1. Instructions...
2. Consultation...
3. Leader Emerging...
4. Completion...

Leaderless Group Test...
E.
1. A Consideration of the application of the Bus-Route Test to P.U.T.C.O. (Public Utility Transport Corporation - a transport company running a large fleet of buses for Africans and employing a big African staff). The test was applied to the following 9 groups:
   1. A new Intake Group
   2. A Clerical Group
   3. A supervisory Group
   4. A Group of Drivers
   5. A Driving Instructors Group
   6. A Group of candidate drivers
   7. A Group of Ticket Inspectors
   8. A mixed groups of clericals, drivers and supervisors.

   None of these groups finished the test, although all groups were given a minimum of 30 minutes on the model. The mixed group continued to argue for 1 hour without arriving at a satisfactory solution. The Supervisory group held a theoretical argument for 35 minutes before positioning a single bus-stop sign, and although allowed to carry on for 1 hour and 36 minutes they were still unsatisfied with their bus-route and began repositioning bus-stops when the test was terminated.

2. Understanding the test instructions:

   All groups understood the instructions without any difficulty. A number of subjects, however, asked questions of the tester immediately the test commenced. The questions asked were always about the same two problems, namely:
1. "Where must we start our bus-route and where must we finish it?"

2. "How many bus-routes must we make?"

Both of these questions were countered with a shrug of the shoulders and the answer: "You men are the owners of the bus company, not me. You know best." This answer always had the desired effect of making the subjects realise that all responsibility for planning rested with them and they immediately went ahead without further questioning.

The instructions regarding the use of traffic signs only after the completion of the bus route, were included after it was noticed that without such instruction the group tended to split into two, one group concentrating on bus-stops and the other on traffic-signs.

3. Differences of approach to the problem:

Observation of the groups tested revealed three basic approaches to the problem:

1. The Haphazard Approach:

   this happened when one member of the group positioned a bus-stop and began working on a route without consulting the others, the rest of the group eventually joining in. This type of approach usually ended in chaos and argument, resulting in some type of compromise or in a complete alteration of the bus-route.

2. The Positioning of Termini Approach:

   an approach adopted by groups composed of more intelligent subjects. The problem being tackled from a holistic viewpoint after some usually very illuminating theoretical arguments among subjects. The layout in such cases was considered as a whole, the most suitable termini chosen and the route joining them planned.
3. The Main and Feeder-Route Approach:

such an approach usually started in the haphazard way but was rescued before utter confusion resulted by the "true leader" who made a compromise between the existing bad position and a leader-bus system attached to the main route, to cover the neglected townships.

In their approach to the task it was observed that the majority of subjects to overcome abstract thinking gave names to all the towns, to the railway-station and to others of significance.

It is interesting to note that bus drivers attempted whenever possible to cut down on the number of sharp turns they had to make because of the difficulty of manoeuvring buses round such roads. They also insisted that all bus-stops be on level stretches or on downgrades to eliminate "overshooting" the stop. They realised the safety offered by rail-bridges and tended to select longer routes in order to miss the level-crossings.

The Supervisory and Clerical Groups stressed the economic aspects. Many of their arguments centred around such topics as: the competition with the railway, the most convenient stops for factory workers "who are always tired", and the consideration of safety precautions when planning a bus-stop for children "because if any kids are killed we may have to pay damages".

4. Intra Group Relations:

As leadership in this test does not require any physical exertion - physical dominance by reason of strength seldom occurred. Intelligence, an ability to evoke cooperation, tact, a thorough understanding of the problem and being able to
deal effectively with criticism, were far more important than being physically active, strong and agile.

In the groups observed a tactical suggestion and an intelligent response in a "debating society atmosphere", was more frequent than the heavy handed leadership found on the Mines Leadership Tests. This, however, is probably due as much to the more sophisticated type of subjects, as to the test situation. This is borne out for as many of the candidates for supervisory posts in secondary industry are selected from the long service older staff members, physical handicaps due to age are eliminated.

On a number of occasions there were heated arguments, one group actually splitting up into two opposing factions, which were eventually drawn together by a compromise solution from the true leader.

It was noticed that groups composed of intelligent subjects considered the problem longer before taking any action, while the less intelligent groups tended to act and think and argue at the same time.

5. The Tests usefulness for Secondary Industrial Leadership selection:

The following points emerged on the basis of observations made on the various groups tested, involving some 50 odd subjects:

1. The subjects fully understood the test instructions and the test appeared to have enough face validity to motivate the groups to action.

