.4	8.9	5.2
				Partial (P)			
1	12.6	7.6	17.2	15.0	13.7	13.4	9.4
2	15.5	8.4	9.3	11.0	14.3	14.0	11.8
3	10.4	8.9	12.0	10.2	10.5	9.6	6.8
4	6.2	5.0	9.8	12.5	10.8	9.2	7.5
5	10.9	11.6	12.9	9.4	7.4	7.7	5.5
6	10.9	5.6	5.0	3.7	3.6	2.9	2.2
7	6.4	4.1	7.0	7.1	6.8	5.4	3.8
8	10.4	5.0	5.2	4.5	4.5	4.5	3.7
9	11.7	5.5	3.9	3.3	2.7	2.6	2.4
10	9.6	8.2	10.0	6.8	4.9	4.8	5.0
11	8.5	4.2	1.8	1.8	1.8	1.8	2.0
12	9.6	5.1	4.6	4.1	4.8	5.3	5.2
13	7.9	2.2	1.2	1.4	2.4	2.6	3.2
14	4.2	1.8	1.5	1.9	2.3	2.2	2.3
15	2.1	5.8	12.0	10.5	8.8	6.5	5.6
16	7.5	4.4	3.6	2.5	2.9	3.3	2.6
17	7.0	6.8	10.3	5.6	5.4	4.9	3.9
N	530	2,147	2,168	2,171	2,167	2,171	8,650

TABLE 11 (APPENDIX)

Per cent of rats per trial retracing into blinds (B) and stems (S) of each unit for each stage of learning—Maze X

UNIT	TRIALS						
	1	2-3	4-5	6-7	8-9	10-11	12-19
				Stems (S)			
1	38.3	29.8	28.4	18.0	14.4	10.7	7.3
2	15.5	17.2	13.6	9.6	8.3	7.3	4.7
3	28.5	20.4	13.8	7.0	5.7	4.0	3.1
4	27.2	19.6	14.2	12.5	9.0	7.0	4.1
5	17.0	8.2	5.4	4.0	2.9	3.1	3.3
6	13.0	10.9	3.9	2.8	1.8	1.8	1.3
7	19.4	12.5	13.5	8.6	5.4	3.6	2.4
8	16.2	13.7	7.8	5.2	3.0	2.2	1.6
9	7.9	3.1	1.9	1.3	1.2	1.2	.6
10	21.3	10.3	5.1	3.4	1.8	2.3	1.6
11	19.6	4.3	2.1	1.4	1.2	1.0	.9
12	13.8	4.8	3.8	3.8	3.0	1.5	1.5
13	8.3	1.9	2.7	1.9	2.1	1.4	1.2
14	6.6	3.3	2.4	2.0	1.8	1.4	.8
15	31.5	23.4	11.7	5.3	2.9	1.9	.8
16	21.3	3.2	1.1	.6	.3	.3	.4
17	18.7	6.6	2.5	.9	1.0	.5	.5
				Blinds (B)			
1	13.2	11.5	11.6	7.2	5.1	3.5	2.7
2	4.7	7.0	5.6	4.1	3.6	3.7	2.1
3	7.5	4.4	5.4	2.8	2.6	2.1	1.4
4	9.4	9.9	7.4	6.8	4.9	3.2	1.9
5	4.7	2.5	1.6	1.3	1.1	1.0	.9
6	4.5	4.0	1.8	1.1	1.3	1.0	.6
7	7.2	5.3	8.0	4.6	3.6	1.6	1.1
8	4.9	5.6	4.0	2.3	2.2	1.6	.8
9	2.6	1.0	.7	.7	.6	.5	.3
10	10.2	5.3	3.1	1.8	1.0	1.0	.7
11	7.0	1.2	.4	.9	.5	.6	.2
12	3.2	2.3	1.5	1.3	1.1	1.2	.9
13	1.9	.9	1.2	1.1	1.2	1.3	1.0
14	2.6	1.5	1.0	1.3	1.3	1.0	.4
15	10.0	9.9	6.8	3.0	1.4	1.4	.4
16	6.8	1.2	.7	.4	.2	.2	.1
17	7.5	3.5	1.5	.2	.3	.2	.1
N	530	2,147	2,168	2,171	2,167	2,171	8,650

