Scand. J. Psychol., 1974, *15*, 124–126

A method for analysing performance in the rod-and-frame test. II

Test of the Statistical Model

HELMUTH NYBORG
BO ISAKSEN

University of Aarhus, Denmark

Abstract.—A new method of scoring the Rod-and-Frame Test (RFT) has been proposed (Nyborg, 1974). The statistical model behind the new method is introduced and tested in the present work.

It has been stated that the Rod-and-Frame Test (RFT) contains perceptual factors not revealed by methods of scoring that are based on the unsigned or absolute errors of the subject (Lester, 1968).

Furthermore, it has been concluded that the response consistency of some of the subjects is low and not represented in the unsigned error score (Gruen, 1957).

Therefore, we developed a method of scoring the RFT (Nyborg, 1974) which gives separate measures of the subject's constant error, the effect of the tilted frame, and the rod starting position effect. What is more, the response consistency of the subject is taken into account in the calculations.

This paper presents and tests the statistical model behind our method.

THE MODEL

The model is based on the 2-way analysis of variance and on the assumption that the RFT scores are normally or near normally distributed.

In an experiment with the RFT the subject is required to adjust the initially tilted rod to physical vertical within the stationary tilted frame n times under each of the four tilt combinations of the frame and the rod.

Let

X_{ijk}

stand for the subject's score (i.e. the signed deviation of the rod in degrees from physical vertical in the subject's final adjustment; clockwise deviation=+value, counter clockwise deviation=−value) in the kth trial in the series where the frame position is i (i=right or left tilt) and the rod starting position is j (j=right or left initial tilt).

For given values of i and j X_{ij1}, X_{ij2}, ..., X_{ijn} are n-double determinations and the four times n measurements are supposed to be normally distributed with a mean value, η_{ij}, dependent of i and j, and a standard deviation σ.

The model for analysing the RFT can now be written

$$\eta_{ij}=\mu+\varphi_i+\varrho_j$$

and says that the mean score in the RFT is a sum of three components and that

1. the first component, μ, is neither dependent on the tilt of the frame nor on the rod starting position, but only stands for the subject's constant error (i.e. his subjective vertical);
2. the second component, φ_i, is dependent only on the position of the frame (i.e. represents the subject's dependence on the tilt of the frame);
3. the third component, ϱ_j, is dependent only on the starting position of the rod (i.e. shows how influenced the subject is by the fact that the rod starts from a tilted position).

As by definition of the model $\div\varphi_{\text{left}}=\varphi_{\text{right}}$, and $\div\varrho_{\text{left}}=\varrho_{\text{right}}$, it is sufficient to calculate φ_{right} and ϱ_{right} only.

According to the model the subject's score can be expressed as

$$X_{ijk}=\mu+\varphi_i+\varrho_j+U_{ijk}$$

where U_{ijk} is normally distributed around 0 with a standard deviation σ.

With point of origin in the subject's observed errors in degrees in adjustments of the rod to physical vertical the values of μ, φ_i, and ϱ_j that fit the model best are now calculated in the following way:

$\mu=\overline{X\ldots}$

$\varphi_i=\overline{Xi\ldots}-\overline{X\ldots}$

$\varrho_j=\overline{X._j.}-\overline{X\ldots}$

where

$\overline{X\ldots}=\frac{1}{4n}\sum_i\sum_j\sum_k X_{ijk}=$ the total mean score

$\overline{X_i\ldots}=\frac{1}{2n}\sum_j\sum_k X_{ijk}=$ the mean of the scores obtained in trials where the frame has been in position i.

$\overline{X._j.}=\frac{1}{2n}\sum_i\sum_k X_{ijk}=$ the mean of the scores obtained in trials where the rod has been in position j.

The subject's response consistency

The response consistency of the subject can be estimated in the following way:

$$\sigma_1=\sqrt{\frac{\sum_i\sum_j\sum_k(X_{ijk}-\overline{X_{ij}.})^2}{4\,(\mathrm{n}-1)}}$$

where

$$\overline{X_{ij}.}=\frac{1}{n}\sum_k X_{ijk}$$

σ_1 estimates the subject's response consistency on the basis of observed variation in the subject's capacity to adjust the rod to physical vertical in a number of identical—and therefore comparable—tilt conditions of the rod and the frame. σ_1 requires at least two observations in each condition, that is $n\geqslant 2$. This estimate has the advantage that the measure of response consistency is obtained independently of the model.

Another estimate of the subject's response consistency can be written

$$\sigma_2=\sqrt{\sum_i\sum_j(\overline{X_{ij}.}-(\overline{X_i\ldots}+\overline{X._j.}-\overline{X\ldots}))^2}$$

and measures the difference between the mean errors obtained under identical tilt conditions, $\overline{X_{ij}.}$, and the value $(\overline{X_i\ldots}+\overline{X._j.}-\overline{X\ldots})$, which the subject is expected to score in accordance with the model.