2. No subject took exception in having to undergo the test and co-operation with the tester was excellent.
(1) Ability to express his ideas
(2) Quality of contributions made
(3) Attempted dominance over group
(4) Deference received from group
(5) Effective criticism of others
(6) Ability to support own contentions and deal with criticism of others
(7) Amount of participation
(8) Calmness and self-control (ease)
(9) Pleasantness of manner
(10) Ability to stick to the point.

COMMENTS:

0 = Very poor
1 = Poor
2 = Low average
3 = High average
4 = Very good
5 = Superior
3. In 5 of the 8 groups tested the subjects became so immersed in the problem that the tester after instructing them to "Stop now please" a couple of times, had to stop between the subjects and the test in order to end their discussion and argument.

4. In all groups tested a leader emerged although a number of leaders were rated as unsatisfactory:

<table>
<thead>
<tr>
<th>Group</th>
<th>+4</th>
<th>+3</th>
<th>+2</th>
<th>+1</th>
<th>0</th>
<th>-1</th>
<th>-2</th>
<th>-3</th>
<th>-4</th>
</tr>
</thead>
<tbody>
<tr>
<td>Supervisory Group</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Clerical Group</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>New Intake</td>
<td>2</td>
<td>3</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Mixed Group</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Ticket Inspectors</td>
<td>1</td>
<td>1</td>
<td>2</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Driving candidates</td>
<td></td>
<td>1</td>
<td>2</td>
<td>3</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Driving Instructors</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Drivers</td>
<td></td>
<td>1</td>
<td>2</td>
<td>3</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

5. The test situation tends to promote the tactful, calm, intelligent, organising type of leadership required by secondary industrial supervisors who deal with urbanised and educated Africans; and although dominance is an important aspect of the leadership situation, in the present set-up it requires a close integration with the above mentioned factors if the leadership is to prove successful.

6. This test layout tends to provide the "dominant but dim" leaders with enough "rope to hang themselves", and when exposed they soon break down under criticism from the rest of the group.

7. The test does not require these more sophisticated
Africans to do any undignified acrobatics, nor does it soil their clothes (very many of them being dressed in suits) and consequently, it in no way developed a wrong set among the suspects.
Example:

1. Find the number of times each \( y \) is greater than an \( x \).

\[ \text{e.g. } y = 2, 5, 7, 8 \]
\[ x = 1, 2, 5, 7, 9 \]

Start with the smallest \( x \); there are 4 \( y \)'s greater. Take the next lowest \( x \) - ignore the tie with the smallest \( y \); this leaves 3 \( y \)'s greater. There are 2 \( y \)'s greater than the next \( x \), 6. The second last \( x \) has a tie and only one \( y \) greater. There are no \( y \)'s greater than the last \( x \).

Therefore the number of \( y \)'s greater than an \( x \) is:

\[ u = 4 + 3 + 2 + 1 + 0 = 10 \]

2. Compute \( c_u^2 = \frac{m \cdot n (m+n+1)}{12} \); where \( m \) = number of \( x \)'s, here 5.
\( n \) = number of \( y \)'s, here 4.

in the case above \( c_u^2 = \frac{5 \cdot 4 \cdot 10}{12} = 16.67 \)

Compute \( E(u) = \frac{m \cdot n}{2} \); for this example \( E(u) = 10 \)

3. Find the value of \( r = \frac{u - E(u)}{\sqrt{c_u^2}} \)

in the case above \( r = \frac{10 - 10}{\sqrt{16.67}} = 0 \)

4. Look up \( r \) in a table of the Cumulative Normal Distribution,
   (see Table II, page 92; Hald's "Statistical Tables and Formulæ") and write down the corresponding probability.

5. Multiply the \( P \) obtained by 100, and then subtract from 100. For example, if a \( P = .9929 \), the answer will be:

\[ 100 - 99.29 = .71\% \]
2. Obtain regression coefficients by following equations:
   (in this particular instance the "compact method" was used)
   \[ a\bar{x}_1 + b\bar{x}_2 + c\bar{x}_3 + \ldots + m\bar{x}_m = \frac{N_1N_2}{N_1+N_2} \left( x_{1M} - x_{1NM} \right) \]
   \[ a\bar{x}_1 + b\bar{x}_2 + c\bar{x}_3 + \ldots + m\bar{x}_m = \frac{N_1N_2}{N_1+N_2} \left( x_{2M} - x_{2NM} \right) \]
   \[ a\bar{x}_1 + b\bar{x}_2 + c\bar{x}_3 + \ldots + m\bar{x}_m = \frac{N_1N_2}{N_1+N_2} \left( x_{3M} - x_{3NM} \right) \]
   and so on
   \[ a\bar{x}_1 + b\bar{x}_2 + c\bar{x}_3 + \ldots + m(N_1+N_2) = 0 \]