TABLE 12 (APPENDIX)

Mean speed (mm. of tape) per trial in each true path for each stage of learning—Maze X

N = 234 F_{12} rats

UNIT	TRIALS									
	1	2-3	4-5	6-7	8-9	10-11	12-13	14-15	16-17	18-19
1	14.8	11.8	11.3	9.3	8.8	7.8	7.9	7.3	7.2	6.1
2	15.1	13.6	10.2	8.3	7.1	7.0	6.7	6.0	5.7	5.4
3	13.0	11.3	10.0	9.8	8.3	8.0	7.6	6.3	6.4	5.1
4	14.8	9.3	7.4	6.5	5.8	5.6	5.9	5.0	5.4	5.2
5	15.1	9.6	6.8	6.0	5.5	5.0	5.4	5.0	5.3	5.1
6	14.2	9.4	6.8	6.8	6.0	4.9	4.6	5.4	4.7	4.5
7	14.3	14.9	10.6	9.6	7.8	5.8	5.6	5.2	5.2	5.6
8	21.4	14.7	8.9	7.0	7.1	6.1	5.0	5.1	5.3	4.6
9	12.3	7.7	5.8	4.6	4.5	4.2	4.1	4.3	3.6	3.5
10	15.9	12.8	9.6	7.1	5.5	5.8	5.9	5.1	5.2	4.9
11	15.6	10.3	7.5	6.2	5.9	7.8	5.3	5.3	4.5	5.2
12	15.3	11.1	7.7	5.6	4.6	4.2	4.3	4.1	3.9	3.9
13	12.7	9.6	6.0	5.6	4.3	5.0	4.7	4.4	4.6	4.2
14	14.9	8.5	7.4	5.4	4.9	4.8	4.0	4.1	3.7	3.6
15	19.7	10.5	6.9	5.1	5.3	4.5	3.9	3.1	3.5	3.3
16	13.9	12.8	9.9	7.3	6.0	5.3	5.0	4.4	4.6	4.6
17	24.8	11.7	6.2	4.4	4.0	4.5	4.1	4.0	3.0	3.0
Σ	267.8	189.6	139.0	114.6	101.4	96.3	90.0	84.1	81.8	77.8

TABLE 13 (APPENDIX)

Total entrances into each blind alley for each stage of learning of 140 P generation rats—Maze Y

N for each stage of two trials includes total rats that ran on the two trials

BLINDS	TRIALS									
	1	2–3	4–5	6–7	8–9	10–11	12–13	14–15	16–17	18–19
1	105	154	119	102	77	77	84	57	68	62
2	78	147	91	82	78	49	56	46	44	51
3	61	105	88	71	46	38	38	40	31	36
4	42	79	57	46	37	27	25	22	17	25
5	107	137	123	105	77	64	70	58	67	55
6	44	37	30	31	18	17	19	19	13	15
7	33	68	21	27	19	11	16	19	13	7
8	124	175	124	104	68	70	60	52	48	38
9	48	78	23	30	25	19	15	15	15	12
10	66	63	57	28	22	22	25	21	23	22
11	70	101	74	48	40	37	32	30	30	31
12	99	104	49	38	26	25	19	12	18	12
13	88	63	43	29	30	24	32	14	23	22
14	120	160	111	88	53	54	53	47	43	42
15	55	130	75	50	45	29	36	32	29	17
16	70	52	28	25	17	19	16	13	12	16
17	91	60	41	31	22	24	26	22	32	13
18	21	9	4	3	7	1	6	6	4	7
19	93	150	130	101	88	64	61	47	46	38
20	75	88	33	27	21	13	19	11	12	18
Σ	1,490	1,960	1,321	1,066	816	684	708	583	588	539
N	139	280	280	279	276	280	280	278	278	278