

EFFECT OF GEOMETRICAL STRUCTURE ON PERCEPTION OF THE VERTICAL IN THE ROD-AND-FRAME TEST¹

HELMUTH NYBORG

*Max-Planck-Institute of Behavior Physiology
Seewiesen, W. Germany²*

Summary.—Male and female subjects were selected on the basis of their unsigned deviation scores (USD) in the rod-and-frame test to be retested and scored by a new method. The new method analyzes performance on this task in terms of the effect of the tilt of the frame (ϕ), the constant deviation (μ), the starting position of the rod (ρ), and the response consistency (σ) of each subject. The geometrical structure of the frame was varied by changing the number of identical stimulus elements in it. Variations in the geometrical structure of the frame affected ϕ -scores primarily in subjects with significantly high ϕ -scores (frame-dependent subjects). Variations in the frame's geometrical structure did not affect μ or ρ . The relationship between USD-scores and the values for ϕ , μ , and ρ for each subject is discussed.

The rod-and-frame test (Witkin & Asch, 1948) is one of the most used instruments in studies on individual differences in spatial perception and on possible relations between perception and personality. The task is used in pedagogical, clinical, and cross-cultural psychology. Despite its widespread use, there is still doubt about what is measured. Witkin, the originator of the test, claimed that it measures the influence of the tilted frame on the subject's perception of vertical. Gruen (1957) pointed out, however, that Witkin's method of scoring the test ". . . covers up initially wide variability in the performance and may be averaging different factors along one continuum." Gruen suggested "that actual performance in these tests is so variable as to make it difficult to accept without modification Witkin's theory of a special perceptual dimension called field-dependency—independency." In agreement with Gruen, Fine and Danforth (1975) stated that, ". . . Witkin appears to have assigned theoretical importance to direction of frame tilt while, at the same time, attributing high 'construct validity' to a scoring method which ignores it." Thus, some authors consider the test to be more complex than the traditional scoring methods can account for.

Our studies support the notion that both the test and the subject's behavior in the test are complex. We found that the tilt of the frame, the constant deviation, the starting position of the rod, and the consistency of a subject's performance affect the outcome of the rod and frame (Nyborg, 1971a, 1971b, 1972). We constructed a model to separate the effects of these variables on

¹This work was done during an Alexander von Humboldt senior-research fellowship, for which the author wants to express his gratitude.

²Address correspondence and requests for reprints to Helmuth Nyborg, Psychological Institute, Aarhus University, DK-8240 Risskov, Denmark.

EFFECT OF GEOMETRICAL STRUCTURE ON PERCEPTION
OF THE VERTICAL IN THE ROD-AND-FRAME TEST¹

HELMUTH NYBORG

*Max-Planck-Institute of Behavior Physiology
Seewiesen, W. Germany²*

Summary.—Male and female subjects were selected on the basis of their unsigned deviation scores (USD) in the rod-and-frame test to be retested and scored by a new method. The new method analyzes performance on this task in terms of the effect of the tilt of the frame (ϕ), the constant deviation (μ), the starting position of the rod (ρ), and the response consistency (σ) of each subject. The geometrical structure of the frame was varied by changing the number of identical stimulus elements in it. Variations in the geometrical structure of the frame affected ϕ -scores primarily in subjects with significantly high ϕ -scores (frame-dependent subjects). Variations in the frame's geometrical structure did not affect μ or ρ . The relationship between USD-scores and the values for ϕ , μ , and ρ for each subject is discussed.

The rod-and-frame test (Witkin & Asch, 1948) is one of the most used instruments in studies on individual differences in spatial perception and on possible relations between perception and personality. The task is used in pedagogical, clinical, and cross-cultural psychology. Despite its widespread use, there is still doubt about what is measured. Witkin, the originator of the test, claimed that it measures the influence of the tilted frame on the subject's perception of vertical. Gruen (1957) pointed out, however, that Witkin's method of scoring the test ". . . covers up initially wide variability in the performance and may be averaging different factors along one continuum." Gruen suggested "that actual performance in these tests is so variable as to make it difficult to accept without modification Witkin's theory of a special perceptual dimension called field-dependency—independency." In agreement with Gruen, Fine and Danforth (1975) stated that, ". . . Witkin appears to have assigned theoretical importance to direction of frame tilt while, at the same time, attributing high 'construct validity' to a scoring method which ignores it." Thus, some authors consider the test to be more complex than the traditional scoring methods can account for.