5. Find sums of squares accounted for by fitting the coefficient from:
   \[ D = a\frac{N_1N_2}{N_1+N_2} (x_{1M} - x_{1NM}) + b\frac{N_1N_2}{N_1+N_2} (x_{2M} - x_{2NM}) + c\frac{N_1N_2}{N_1+N_2} (x_{3M} - x_{3NM}) + \ldots \]

6. Compute the Multiple R.
   \[ R = \frac{D}{\sqrt{\frac{N_1N_2}{N_1+N_2}}} \]

7. Complete the following table:

<table>
<thead>
<tr>
<th>Sums of Squares</th>
<th>( \nu )</th>
<th>Mean Squ.</th>
<th>Sum of Squ.</th>
<th>Ratio</th>
</tr>
</thead>
<tbody>
<tr>
<td>( D )</td>
<td>Number of tests</td>
<td>( \frac{D}{\nu} = A )</td>
<td>Sum of 3 ( \bar{x}_m ) = B</td>
<td>( \frac{A}{B} )</td>
</tr>
<tr>
<td>( \frac{N_1N_2}{N_1+N_2} ) - ( D )</td>
<td>( N_1 - N_2 - 1 - (\nu \of tests) )</td>
<td>( \frac{N_1N_2}{N_1+N_2} )</td>
<td>( \frac{N_1N_2}{N_1+N_2} - 1 )</td>
<td></td>
</tr>
</tbody>
</table>

8. Compute the battery scores for each individual and compile the frequency distributions of these scores for the Mech. and Non-mech. Groups.
ANALYSIS OF COVARIANCE:

The formulae employed for controlling the influence of
education alone, or age alone.

1. The following quantities are required:
   \( E_x^2, E_y^2, E_{xy}, E_x, E_y, \)
   for each group separately, and for both groups combined.
   \( x \) is the education score, or the age score; \( y \) is the
   test score.

2. Compute the following:
   i) \( E_{xy} = \frac{E_{x_1} E_{y_1}}{N_1} = A_1, A_2 \)
       \( E_{x_1}^2 = N_1 \bar{E_x}^2 = B_1, B_2 \)
       \( E_{y_1}^2 = N_1 \bar{E_y}^2 = C_1, C_2 \)
   ii) \( E_{xy} = N \left( \frac{\bar{E_x} \bar{E_y}}{N} \right) = A \)
       \( E_{x_1}^2 = N \left( \frac{\bar{E_x}^2}{N} \right) = B \) for both groups
       combined.
       \( E_{y_1}^2 = N \left( \frac{\bar{E_y}^2}{N} \right) = C \)

3. Complete the following table:

<table>
<thead>
<tr>
<th></th>
<th>X SUM OF SQUARES</th>
<th>Y SUM OF SQUARES</th>
<th>XY SUM OF SQUARES</th>
<th>REGRESSION COEFFICIENTS</th>
<th>RESIDUAL SUMS OF SQUARES</th>
</tr>
</thead>
<tbody>
<tr>
<td>Between groups</td>
<td>( b ) (by subtraction)</td>
<td>( p ) (by subtraction)</td>
<td>( a ) (by subtraction)</td>
<td>( b - \bar{a} )</td>
<td>( b ) (by subtraction)</td>
</tr>
<tr>
<td>Within groups</td>
<td>( B_1 + B_2 )</td>
<td>( C_1 + C_2 )</td>
<td>( A_1 + A_2 )</td>
<td>( b_a = \frac{A_1 + A_2}{B_1 + B_2} )</td>
<td>( C_1 + C_2 - B_1 + B_2 )</td>
</tr>
<tr>
<td>Total:</td>
<td>( B )</td>
<td>( C )</td>
<td>( A )</td>
<td>( b_a = \frac{A}{B} )</td>
<td>( C - \frac{A}{B} )</td>
</tr>
</tbody>
</table>

\( p \) = Number of groups (2 in this case)
\( N \) = Total number of individuals.

\( b_1 \) = the regression of \( y \) and \( x \) when both groups are combined,
\( b_a \) = the pooled regression of \( y \) on \( x \) within groups, (i.e.
   eliminating differences due to real differences between
   group means).

