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Some Components of Mechanical Composition*

By GILBERT E. MILLER

In the search for unitary mental traits it appears that the answer may not be finite. In view of this conclusion on the part of several investigators (2), the writer suggests the probability that psychological tests intended to measure ability in a specified area may contain a number of psychological components. As mechanical comprehension is one of the important areas of psychological testing, the writer believes that determination of the components of this area would be of great value.

THE PROBLEM

In reviewing the development of factorial studies of human ability it was noted that instead of unitary "primary abilities," it may be that the primary abilities are actually groups of abilities. Therefore the possibility exists that a test designed to measure some presumably unitary ability may be heterogenous in nature.

Therefore, this study was designed to fulfill three objectives. First, to examine the complex interrelations between items on the Owens-Bennett Test of Mechanical Comprehension in the hope of discovering clusters of variables representative of some of the components of mechanical comprehension. Second, to describe the clusters of variables in such a manner as to provoke speculation as to their causal structure. Third, to provide a basis for further experimental work in the area of mechanical comprehension.

In designing the present study four assumptions were made:

1. Mechanical comprehension is a complex of special abilities possessed to a different degree by different subjects; and, as such, it can be measured reasonably reliably by psychological tests.
2. Mechanical comprehension is a heterogeneous, complex area of human behavior, and as such must be composed of a number of complex components of behavior.
3. Some of the components of mechanical comprehension are measured by the Owens-Bennet Test of Mechanical Comprehension.
4. All subjects were motivated to give maximum performance in the test situation.

PROCEDURE

The data used in this study were available at the Testing Bureau at Iowa State College, and were gathered in connection with the

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Engineering Testing Program. All engineering students entering the above institution as first quarter freshmen in the fall quarter of 1950 were required to take a battery of psychological tests; the Owens-Bennett Test of Mechanical Comprehension was included in this battery. A total of 319 male students was included in this program.

In conducting the present study, it was decided to use a sample of 200 cases. It was felt that such a sample, properly selected, would provide a representative sample of the population of first quarter male engineering students at Iowa State College and other similar institutions. The sample was selected using Snedecor's table of random numbers. (3 pp. 10-13).

The 1770 intercorrelations between the 60 items on the Owens-Bennett Test of Mechanical Comprehension, based on the sample of 200 subjects, were computed using computing diagrams for tetrachoric correlation (1), which are a close approximation of r_t . Because of the size of the sample used the tetrachoric r values should approximate the true correlation values.

The correlation matrix for the 60 items composing the test was analyzed using Tryon's method of correlation-profile-correlation. This technique was used because it appears to fulfill the objectives of the study and is the most parsimonious method available. The derivations of the formulas used in the analysis and their mathematical proof are given by Tryon (4).

RESULTS AND EVALUATION

The 60 items in the Owens-Bennett Test of Mechanical Comprehension appeared to form nine clusters. These nine clusters contained 52 of the items in the test; the remaining eight items were residuals.

The items contained in each cluster and the residuals were:

- C₁ 1, 4, 5, 6, 15, 38, 44, 58, 60
 - C₂ 17, 19, 28, 29, 32, 35, 47, 49, 52
 - C₃ 2, 12, 16, 22, 42, 43, 45, 51
 - C₄ 3, 10, 14, 37, 50, 54
 - C₅ 20, 21, 23, 25, 27
 - C₆ 8, 24, 31, 39, 48, 56
 - C₇ 26, 30, 40
 - C₈ 33, 36, 55
 - C₉ 7, 46, 53
- Residuals: 9, 11, 13, 18, 34, 41, 57, 59

A quantitative analysis of the clusters was made to aid in the evaluation of the correlation profiles of the clusters. The results of this analysis are shown in Table 1 and Table 2. Examination of

these tables shows that with the exception of Cluster 5 and Cluster 9, the clusters appeared, on the basis of empirical evidence, to be rather clear-cut, consistent, operational unities.

Table I

Average Congruence Between the Profiles of the Individual Items in the Clusters; On the Diagonal is the Average Congruence of Profiles of Variables within Each Cluster.

