Genetic specificity in maze performance¹

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Four groups of randomly selected inbred strains of rats tested in a Hebb-Williams maze situation showed high intra-strain consistency of performance. Test reliability on the elevated maze was very low across strains raising theoretical questions on the specificity of genetic effects and on common principles of test construction.

Genetic factors in maze performance of the rat have been investigated for over half a century. Earlier work progressed from investigations of sib correlations to selective breeding programs. Only in recent years has there been a turn toward use of inbred rather than selectively bred animals (Thompson, 1954; Das & Broadhurst, 1959).

Over this same period of time there has been much development and refinement of the mazes used for behavioral research. Currently the Hebb-Williams (1947) maze seems to occupy a pre-eminent position. Such work as has been done with inbred strains of rats has been with this apparatus. It satisfies many of the criticisms of earlier apparatus, approximates intuitive expectations of the nature of an intelligence test, and has shown adequate reliability.

Despite advances in technique and sophistication the outstanding characteristic of methodology in behavior genetics of the rat has been a one sided approach. Most studies in the field have used behavior as the independent variable and genotype as the dependent variable. Behavior has been observed followed by breeding selection on the basis of that behavior. If the resulting genotypes then have shown other characteristics these have been investigated as possible variables explanatory of the behavior. Such other variables may be accidental. A full understanding of genetic origins of behavior cannot be reached without adequate emphasis on studies where the genotype is varied and behavior is the dependent variable.

This study used genotype as the independent variable to investigate genetic variation in performance in a Hebb-Williams type maze.

Method

Four inbred strains of rats, A35322, ACI, PVC, WAG, were randomly selected from the colony of this laboratory. Six naive males were selected from each strain and six naive females from each of the last three, all 100-150 days of age. Prior maintenance conditions were standard for the colony, natural light cycle to weaning, 24 hr. light after weaning, and assignment to individual cages two weeks prior to experimentation. For the study, animals were placed on 23 hr. food deprivation with ad lib water.

Both elevated and closed field Hebb-Williams mazes

were used. The closed field maze was totally enclosed in a black drape cube and lighted from above to yield a luminance of .20 mL measured at the floor of the maze. The floor was rough surfaced frosted glass, opaque from above but translucent from below. Dimensions and patterns were those of Rabinovitch & Rosvold (1951). Observation was from beneath the maze.

The elevated maze was enclosed in a 48 in. cube with flat white walls, foam rubber floor and black top. The fourth wall was 37 in. high for access. Runways were 3 in. wide, flat black, 25 in. from the floor. A single center top light source provided a luminance of .33 mL at the runways. Patterns were derived by modifying previously reported patterns to give a one to one topographic correspondence between closed-field and elevated patterns. The procedures for derivation were specifically intended to maximize similarity between the mazes for those factors, derived from components analysis, and from factor analysis of maze performance data, which have been proposed as the relevant underlying variables (Tryon, 1940; Wherry, 1941).

Testing followed standard procedures for the six pretest training patterns and 12 test patterns for each maze. All animals were tested on both the open field and on the elevated maze with half beginning with one and half with the other. Errors were recorded.

Results and Discussion

For present purposes it is sufficient to summarize the results for the closed field test since more extended data will be available from testing now in progress on additional animals. Not unexpectedly, significant strain differences were found; and on analysis of components of variance, strain accounted for about half of the total variance. No sex effects were observed. There were no effects of order of testing between closed field and elevated mazes. Closed field odd-even uncorrected reliability was .72 confirming previous reports of reliabilities of about .75.

The elevated maze data, however, revealed a striking pattern. An odd-even reliability of .20 did not confirm previously reported results. It would follow that one could not have obtained the high correlation of previous studies between closed field and elevated maze tests. The observed correlation between the two was, in fact, .21. Furthermore, an analysis of variance revealed no strain differences, again an expected result if the measures are unreliable.

Such a lack of reliability is not consistent with previous research. The closed field showed adequate reliability and in general, elevated mazes tend to be more reliable than closed mazes (Munn, 1950). The elevated maze items were designed to maximize simi-

larity to the topography of the closed field. Such a procedure should have increased the correlation between tests above previously reported levels since it equated the items on the two tests for those factors previously identified by components analysis and by factor analysis of genetic differences in maze performance.

To test the possibility that items on the elevated maze elicited different behaviors from different strains, i.e., that there was a genetic-test item interaction, item difficulty was ranked for each animal. With this procedure Kendall's (1948) W can be considered a non-parametric analog of an analysis of variance showing the proportion of the total variance attributable to group characteristics. Considering each strain independently, W 's ranged from .45 to .60. For tests of significance these yielded χ^2 's ranging from 33.7 to 79.2 all of which were significant ($p < .001$, $df = 11$). On the other hand, ranking the mean ranks for each strain yielded nonsignificant results ($W = .13$, $\chi^2 = 5.63$, $df = 11$, $p > .80$). Clearly, the test was consistent hence reliable within strains and about half of the total variance could be attributed to strain communality. On the other hand, there was no consistency or reliability across strains.

Using parametric statistics all possible pairs of animals were correlated over items. The correlations were then averaged after transforming to Fisher's z . For A35322, ACI, PVC, and WAG strains the average correlations were, respectively, .68, .42, .60, .43. The mean intercorrelation of strain means was .18.

The data show clearly a substantial genetic component of maze behavior accounting for roughly half of the total variance. For such results to occur requires a relatively low error of measurement, yet by the conventional measure, the test was unreliable in this situation. Several implications would appear to follow.

Finding strong within-strains consistency of behavior and little between-strains consistency reveals the methodological advantages of reducing within groups variance by using a variety of inbred strains. The high degree of item specificity obtained with homogeneous groups suggests that unravelling the genetics of behavior may require a close attention to specific stimulus-response relationships rather than to global concepts such as intelligence or the relatively limited number of factors that have been proposed as comprising the global behavior. Since genetic effects stem ultimately from macromolecules such a conclusion does not seem unreasonable.

Behavioral effects are several steps removed from primary gene action. Since genic interactions and much pleiotropy are probably the rule rather than

the exception, it should not be surprising to find genotype-item interactions at the behavioral test level. Complex behavioral processes undoubtedly involve a very large number of genes and genic interactions. Hence, even selective breeding should not lead to a marked change in gene frequencies from an initial equilibrium state. This very heterogeneity could be an explanation for previous reliability findings. Items for performance tests are ordinarily selected on the basis of their correlation with the test as a whole. The higher the intercorrelations the more reliable the test. The uncorrelated component of variance is the error of measurement. From a genetic frame of reference, this item selection procedure could best be accomplished by selecting items insensitive to the major genic interactions in the population and items for which modifiers have a low gene frequency. The result would be a test biased against detection of genetic factors and hence supportive of a strongly environmental interpretation of behavioral origins. The error of measurement would be proportional to the remaining genetic interaction effects and would place an apparent ceiling on prediction from tests. The data suggest that this hypothetical mode of test construction could fit reality and could partially explain both the dominant environmentalist theme of psychological history and the empirical limits of predictability which have acutely concerned test specialists for a number of years. The consistency of performance observed here with close attention to the "fine grain" of performance would seem to indicate that increasing attention to behavior genetics should lead to substantial gains in prediction.

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Note

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