\( b_m \) = the regression of \( y \) on \( x \) of the group means

\[ \left( \frac{C_1 + C_2 - \left( A_1 + A_2 \right)^2}{B_1 + B_2} \right) \frac{1}{N-P-1} \]

is the best estimate of the variance
of the random fluctuations of test
scores about the mean score for each
educational class.
Apply the following tests:

i. To test for the existence of a regression of \( y \) on \( x \):
   Apply the F test to the ratio of
   \[
   \frac{(\hat{a}_1^2 + \hat{a}_2^2)}{\frac{1}{B_1 + B_2}}
   \]
   and
   \[
   C_1 + C_2 = \frac{(\hat{a}_1 + \hat{a}_2)^2}{B_1 + B_2} \frac{1}{N-P-1}
   \]
   with 1 and \( N-P-1 \) degrees of freedom respectively.
   This tests whether the sum of squares accounted for by fitting \( b_a \) (i.e., with differences due to real differences between group means eliminated) is significantly different from the sum of squares due to deviations from the regression line.

ii. To test whether there are significant differences between group means of \( y \) after they have been corrected for the regression of \( y \) on \( x \):
   Apply the F test to the ratio of
   \[
   \frac{\hat{a}}{F-1}
   \]
   and
   \[
   C_1 + C_2 = \frac{(\hat{a}_1 + \hat{a}_2)^2}{B_1 + B_2} \frac{1}{N-P-1}
   \]
   with \( F-1 \) and \( N-P-1 \) degrees of freedom respectively.
   This tests whether the variance of the deviations of the group means from the regression line \( b_m \) and the difference between \( b_a \) and \( b_m \) are significantly different from the variance of random fluctuations.
ANALYSIS OF COVARIANCE.

Computation for removing the effects of both Age and Education.

The "within groups" and "overall" regression coefficients are computed and from them the sum of squares accounted for by each set is found. The residual sum of squares, "within groups" and "overall" are found by deduction, and the difference between these residuals is tested against the "within groups" residual by the usual F test.

The following quantities are required:

FOR EACH TEST SEPARATELY

\[ \Sigma E_t, \Sigma A_t, \Sigma EAt, \Sigma ET \] for both groups combined.

\[ \Sigma E_t^2, \Sigma A_t^2, N_t, \Sigma ET_t, \Sigma EAT_t, \Sigma ET_t^2 \]

and

\[ \Sigma E_M, \Sigma E^{NM}, \Sigma A_M, \Sigma E^{NM}M, N_M, N^{NM} \]

\[ \Sigma E_M, \Sigma E^{NM} \]

where

- \( \Sigma E \) = sum of Education squares
- \( \Sigma E^2 \) = sum of squared Education scores
- \( E^A \) = sum of Age scores.
- \( E^A_E \) = sum of Age \times Education cross-products
- \( N \) = number of individuals
- \( ET \) = sum of test scores


1. Compute:

\[ x_1 = \frac{\Sigma E_t^2 - (\Sigma E_t)^2}{N_t} - \frac{(\Sigma E^{NM})^2}{N^{NM}} \]

\[ y_1 = \frac{\Sigma A_t^2 - (\Sigma A_t)^2}{N_t} - \frac{(\Sigma E^{NM})^2}{N^{NM}} \]

\[ xy_1 = \frac{\Sigma EAt - (\Sigma E_t)(\Sigma A_t)}{N_t} - \frac{(\Sigma E^{NM})(\Sigma A^{NM})}{N^{NM}} \]

and

\[ x_T = \frac{\Sigma E_t^2}{N_t} - \frac{(\Sigma E_t)^2}{N_T} \]

\[ y_T = \frac{\Sigma A_t^2}{N_t} - \frac{(\Sigma A_t)^2}{N_T} \]

\[ xy_T = \frac{\Sigma EAt}{N_t} - \frac{(\Sigma E_t)(\Sigma A_t)}{N_T} \]
2. Invert the following matrices:

\[
\begin{bmatrix}
x_1 & xy_1 \\
x_1y_1 & y_1
\end{bmatrix}
\quad \text{and} \quad
\begin{bmatrix}
x_1 & xy_1 \\
x_1y_1 & y_1
\end{bmatrix}
\]

The inverses are:

(a) "within groups"

\[
\begin{bmatrix}
\frac{y_1}{\Delta_1} & -\frac{xy_1}{\Delta_1} \\
-\frac{xy_1}{\Delta_1} & \frac{y_1}{\Delta_1}
\end{bmatrix}
\quad \text{where} \quad \Delta_1 = x_1y_1 - (xy_1)^2
\]

(b) "overall"

\[
\begin{bmatrix}
\frac{y_T}{\Delta_T} & -\frac{xy_T}{\Delta_T} \\
-\frac{xy_T}{\Delta_T} & \frac{y_T}{\Delta_T}
\end{bmatrix}
\quad \text{where} \quad \Delta_T = x_Ty_T - (xy_T)^2
\]

3. The regression coefficients are given by the following:

(a) "within groups"