Our studies support the notion that both the test and the subject's behavior in the test are complex. We found that the tilt of the frame, the constant deviation, the starting position of the rod, and the consistency of a subject's performance affect the outcome of the rod and frame (Nyborg, 1971a, 1971b, 1972). We constructed a model to separate the effects of these variables on

¹This work was done during an Alexander von Humboldt senior-research fellowship, for which the author wants to express his gratitude.

²Address correspondence and requests for reprints to Helmuth Nyborg, Psychological Institute, Aarhus University, DK-8240 Risskov, Denmark.

rod-and-frame performance (Nyborg, 1974b) and tested our model (Nyborg & Isaksen, 1974).

The present study was carried out mainly to test our model further. Three of the assumptions of the model were tested. The first assumption is that the ϕ -parameter is a function of the tilted frame configuration. This assumption was tested by determining whether the geometrical structure of the tilted frame affected the value for ϕ . The geometrical structure of the frame was changed by varying its completeness from luminous points in the form of a square to a continuous luminous frame (Fig. 1). According to our model, the value for ϕ will change as a function of the geometrical structure of the frame configuration. Evidence against our model would be obtained if greater completeness of the frame did not affect the values for ϕ . The second assumption is that the geometrical structure of the frame would affect subjects with high ϕ -values (so-called frame-dependent subjects) more than subjects with low ϕ -values (so-called frame-independent subjects). This assumption was tested statistically by comparison of scores on the rod-and-frame test for frame-dependent and frame-independent subjects tested under varying conditions of geometrical structure of the frame.



FIG. 1. Configurations of the frames shown to subjects in the rod and frame. The geometrical relation of the configurations was changed by addition of identical stimulus elements to increase the "Gestalt-quality" of the tilted frame. The stimulus elements were vertical regardless of the side to which the frame configuration tilted.

Evidence against our model would be obtained were there no differences between frame-dependent and frame-independent subjects in the effect of the geometrical structure of the frame on their ϕ -values. The third assumption is that the parameters ϕ (frame-tilt effect), μ (subject's constant deviation effect), and ρ (rod-starting-position effect) are independent and additively related. This assumption was tested by determining whether changes in ϕ induced by changes in the geometrical structure of the frame were associated with changes in μ and/or ρ . Evidence against our model would be obtained if changes in the geometrical structure of the frame lead to changes in μ and/or ρ , in addition to changes in ϕ .

In addition, the present study was carried out to enable us to compare further our scoring method to the unsigned deviation method of scoring the rod and frame (Nyborg, 1974b, 1977). In particular, it was of interest to determine the relationship between the field-dependence score given by the unsigned

deviation method and the scores for ϕ , μ , and ρ given by our new method of scoring the rod and frame. Our previous work suggested that the two methods of scoring classified subjects differently. The subjects selected for the present study were well-suited for a comparison of the classification given by the two methods of scoring the test.

MATERIAL AND METHOD

Eleven males and nine females were selected from 150 freshman students of psychology on the basis of their unsigned deviation scores (USD) on the rod and frame. Ten of the students were field-dependent ($\text{USD} > 8^\circ$) and the other 10 were field-independent ($\text{USD} < 2^\circ$). The subjects were retested on the rod and frame and scored by the new method. The frame dependence (ϕ), constant deviation (μ), rod-starting-position effect (ρ), and response consistency (σ) parameters were calculated for each subject. Eight subjects obtained ϕ -values significantly different from zero (frame-dependent group) while the ϕ -values in the other subjects were not significantly different from zero (frame-independent group).

Immediately before the tests the subject was blind-folded and placed standing upright in a man-sized box, supported by inflated rubber cushions and a firm head rest to prevent body and head movements (Nyborg, 1971a). Then, the room was totally darkened and the blindfold removed. The subject faced at a distance of approximately 2.25 m. two acrylic plates, one before the other. A rod configuration on one plate and a frame-figure on the other appeared when lighted from behind by a projector (Nyborg, 1972). The configurations could rotate independently of each other about a common axis. The tilt of the frame-figure was controlled by the experimenter while the rod was directed by the subject by means of electronics.

