THE ROD-AND-FRAME TEST

Previously published papers with relation to the present treatise

1) Tactile stimulation and perception of the vertical I. Effects of diffuse vs. specific tactile stimulation. Scand. J. Psychol., 12: 1-13, 1971a.

2) Tactile stimulation and perception of the vertical II. Effects of field dependency, arousal, and cue function. Scand. J. Psychol., 13: 135-143, 1971b.

3) Light intensity and perception of the vertical: Two experiments with the Rod-and-Frame Test, Scand. J. Psychol., 13: 1-13, 1972.

4) A method for analysing performance in the rod-and-frame test I. Scand. J. Psychol., 15: 119-123, 1974.

5) A method for analysing performance in the rod-and-frame test II. Test of the statistical model. Scand. J. Psychol., 15: 124-126, 1974. (in collaboration with Bo Isaksen).

6) Light intensity and perception of the vertical II. Two experiments with the Rod-and-Frame Test reconsidered. Scand. J. Psychol., 15: 236-237, 1974b.

THE ROD-AND-FRAME TEST AND THE FIELD DEPENDENCE DIMENSION: SOME METHODOLOGICAL, CONCEPTUAL, AND DEVELOPMENTAL CONSIDERATIONS

Helmuth Nyborg

DANSK PSYKOLOGISK FORLAG
1977

ISBN 87 87580 06 3

THE ROD-AND-FRAME TEST
AND THE FIELD DEPENDENCE
DIMENSION: SOME METHODO-
LOGICAL, CONCEPTUAL, AND
DEVELOPMENTAL CONSIDERATIONS

Reproduktion og tryk
F.B. Bogtryk

ISBN 87 8758o o6 3

Denne afhandling samt artiklerne:

Tactile stimulation and perception of the vertical I.
Tactile stimulation and perception of the vertical II.
Light intensity and perception of the vertical.
A method for analysing performance in the rod-and-frame test I.
A method for analysing performance in the rod-and-frame test II. (i samarbejde med Bo Isaksen)
Light intensity and perception of the vertical II.

som er publicerede i The Scandinavian Journal of Psychology, 1971, 1972 og 1974, er af Det psykologiske Fagråd ved Aarhus Universitet antaget til offentligt at forsvares for den filosofiske doktorgrad.

Aarhus Universitet
den 1. juli 1977

Jens Mammen
Formand for
Det psykologiske Fagråd

Forsvaret finder sted fredag den 7. oktober 1977, kl. 13.00
i festsalen, Psykiatrisk Hospital, Skovagervej 2, Risskov

to

Merete,
Casper, and Catrine

PREFACE

My studies were done in the period between 1968 and 1976. The experiments were performed at the Institute of Psychology, the Institute of Biological Psychiatry, and the Laboratory of Cytogenetics, all situated in Risskov, Denmark. The equipment necessary for some of the studies were constructed and used in these institutes. I wish to express my gratitude to these institutes for their hospitality and financial support.

The first series of experiments was performed during a junior research fellowship sponsored by professor, dr.phil. Gerhard Nielsen. It is a pleasure for me to thank Gerhard Nielsen for his valuable help in raising financial support for the first experiments as well as for valuable advice. Some of the later studies were done when I was awarded a research fellowship by the "Faculty of the medical sciences", University of Aarhus. I wish to thank this faculty for the opportunity to do research for a period of two years. I also wish to thank professors dr.med. Erik Strömgren and dr.med. Mogens Schou, both at the State Hospital of Risskov, for excellent research opportunities and for their kind interest in the projects. The fine cooperation in the Turner study with overlæge, dr.med. Johannes Nielsen is gratefully acknowledged.

It is a special pleasure for me to acknowledge my indebtedness to my friend and collegue, lektor, cand.scient. Bo Isaksen with whom I have discussed most of the statistical problems in the studies; he has to an unmeasurable extent participated in the construction and testing of the statistical model presented in one of the chapters to follow. I am deeply indepted to him for this as well as for the fine personal qualities he showed throughout the years of our collaboration.

I also wish to thank professor, dr.phil. I. Kr. Moustgård and afdelingsleder, cand.psych. Torsten I. Nielsen, Copenhagen, for inspiring and stimulating discussions.

Furthermore I wish to express my appreciation to the following: adjunkt, cand.stat. Tage Poulsen for statistical assistance in the first series of experiments; afdelingsleder, cand.stat. Gustav Leunbach for critical comments on series VII; stud.psych. Signe Tonsgård for assistance in collecting data in the first series; cand.psych. Søren Kelldorf and cand.psych. Carsten Fonsmark who assisted in series III; lektor, mag.art. Steen Folke Larsen who contributed to a more concise form of some of the reports; to stud.psych. Nina Kroll and Miss Anne-Grethe Jensen for typings various editions of the manuscript; Donald Smith, Ph.D., lic.med. for correcting the English text; to Miss Renate Alton for drawing the figures.