Education:

\[
\beta_1 = \frac{\Delta_1}{\lambda_1} \left\{ \frac{\sum_{u} (E_M) (E_T) (E_{NM})}{N_M} - \frac{(E_M) (E_T) (E_{NM})}{N_{NM}} \right\} - \frac{xy_1}{\Delta_1} \left\{ \frac{E_{AT}}{N_M} - \frac{(E_A) (E_T) (E_{NM})}{N_{NM}} \right\}
\]

\[
\beta_1 = \frac{y_1}{\Delta_1} \alpha_1 + \frac{-xy_1}{\Delta_1} \beta_1
\]

(b) "overall"

\[
\beta_1 = \frac{-xy_1}{\Delta_1} \alpha_1 + \frac{x_T}{\Delta_1} \beta_1
\]
(b) "Overall"

Regression:

\[
\bar{Y}_T - \bar{Y}_T \left( \frac{\bar{Y}_T}{N_T} \right) = \bar{Y}_T - \bar{Y}_T = \frac{\sum_{i=1}^{N_T} \left( \bar{Y}_T - \frac{\sum_{i=1}^{N_T} \bar{Y}_T}{N_T} \right)^2}{N_T - 1} - \frac{\sum_{i=1}^{N_T} \left( \bar{Y}_T - \frac{\sum_{i=1}^{N_T} \bar{Y}_T}{N_T} \right)^2}{N_T - 1}
\]

\[
\frac{\sum_{i=1}^{N_T} \left( \bar{Y}_T - \frac{\sum_{i=1}^{N_T} \bar{Y}_T}{N_T} \right)^2}{N_T - 1} - \frac{\sum_{i=1}^{N_T} \left( \bar{Y}_T - \frac{\sum_{i=1}^{N_T} \bar{Y}_T}{N_T} \right)^2}{N_T - 1}
\]

\[
\frac{\sum_{i=1}^{N_T} \left( \bar{Y}_T - \frac{\sum_{i=1}^{N_T} \bar{Y}_T}{N_T} \right)^2}{N_T - 1} - \frac{\sum_{i=1}^{N_T} \left( \bar{Y}_T - \frac{\sum_{i=1}^{N_T} \bar{Y}_T}{N_T} \right)^2}{N_T - 1}
\]

\[
\frac{\sum_{i=1}^{N_T} \left( \bar{Y}_T - \frac{\sum_{i=1}^{N_T} \bar{Y}_T}{N_T} \right)^2}{N_T - 1} - \frac{\sum_{i=1}^{N_T} \left( \bar{Y}_T - \frac{\sum_{i=1}^{N_T} \bar{Y}_T}{N_T} \right)^2}{N_T - 1}
\]

\[
\frac{\sum_{i=1}^{N_T} \left( \bar{Y}_T - \frac{\sum_{i=1}^{N_T} \bar{Y}_T}{N_T} \right)^2}{N_T - 1} - \frac{\sum_{i=1}^{N_T} \left( \bar{Y}_T - \frac{\sum_{i=1}^{N_T} \bar{Y}_T}{N_T} \right)^2}{N_T - 1}
\]

\[
\frac{\sum_{i=1}^{N_T} \left( \bar{Y}_T - \frac{\sum_{i=1}^{N_T} \bar{Y}_T}{N_T} \right)^2}{N_T - 1} - \frac{\sum_{i=1}^{N_T} \left( \bar{Y}_T - \frac{\sum_{i=1}^{N_T} \bar{Y}_T}{N_T} \right)^2}{N_T - 1}
\]

4. The sum of squares accounted for by the regression equations are:

(a) "within groups"

\[
S_1 = \bar{X}_1 a_1 + \bar{Y}_1 \beta_1
\]

(b) "overall"

\[
S_\tau = \bar{X}_\tau a_\tau + \bar{Y}_\tau \beta_\tau
\]

5. The "residual sum of squares" are computed from:

(a) "within groups"

\[
\left[ \sum_{i=1}^{N_T} \left( \bar{Y}_T - \frac{\sum_{i=1}^{N_T} \bar{Y}_T}{N_T} \right)^2 \right] - \left[ \sum_{i=1}^{N_T} \left( \bar{Y}_T - \frac{\sum_{i=1}^{N_T} \bar{Y}_T}{N_T} \right)^2 \right] = S_1 = R_1
\]

(b) "overall"

\[
\left[ \sum_{i=1}^{N_T} \left( \bar{Y}_T - \frac{\sum_{i=1}^{N_T} \bar{Y}_T}{N_T} \right)^2 \right] - S_T = R_T
\]

6. The "between groups residual" is computed from:

\[
R_B = R_T - R_1
\]

7. And the test whether the two groups still differ significantly after removing the effects of differences in age and education distributions is:

\[
\frac{R_B}{1} \times \frac{N - 4}{\sigma^2} \quad \text{which is compared with the figure given in the F table with 1 and N-4 degrees of freedom.}
\]
ANALYSIS OF COVARIANCE.