During the experiment the geometrical structure of the frame-figure configuration was changed by adding more and more identical, uprightstanding stimulus-elements. The addition of new stimulus-elements was kept within the geometrical area of the traditional frame.

The subjects were informed that their task was to adjust the luminous rod to what appeared to them to be a vertical position. Several descriptive definitions of upright were offered, examples from everyday life were given, and it was assured that the subject had a clear understanding of what was meant by the term upright. The presentation of the frame-figure configurations was randomized; they were exposed "tilted" 28° to the right or left of the gravitational vertical. The rod starting position was 28° to the right or left of gravitational upright. Each subject was tested once with the three configurations and the full frame in each of the four possible tilt-combinations with the rod. On the first single trials the subject was repeatedly requested to adjust the rod, and if necessary to re-adjust it until he felt quite convinced that the rod was positioned upright. When the subject finally reported the rod to be upright, the illumination of the configuration was switched off, and the next trial began, after the prescribed changes in "frame" configuration and tilt. This procedure provided 16 scores for each subject. The position of the rod was measured in whole degrees by the experimenter who stayed in a light-tight room adjacent to the experimental room. The experiment took approximately 1 hr. for each subject.

Analyses of regression were performed in order to determine whether the ϕ -values, μ -values, and ρ -values for each single subject were linearly related to the degree of ambiguity (incompleteness) of the frame-figure configurations. The slope of the regression lines was then examined.

RESULTS AND DISCUSSION

A statistically significant linear relation ($p < 0.05$) was found between the degree of "completeness" of the frame-figure configuration and the ϕ -parameter values in 19 of the 20 subjects. The regression line for "completeness" of frame-figure configuration versus ϕ -parameter value was significantly positively sloped ($p < 0.05$) in seven subjects while the slopes for the other 13 subjects were not significant. The data presented in Table 1 show that six of the subjects with positively sloped regression lines were "frame-dependent" while eleven of the 13 subjects with unsloped regression lines were "frame-independent" according to the ϕ -values obtained when they were shown the "completed" frame.

TABLE 1
FREQUENCY OF SIGNIFICANTLY SLOPED REGRESSION LINES ($\beta \neq 0$) AND UNSLOPED REGRESSION LINES ($\beta = 0$) FOR FRAME-FIGURE CONFIGURATION VERSUS ϕ , μ , AND ρ IN FRAME-DEPENDENT* AND FRAME-INDEPENDENT SUBJECTS ON ROD AND FRAME

Parameter	Group	Regression line slope	
		$\beta \neq 0$	$\beta = 0$
ϕ	Frame-dependent	6	2
	Frame-independent	1	11
μ	Frame-dependent	1	7
	Frame-independent	1	11
ρ	Frame-dependent	0	8
	Frame-independent	1	11

*Frame-dependent subjects have a ϕ -value significantly different from zero in the rod-and-frame test under normal conditions and calculated according to Nyborg (1974).

Fisher's exact test (Fisher, 1970) indicated a statistically significant difference ($p < 0.01$) between the proportion of frame-dependent and frame-independent subjects, with positively sloped or unsloped regression lines for frame-figure-completeness versus ϕ -values. Table 1 also shows data on the effect of frame-figure configuration on the values for μ and ρ on the rod and frame. The slope of regression lines for frame-figure configuration versus μ was significant for only 2 of 20 subjects; the slope was positive for one subject and negative for the other. The slope of regression lines for frame-figure configuration versus ρ was significant for only 1 of 20 subjects; for this subject it was negative. No significant difference was found between frame-dependent and frame-independent groups in the slope of regression lines for figure-frame completeness versus either μ or ρ .