Clusters	C ₁	C ₂	C ₃	C ₄	C ₅	C ₆	C ₇	C ₈	C ₉
C ₁	.3221	.0817	.2074	.3304	.0593	.1181	.0358	.1275	.0093
C ₂	.0817	.3421	.1390	.2368	-.0621	-.0221	-.0665	.1076	.2150
C ₃	.2074	.1390	.3152	.0662	.0615	.0428	-.0599	.1369	.0376
C ₄	.3304	.2368	.0662	.4186	-.0103	.1427	-.1137	.2221	.1504
C ₅	.0592	-.0621	.0615	-.0103	.1716	.0019	-.0156	-.1794	-.0849
C ₆	.1181	-.0221	.0428	.1427	.0019	.3222	.0424	.1208	.0737
C ₇	.0348	-.0665	-.0599	-.1137	-.0156	.0424	.3155	.0539	-.1418
C ₈	.1275	.1076	.1369	.2221	-.1794	.1208	.0539	.3469	.1077
C ₉	-.0093	.2150	.0376	.1504	-.0849	.0737	-.1418	.1077	.1988

Table II

Congruence Between the Average Profiles of the Clusters; On the Diagonal is the Estimated Reliability of That Mean Profile.

Clusters	C ₁	C ₂	C ₃	C ₄	C ₅	C ₆	C ₇	C ₈	C ₉
C ₁	.8104	.2012	.5197	.7299	.1617	.2839	.0770	.2691	-.0217
C ₂	.2012	.8239	.3408	.5119	-.1660	-.0521	-.1400	.2223	.4888
C ₃	.5197	.3408	.7864	.1456	.1673	.1025	-.1285	.2879	.0872
C ₄	.7299	.5119	.1456	.8120	-.0248	.3014	-.2147	.4118	.3070
C ₅	.1617	-.1660	.1673	-.0248	.5088	.0050	-.0366	.4111	-.2142
C ₆	.2839	-.0521	.1025	.3014	.0050	.7404	.0873	.2438	.1637
C ₇	.0770	-.1400	-.1285	-.2147	-.0366	.0873	.5803	.0973	-.2817
C ₈	.2691	.2223	.2879	.4118	-.4111	.2438	.0973	.6145	.2100
C ₉	-.0217	.4888	.0872	.3070	-.2142	.1637	-.2817	.2100	.4267

Inspection of the items in the respective clusters shows the following as their likely common components:

- C₁—abstract visualization of the relationship of moving objects or forces;
- C₂—ability to determine the effects of forces applied to stationary objects;
- C₃—knowledge of elementary physics, especially principles concerned with fluids;
- C₄—comprehension of the vectors of complex forces;
- C₅—because of the error of measurement present in this cluster no attempt was made to determine its components;

- C₄—the writer was unable to conceive of a component, common to the items in this cluster, as both speed and leverage problems are involved;
- C₇—determination of the effects of forces upon objects;
- C₈—stress of a mechanical nature;
- C₉—the error of measurement is so large that speculation as to the common components of this cluster was considered to be of little or no value.

SUMMARY AND CONCLUSIONS

A cluster analysis of the Owens-Bennett Test of Mechanical Comprehension was made using Tryon's method of correlation-profile-correlation. Examination of the correlation profiles, and of the quantitative analysis, indicated that there may be seven to nine operational unities present in the test.

An explanation for the presence of operational unities in the test is suggested in the hypothesis of common or correlated components at work in the different operational unities. Inspection of the correlation profiles indicated that the variables in each cluster operate in a similar or unitary fashion. Theoretically, common or correlated components cause such similarity. The evidence indicates that each cluster contains radical psychological components absent in the other operational unities and, on the basis of the empirical evidence in this study, the above hypothesis appears to offer a reasonable explanation of the operational unities isolated.

Further hypotheses concerning the operational unities and their underlying structure could be offered. The operational unities, although of great psychological importance themselves, provide a broad field for speculation. The writer has made certain speculations concerning the nature of the operational unities. He feels the most important hypothesis resulting from these speculations has been presented.

On the basis of the evidence presented the following conclusions were drawn:

1. Empirical evidence indicated the presence of operational unities in the Owens-Bennett Test of Mechanical Comprehension.
2. Each operational unity appeared to have a component, or components, peculiar to that operational unity, and, to a large degree, absent in the other operational unities.
3. The evidence indicated that items within the operational unity overlap with other items in the operational unity in a similar manner.
4. Further research is needed to clarify the nature of the radicals, or underlying structures, within the operational unities.

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