1. To test the usefulness of including a coefficient for age after first taking account of education, take the difference between the "within groups residual" in the table with education alone - given in the Covariance Analysis on Education -, and $R_r$ - given in the last Covariance calculations.

Let this difference be $D_1$

Then test the ratio

$$
\frac{D_1}{T} \times \frac{N - 4}{R_r}
$$

with the F tables with 1 and $N-4$ degrees of freedom.
ANALYSIS OF COVARIANCE.

To test the usefulness of including a coefficient for "job experience" after first accounting for the influence of age and education.

1. Carry out a pivotal condensation to obtain the test regression weights.

2. Multiply each set of weights by the corresponding criterion correlation. Call the results $R^2_S, R^2_T, R^2_K$ (subscripts S, T and K stand for Screws Test, Tripod Test and Kohs Blocks Test respectively).

3. Compute the "residual mean square" from:

$$\frac{1 - R^2_S}{N-4}$$

4. To obtain the regression weights for Age and Education alone, compute:

$$\Delta = 1 - R^2_{EA}$$

and the matrix

$$\left[ \begin{array}{cc}
\frac{1}{\Delta} & -R^2_{EA} \\
-R^2_{EA} & 1
\end{array} \right] = \left[ \begin{array}{cc}
C_{11} & C_{12} \\
C_{12} & C_{22}
\end{array} \right]$$

5. Carry out the matrix multiplications:

$$\left[ \begin{array}{cc}
C_{11} & C_{12} \\
C_{12} & C_{22}
\end{array} \right] \times \left[ \begin{array}{ccc}
R_{ES} & R_{ET} & R_{EK} \\
R_{ET} & R_{ET} & R_{ET} \\
R_{EK} & R_{ET} & R_{ET}
\end{array} \right] = \left[ \begin{array}{ccc}
\beta_{ES} & \beta_{ET} & \beta_{EK} \\
\beta_{AS} & \beta_{AT} & \beta_{AK}
\end{array} \right]$$

Each column represents the $\beta$ weights for one of the tests on Education and Age alone.

6. Compute the sum of squares accounted for by fitting Education and Age.

$$R^2_S = \beta_{ES}^2 \cdot R_{ES}^2 + \beta_{AS}^2 \cdot R_{AS}^2$$

$$R^2_T = \beta_{ET}^2 \cdot R_{ET}^2 + \beta_{AT}^2 \cdot R_{AT}^2$$

$$R^2_K = \beta_{EK}^2 \cdot R_{EK}^2 + \beta_{AK}^2 \cdot R_{AK}^2$$

7. To test whether the inclusion of job experience as an additional variable makes a significant reduction in the residual sum of squares, i.e. a significant reduction in the scatter of the observed values about the predicted values, compute:

$$\frac{R^4_S - R^2_S}{N - 4} \times \frac{1 - R^2_S}{N - 4} = F_{RS}$$

and look up in the $F$ tables with 1 and $N-4$ degrees of freedom.
ANALYSIS OF COVARIANCE.

Computation for controlling the effects of both Age and Education in the Job Experience groups.

The "within groups" and "overall" regression coefficients are computed and from them the sum of squares accounted for by each set is found. The residual sum of squares, "within groups" and "overall" are found by deduction, and the difference between these residuals is tested against the "within groups" residual by the usual F test.

1. The following quantities are required:

FOR EACH TEST SEPARATELY

for both groups combined.

and

and

where

Subscripts I, II and III, and T stand for Job Experience

Group I, Job Experience Group II and Job Experience Group III, and Job Experience Group I + Group II + Group III respectively.

Group I: Subjects with long present job experience and long industrial experience, i.e.: a stay of 10 years or more in the Urban Areas and 4 years or more in the present job.

Group II: Subjects with short present job experience and long industrial experience, i.e.: a stay of less than 1 year in the present job but more than 10 years in the Urban Areas.