Table 2 presents the traditional USD scores as well as ϕ , μ , and ρ scores for each subject on the rod and frame. It is apparent that as a rule the USD score for each subject was well-related to only one of the new parameters; either ϕ , μ , or ρ . Of the 9 subjects with USD scores less than 2° (field-independent groups),³ 4 were predominantly frame-dependent, 4 were characterized

³Upon retesting, one of the field-independent subjects from our previous study obtained a USD score greater than 2° .

TABLE 2
COMPARISON OF USD SCORES CALCULATED BY TRADITIONAL METHOD OF SCORING
ROD-AND-FRAME TEST AND VALUES FOR ϕ , μ , AND ρ CALCULATED BY NEW METHOD
OF SCORING

Subject No.	Traditional method USD score	New method		
		ϕ	μ	ρ
14	.50	.50	.00	.00
18	.50	.50	.00	.00
1	1.00	.00	-.50	1.00
2	1.25	.75	1.25	-.25
4	1.50	1.50	-.50	-.50
11	1.50	.50	1.50	-.50
15	1.50	1.50*	.00	-.50
10	1.75	.75	1.75	.25
17	2.00	1.50	2.00	.00
19	3.50	3.50	1.00	-.50
6	3.75	-1.25	3.75	-.25
20	4.00	3.50*	-3.50	-1.00
5	5.00	4.00*	-.50	5.00
3	5.75	5.75*	-.75	4.25
12	5.75	5.75*	-2.75	3.25
13	6.00	3.50	6.00	1.50
8	8.00	8.00	.00	4.00
7	8.25	8.25*	-1.75	5.25
9	9.00	9.00*	.00	.50
16	9.25	9.25*	.75	.25

* = significantly different from zero ($p < 0.05$).

Note.—The dominant parameters calculated by the new are italicized. Negative values for ϕ indicate that the subject adjusted the rod to the side opposite that to which the frame was tilted. Negative μ -values indicate that the rod was adjusted to the left of physical vertical. Negative ρ -values indicate that the rod was adjusted to the side opposite the starting-position of the rod.

by constant deviation while the remaining subject was predominantly influenced by the rod-starting-position on the test. Of the 7 subjects with USD scores between 2° and 8° (moderately field-dependent group), 3 were predominantly frame-dependent, 2 were characterized by constant deviation, 1 was influenced predominantly by the rod-starting-position, while 1 subject showed both frame-dependence and constant deviation. Of the 4 subjects with USD scores of at least 8° , all were predominantly frame-dependent.

Eight subjects had ϕ -values significantly different from zero. Table 3 shows the distribution of significant ϕ -values and insignificant ϕ -values with respect to the USD scores. A χ^2 test showed that the difference in the distribution of significant and insignificant ϕ -values was significant ($p < 0.01$). Inspection of the data shows that the frequency of significant ϕ -values tended to be higher for field-dependent and moderately field-dependent subjects than for field-independent subjects.

TABLE 3
 FREQUENCY OF FRAME-INDEPENDENT ($\phi = 0$) AND FRAME-DEPENDENT ($\phi \neq 0$)
 SCORES IN FIELD-INDEPENDENT ($USD < 2^\circ$) AND FIELD-DEPENDENT
 ($USD \geq 2^\circ$) SUBJECTS

Group	$\phi = 0$	$\phi \neq 0$
Field-independent	8	1
Field-dependent	4	7

Three of the assumptions of our model for analyzing rod-and-frame performance were tested in the present study. These assumptions were (1) that the ϕ -parameter is a function of the tilted frame configuration, (2) that the geometrical structure of the frame would affect frame-dependent subjects more than frame-independent subjects, and (3) that the parameters ϕ , μ , and ρ are independent and additively related. The finding that variations in the geometrical structure of the frame resulted in corresponding variations in the ϕ -parameter values supports the first assumption. The finding that variations in the geometrical structure of the frame resulted in corresponding variations in the ϕ -parameter values only in subjects previously classified as frame-dependent supports the second assumption. The finding that changing the geometrical structure of the frame affected ϕ -parameter values but did not affect reliably μ -values or ρ -values supports the third assumption. No evidence against the three assumptions of our model was obtained.