We are now able to calculate the values of the subject's μ, φ, and ϱ, and we can estimate his response consistency, σ_1. A high degree of response inconsistency may, however, by chance lead to high values of μ, φ, and ϱ, respectively. It can be shown by the theory of analysis of variance that the following formulas give values that are dispersed according to a Student's distribution.

$$t\mu=\frac{\mu}{\sigma_1}2\sqrt{2};\quad t\varphi=\frac{\varphi}{\sigma_1}2\sqrt{2};\quad t\varrho=\frac{\varrho}{\sigma_1}2\sqrt{2}.$$

Estimating their values by the Student's distribution with 4 (n-1) degrees of freedom it can be determined whether the values are due to random fluctuation or are significantly different from zero.

Test of the model

The fact that σ_1 estimates the consistency of scoring independently of the model of scoring proposed here but that σ_2 presupposes it can be used to test the model. Thus, if σ_2 is large compared with σ_1 there are reasons to believe that the model does not describe the observations adequately; if σ_2 and σ_1 are of the same or nearly the same size it speaks in favour of the model and suggests that the subject's mean signed error score, $\eta_{ij}.$, can be legitimately written as a sum of the proposed single effects.

It follows that the model may be tested by calculating

$$(1)\;F=\frac{\sigma_2^2}{\sigma_1^2}=\frac{\sum_{ij}(\overline{X_{ij}.}-\overline{X_i\ldots}''\overline{X._j.}+\overline{X\ldots})^2}{\sum_{ijk}(X_{ijk}-X_{ij}.)^2/4\,(n-1)}$$

and evaluating F according to an F-distribution with 1 and 4 $(n-1)$ degrees of freedom.

EXPERIMENTS AND RESULTS

In order to test the model the following experiment was carried out. In two series, each containing 37 introductory-course students in psychology, the signed errors in the RFT were observed and F was calculated according to formula (1) for each of the 2×37 sets of observations.

The F-values for the two series were compared with the expected F-values deduced from the model in the following way. Five intervals were

Table 1. *Comparison between F-values expected from the proposed model of scoring the RFT and F-values based on observations in two test series*

	Interval no.					
F-values	1	2	3	4	5	Total
Expected						
Percent	20	20	20	20	20	100
Number	7.4	7.4	7.4	7.4	7.4	37
Observed number						
Series 1	9	8	3	9	8	37
Series 2	8	6	10	5	8	37

constructed in such a way that each interval was expected to contain 20 percent of the *F*-values in progressively increasing order of magnitude (too many large *F*-values suggest that the model does not fit). The *F*-values calculated on the basis of the observations in the two series were then compared with the expected *F*-values (see Table 1).

Table 1 shows that the *F*-values calculated from actual observations in the two series are fairly consistent. To investigate how close the observed values in the two series are to the expected values, a χ^2-test was applied. In the two series it was found that $\chi^2=3.41$ ($p=0.49$), and $\chi^2=2.05$ ($p=0.73$), respectively, which support the proposed model.

CONCLUSION

This paper has presented the statistical model behind the method of analysing performance in the RFT which was put forward by Nyborg (1974). The model is based on the assumption that responses in the RFT may be partitioned into three additive components, μ, φ, and ϱ, all shown separately to be important in varying degree for different subjects (Gibson & Radner, 1937; Witkin & Asch, 1948; Werner & Wapner, 1952). An experiment with the RFT supported this assumption.

In addition, the method makes it possible to estimate the response consistency of the subject in a way that allows discrimination between "genuinely" frame-dependent subjects (i.e. subjects responding consistently and systematically to the tilt of the frame) and subjects who are not responding systematically to the tilt of the frame, but who nevertheless get high mean unsigned error scores.

REFERENCES

Gibson, J. J. & Radner, M. (1937). Adaptation, after-effect, and contrast in the perception of tilted lines. I. Quantitative studies. *J. exp. Psychol. 20,* 453–467.

Gruen, A. (1957). A critique and re-evaluation of Witkin's Perception-Personality work. *J. Gen. Psychol. 56,* 73–93.

Lester, F. (1968). The Rod-and-Frame Test. *Percept. Mot. Skills 26,* 1307–1314.

Nyborg, H. (1974). A method for analysing performance in the Rod-and-Frame Test. I. *Scand. J. Psychol. 15,* 119–123.

Werner, H. & Wapner, S. (1952). Experiments on sensory-tonic field theory of perception: Effects of initial position of a rod on apparent verticality. *J. exp. Psychol. 43,* 68–74.

Witkin, H. A. & Asch, S. E. (1948). Studies in space orientation: IV: Further experiments on perception of the upright with displaced visual fields. *J. exp. Psychol. 38,* 762–782.

Postal address:

H. Nyborg
Institute of Psychology
University of Aarhus
Asylvej 4
DK-8240 Risskov
Denmark