Group III: Subjects with short present job experience and short industrial experience, i.e.: a stay of less than 1 year in the present job and less than 4 years in the Urban Areas.
2. Compute:

\[
x_1 = \sum E^2 - \frac{(\sum E_1)^2}{N_1} - \frac{(\sum E_{II})^2}{N_{II}} - \frac{(\sum E_{III})^2}{N_{III}}
\]

\[
y_1 = \sum A^2 - \frac{(\sum A_1)^2}{N_1} - \frac{(\sum A_{II})^2}{N_{II}} - \frac{(\sum A_{III})^2}{N_{III}}
\]

\[
xy_1 = \sum E^2 \cdot \sum A^2 - \frac{(\sum E_1)(\sum A_1)}{N_1} - \frac{(\sum E_{II})(\sum A_{II})}{N_{II}} - \frac{(\sum E_{III})(\sum A_{III})}{N_{III}}
\]

and

\[
x_T = \sum E^2 - \frac{(\sum E_T)^2}{N_T}
\]

\[
y_T = \sum A^2 - \frac{(\sum A_T)^2}{N_T}
\]

\[
xy_T = \sum E^2 \cdot \sum A^2 - \frac{(\sum E_T)(\sum A_T)}{N_T}
\]

3. Invert the following matrices:

\[
\begin{bmatrix}
    x_1 & xy_1 \\
    xy_1 & y_1
\end{bmatrix}
\quad \text{and} \quad
\begin{bmatrix}
    x_T & xy_T \\
    xy_T & y_T
\end{bmatrix}
\]

The inverses are:

(a) "within group"

\[
\begin{bmatrix}
    \frac{y_1}{\delta_1} & \frac{-xy_1}{\delta_1} \\
    \frac{-xy_1}{\delta_1} & \frac{x_1}{\delta_1}
\end{bmatrix}
\quad \text{where} \quad
\delta_1 = x_1y_1 - (xy_1)^2
\]

and

(b) "overall"

\[
\begin{bmatrix}
    \frac{y_T}{\delta_T} & \frac{-xy_T}{\delta_T} \\
    \frac{-xy_T}{\delta_T} & \frac{x_T}{\delta_T}
\end{bmatrix}
\quad \text{where} \quad
\delta_T = x_Ty_T - (xy_T)^2
\]

4/........
4. The regression coefficients are given by the following:

(a) "within groups"

Education:

\[
E_i = \frac{y_i}{\lambda_i} \left[ \frac{EB_i T_i}{N_i} - \frac{(E E_i)(E T_i)}{N_i^2} - \frac{(E E_i)(E T_i)}{N_i^2} - \frac{(E E_i)(E T_i)}{N_i^2} \right]
\]

\[
+ \frac{-xy_i}{\lambda_i} \left[ \frac{EA_i T_i}{N_i} - \frac{(E A_i)(E T_i)}{N_i^2} - \frac{(E A_i)(E T_i)}{N_i^2} - \frac{(E A_i)(E T_i)}{N_i^2} \right]
\]

\[
= \frac{y_i}{\lambda_i} \alpha + \frac{-xy_i}{\lambda_i} \beta
\]

Age:

\[
A_i = \frac{-xy_i}{\lambda_i} \left[ \frac{EB_i T_i}{N_i} - \frac{(E E_i)(E T_i)}{N_i^2} - \frac{(E E_i)(E T_i)}{N_i^2} - \frac{(E E_i)(E T_i)}{N_i^2} \right]
\]

\[
+ \frac{x_i}{\lambda_i} \left[ \frac{EA_i T_i}{N_i} - \frac{(E A_i)(E T_i)}{N_i^2} - \frac{(E A_i)(E T_i)}{N_i^2} - \frac{(E A_i)(E T_i)}{N_i^2} \right]
\]

\[
= \frac{-xy_i}{\lambda_i} \alpha + \frac{x_i}{\lambda_i} \beta
\]

(b) "overall"

Education:

\[
E_T = \frac{y_T}{\lambda_T} \left[ \frac{EB_T}{N_T} - \frac{(E E_T)(E T_T)}{N_T^2} \right] + \frac{-xy_T}{\lambda_T} \left[ \frac{EA_T}{N_T} - \frac{(E A_T)(E T_T)}{N_T^2} \right]
\]

\[
= \frac{y_T}{\lambda_T} \alpha_T + \frac{-xy_T}{\lambda_T} \beta_T
\]

Age:

\[
A_T = \frac{-xy_T}{\lambda_T} \left[ \frac{EB_T}{N_T} - \frac{(E E_T)(E T_T)}{N_T^2} \right] + \frac{x_T}{\lambda_T} \left[ \frac{EA_T}{N_T} - \frac{(E A_T)(E T_T)}{N_T^2} \right]
\]

\[
= \frac{-xy_T}{\lambda_T} \alpha + \frac{x_T}{\lambda_T} \beta
\]
5. the sums of squares accounted for by the regression equation are:

(a) "within groups",
\[ S_i = \sum a_i + \bar{a}_i \beta_i \]