It is necessary to consider whether an artifact of the test procedure rather than an effect of the geometrical structure of the frame was responsible for the results obtained. It is to be noted that the variations in the geometrical structure of the frame led to variations of the light intensity in the visual field of the task. But the alterations in light intensity cannot account for the present results because previous studies show that light intensity has only negligible effects on perception of the vertical on the rod and frame (Nyborg, 1972; Nyborg, 1974a). No other artifacts can be found that could have led to the present findings.

The traditional method of scoring the test classifies subjects on a field-dependence versus field-independence continuum based on their USD scores. It was pointed out previously, however, that there is uncertainty about what is "really" measured on the task and whether USD scores provide an adequate measure of performance. The present findings show that USD scores do not represent the effects of any particular aspect of the test, such as the frame, for example, on the subject's performance. Our data show that in some subjects the USD score was mainly due to effects of the tilt of the frame (ϕ), while in others the USD score was primarily due to either the subject's constant deviation (μ), or the rod-starting-position effect (ρ), or a combination of effects. A relationship was nevertheless observed between significant ϕ -scores and high USD scores. This relationship indicates that frame-dependent subjects are

usually also field-dependent. However, the failure of high USD scores to be reliably associated with significant ϕ -scores indicates that field-dependence is not synonymous with frame dependence.

USD scores did not discriminate between effects of the components of the test, e.g., the frame, the constant deviation, and the starting position of the rod, on the performance of the subjects. It is to be noted that the traditional method of scoring the test by USD scores has been used in many studies on person-specific differences in frame dependence (see: Witkin, *et al.*, 1973; Witkin, *et al.*, 1974). Unfortunately, USD scores are inappropriate and inadequate for this purpose. Only the ϕ -scores obtained by the new method of scoring give a valid measure of a subject's degree of frame dependence. The traditional method gives only nonspecific information about the subject's perception of vertical while the new method can indicate the source of the subject's deviation in adjustment of the rod to vertical. Our findings suggest that the new method of scoring the rod-and-frame task can be used to specify the source of individual differences in perception of the vertical.

REFERENCES

- FINE, B. J., & DANFORTH, A. V. Field-dependence, extraversion, and perception of the vertical: empirical and theoretical perspectives of the rod-and-frame test. *Perceptual and Motor Skills*, 1975, 40, 683-693.
- FISHER, R. A. *Statistical methods for research workers*. Edinburgh: Oliver & Boyd, 1970.
- GRUEN, A. A critique and re-evaluation of Witkin's perception and perception-personality works. *Journal of Genetic Psychology*, 1957, 56, 73-93.
- NYBORG, H. Tactile stimulation and perception of the vertical: I. Effects of diffuse vs. specific tactile stimulation. *Scandinavian Journal of Psychology*, 1971, 12, 1-13. (a)
- NYBORG, H. Tactile stimulation and perception of the vertical: II. Effects of field dependency, arousal, and cue function. *Scandinavian Journal of Psychology*, 1971, 12, 135-143. (b)
- NYBORG, H. Light intensity and perception of the vertical: two experiments with the rod-and-frame test. *Scandinavian Journal of Psychology*, 1972, 13, 1-13.
- NYBORG, H. Light intensity in the rod-and-frame test reconsidered. *Scandinavian Journal of Psychology*, 1974, 15, 236-237. (a)
- NYBORG, H. A method for analysing performance in the rod-and-frame test: I. *Scandinavian Journal of Psychology*, 1974, 15, 119-123. (b)
- NYBORG, H. Sex chromosome abnormalities and cognitive performance: III. Field dependence, frame dependence, and failing development of perceptual stability in girls with Turner's syndrome. *Journal of Psychology*, 1977, in press.
- NYBORG, H., & ISAKSEN, B. A method for analysing performance in the rod-and-frame test: II. Test of the statistical model. *Scandinavian Journal of Psychology*, 1974, 15, 124-126.
- WITKIN, H. A., & ASCH, S. E. Studies in space orientation: IV. Further experiments on perception of the upright with displaced visual fields. *Journal of Experimental Psychology*, 1948, 38, 762-782.
- WITKIN, H. A., COX, P. W., FRIEDMAN, F., HRISHIKESAN, A. G., & SIEGEL, K. N. *Supplement No. 1, Field-dependence-independence and psychological differentiation: bibliography with index*. Princeton, N. J.: Educational Testing Service, 1974. (Research Bulletin 74-42)
- WITKIN, H. A., OLTMAN, P. K., COX, P. W., EHRLICHMAN, E., HAMM, R. M., & RINGLER, R. W. *Field-dependence-independence and psychological differentiation: a bibliography through 1972 with index*. Princeton, N. J.: Educational Testing Service, 1973. (Research Bulletin 73-62)