(b) "overall"
\[ S_T = \sum a_T + \bar{a}_T \beta_T \]

6. The "residual" sum of squares is computed from:

(a) "within groups"
\[ \left\{ \frac{\sum T^2}{N} - \frac{\sum T_{III}^2}{N_{III}} - \frac{(\sum T_{II})^2}{N_{II}} - \frac{(\sum T_{I})^2}{N_I} \right\} - S_i = R_i \]

(b) "overall"
\[ \left\{ \frac{\sum T^2}{N_T} - \frac{(\sum T_{II})^2}{N_{II}} \right\} - S_T = R_T \]

7. The "between groups" residual is computed from:
\[ R_B = R_T - R_i \]

8. To test whether the two groups still differ significantly after removing the effects of differences in age and education distributions is:
\[ \frac{R_B}{N - 5} \]
which is compared with the figure given in the F table with 1 and N-4 degrees of freedom.
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A. General:

1. COLUMBIA INDUSTRIAL REPORTS (1951): Series No. 1, "Frontiers of Personnel Administration."

B. Job Analysis Theory:


C. African Studies:


20. MALAN, DR. D.F. (Sept. 24, 1951): "South Africa's Rapid Industrial Development," the text of a speech delivered by the Prime Minister at the opening of the annual congress of the South African Federated Chamber of Industries. Published by the Director, State Information, Pretoria.


D. Testing Theory:


E. Statistical Theory:


F. Leadership Theory:

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SUMMARY OF RESEARCH

1. In 1946 at the request of the Transvaal Chamber of Mines and Associated Mining Companies, the National Institute for Personnel Research devised a battery of nine tests to classify African Mine labour into broad occupational groups.

2. The General Adaptability Test Battery constructed for this purpose proved a most satisfactory classificatory device for mine labour.

3. The present study considers the use of this battery for African selection in a new field - namely, for secondary industrial selection.

4. Great differences in age and education exist within the African secondary industrial population so the influence of these factors on test performance was also studied.

5. The tests were applied to two samples:
   a) an industrial sample of 1000 subjects
   b) a school sample of 2000 subjects.

6. The industrial sample was classified on the basis of a job analysis criterion into:
   a) Mechanical workers
   b) Non-Mechanical workers.

7. Results show that as a group Mechanical workers do significantly better on the tests than Non-Mechanical workers.

8. A considerable overlap on all test scores exists between the two groups however.

9. The test battery has a 61% discriminative ability between these two groups in secondary industry.

10. Education exerts a significant influence on test scores.

11. In seven of the tests education is not the main differentiating factor between the test scores of the two groups of workers.
12. The battery functions to some extent as a test of educational achievement.

15. Age exerts a significant influence on test scores.

16. On none of the tests is age the main differentiating factor between the two groups of workers.

17. The better educated worker does better on the tests, the older worker does worse on the tests.

18. Length of job experience exerts a significant influence on test scores.

19. As a group boys do better on the tests than girls.

20. Seven of the nine tests differentiate significantly between the sexes.
PHOTOGRAPHIC SEQUENCE OF THE MAIN JOBS AND JOB FAMILIES:

1. STOCKAGE
2. STORE ROOMS MATERIALS UNIT
3. UNLOADING
4. WELDING A JIG
5. WELDING FLOOR
6. WELDING BODY
7. FILE WIPING - BODY LINE
8. DISCING
9. ROUTING & Wiring
10. STORE ROOM - WIRING
11. UNBOXING
12. JIG MAKING EXP BAY
13. WELDING JIG
14. SPOT WELDING - JIG BAY
15. DOOR FITTING - DR FITTING
16. SEAT PULLING
17. HEADLIN IJG - TRIM LINE
18. ARMRESTS
19. DOCKS
20. SPEEDO CABLE ELECTRIC LINE
21. PANEL WIRING
22. MANUFACTURING BODY - PROD LINE
23. ENGINE FITTING - ENGINE LINE
24. LEAD WIPING
25. DOOR FITTING - FITTING DRI
26. CANOPY MOUNTING & Wiring
27. ENGINE FITTING - ENGINE LINE
28. LEAD WIPING - DR FITTING
29. DOOR FITTING - DR FITTING
30. SHEET TO CHASSIS-CHS LINE
31. UPHOLSTERY - UPHOL 5EPT
32. SEAT PULLING
33. CHASSIS HEADY
34. FINAL FINISH
35. NATIONAL MOTOR ASSEMBLY 44-45 W.
Author  De Ridder J C
Name of thesis An investigation into educational and occupational differences in test performance on a battery of adaptability tests designed for Africans  1956

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