Accepted January 11, 1977.

usually also field-dependent. However, the failure of high USD scores to be reliably associated with significant ϕ -scores indicates that field-dependence is not synonymous with frame dependence.

USD scores did not discriminate between effects of the components of the test, e.g., the frame, the constant deviation, and the starting position of the rod, on the performance of the subjects. It is to be noted that the traditional method of scoring the test by USD scores has been used in many studies on person-specific differences in frame dependence (see: Witkin, *et al.*, 1973; Witkin, *et al.*, 1974). Unfortunately, USD scores are inappropriate and inadequate for this purpose. Only the ϕ -scores obtained by the new method of scoring give a valid measure of a subject's degree of frame dependence. The traditional method gives only nonspecific information about the subject's perception of vertical while the new method can indicate the source of the subject's deviation in adjustment of the rod to vertical. Our findings suggest that the new method of scoring the rod-and-frame task can be used to specify the source of individual differences in perception of the vertical.

REFERENCES

- FINE, B. J., & DANFORTH, A. V. Field-dependence, extraversion, and perception of the vertical: empirical and theoretical perspectives of the rod-and-frame test. *Perceptual and Motor Skills*, 1975, 40, 683-693.
- FISHER, R. A. *Statistical methods for research workers*. Edinburgh: Oliver & Boyd, 1970.
- GRUEN, A. A critique and re-evaluation of Witkin's perception and perception-personality works. *Journal of Genetic Psychology*, 1957, 56, 73-93.
- NYBORG, H. Tactile stimulation and perception of the vertical: I. Effects of diffuse vs. specific tactile stimulation. *Scandinavian Journal of Psychology*, 1971, 12, 1-13. (a)
- NYBORG, H. Tactile stimulation and perception of the vertical: II. Effects of field dependency, arousal, and cue function. *Scandinavian Journal of Psychology*, 1971, 12, 135-143. (b)
- NYBORG, H. Light intensity and perception of the vertical: two experiments with the rod-and-frame test. *Scandinavian Journal of Psychology*, 1972, 13, 1-13.
- NYBORG, H. Light intensity in the rod-and-frame test reconsidered. *Scandinavian Journal of Psychology*, 1974, 15, 236-237. (a)
- NYBORG, H. A method for analysing performance in the rod-and-frame test: I. *Scandinavian Journal of Psychology*, 1974, 15, 119-123. (b)
- NYBORG, H. Sex chromosome abnormalities and cognitive performance: III. Field dependence, frame dependence, and failing development of perceptual stability in girls with Turner's syndrome. *Journal of Psychology*, 1977, in press.
- NYBORG, H., & ISAKSEN, B. A method for analysing performance in the rod-and-frame test: II. Test of the statistical model. *Scandinavian Journal of Psychology*, 1974, 15, 124-126.
- WITKIN, H. A., & ASCH, S. E. Studies in space orientation: IV. Further experiments on perception of the upright with displaced visual fields. *Journal of Experimental Psychology*, 1948, 38, 762-782.
- WITKIN, H. A., COX, P. W., FRIEDMAN, F., HRISHIKESAN, A. G., & SIEGEL, K. N. *Supplement No. 1, Field-dependence-independence and psychological differentiation: bibliography with index*. Princeton, N. J.: Educational Testing Service, 1974. (Research Bulletin 74-42)
- WITKIN, H. A., OLTMAN, P. K., COX, P. W., EHRLICHMAN, E., HAMM, R. M., & RINGLER, R. W. *Field-dependence-independence and psychological differentiation: a bibliography through 1972 with index*. Princeton, N. J.: Educational Testing Service, 1973. (Research Bulletin 73-62)

Accepted January 11, 1977.