The system-analytic approach was facilitated by a senior research fellowship from the Alexander v. Humboldt Stiftung, Bonn. W. Germany, which made it possible for me to work in the stimulating atmosphere at the Max-Planck-Institut für Verhaltensphysiologie, Seewiesen, W. Germany. I wish to thank these two institutions. Special thanks are to be given (alphabetically) to professors, dr. Norbert Bischof, University of Zurich, dr. Horst Mittelstaedt, Max-Planck-Institut, Seewiesen, dr. Henrik Poulsen, University of Aarhus, and dr. Hermann Schöne, Max-Planck-Institut, Seewiesen, who together with dr. Cornelia Fitger, Max-Planck-Institut, Seewiesen, read the manuscript and gave valuable critical comments and suggestions. The remaining errors are to be ascribed to the author.

Finally I wish to express great admiration for my wife who mastered the problem of living "together" with a person who LIVED with apparently endless experimental sessions for extended periods of time.

Max-Planck-Institut für
Verhaltensphysiologie,
Seewiesen, W. Germany, 1976

Helmuth Nyborg

CONTENTS

INTRODUCTION page

1. Questions that initiated the studies 13
2. Aims and methods 18

PART I

FIELD DEPENDENCE, THE ROD-AND-FRAME TEST, AND OUR FIRST EXPERIMENTS

CHAPTER I

THE EMPIRICAL BACKGROUND FOR THE DEVELOMENT OF THE ROD-AND-FRAME TEST AND THE CONCEPT OF FIELD DEPENDENCE

1. Introduction 23
2. Perception of the verticality:
   a. of a "rod" 23
   b. of one's own body 25
   c. of a "rod" with tilted subjects 25
3. The development of the rod-and-frame test 26
4. The formulation of the concept of field dependence in relation to the rod-and-frame test 27
5. A developmental perspective on field dependence and psychological differentiation 29

CHAPTER II

OUR OWN EXPERIMENTS WITHIN THE TRADITIONAL FIELD DEPENDENCE FRAME OF REFERENCE

1. Series I
   "Tactile stimulation and perception of the vertical I. Effects of diffuse vs. specific tactile stimulation"
   a. Introduction 33
   b. Results and discussion 35

2. Series II page

"Tactile stimulation and perception of the vertical II. Effects of field dependence, arousal, and cue function"

a. Introduction 36

b. Results and discussion 36

3. Series III

"Light intensity and perception of the vertical. Two experiments with the rod-and-frame test"

a. Introduction 36

b. Results and discussion 37

PART II

MEASURES OF FIELD DEPENDENCE IN THE ROD-AND-FRAME TEST

CHAPTER III

TRADITIONAL WAYS OF MEASURING FIELD DEPENDENT PERFORMANCE IN THE ROD-AND-FRAME TEST

1. Introduction 41

2. Methods of scoring the rod-and-frame test performance

a. Unsigned deviation 41

b. Constant deviation 42

c. Variable error 43

d. Standard error 44

3. Difficulties with the traditional measures of RFT performance

a. Review of the literature 44

b. Our own problems 47

CHAPTER IV

DEVELOPMENT OF A NEW METHOD FOR ANALYSING PERFORMANCE IN THE ROD-AND-FRAME TEST

1. Series IV page

"A method for analysing performance in the rod-and-frame test I"

a. Discussion 51

2. Series V

"A method for analysing performance in the rod-and-frame test II. Test of the statistical model"

a. Discussion 53

PART III

OUR OWN EXPERIMENTS WITH THE NEW METHOD

CHAPTER V

THE LIGHT INTENSITY STUDY RECONSIDERED

1. Series VI

"Light intensity in the rod-and-frame test reconsidered"

a. Discussion 58

CHAPTER VI

THE GEOMETRICAL STRUCTURE CHANGE STUDY

1. Series VII

"The effect of geometrical structure on perception of the vertical in the rod-and-frame test"

a. Introduction 60

b. The problem 61

c. Material and methods 63

d. Results 65

e. Discussion 67

f. Figures and tables 70

CHAPTER VII

SEX CHROMOSOME ABNORMALITIES AND COGNITIVE PERFORMANCE II. FIELD DEPENDENCE,FRAME DEPENDENCE AND PERCEPTUAL INSTABILITY IN GIRLS WITH TURNER'S SYNDROME

1. Series VIII page

"Sex chromosome abnormalities and cognitive performance II. Field dependence, frame dependence, and perceptual instability in girls with Turner's syndrome"

a. Introduction 75
b. The problems 76
c. Material and methods 78
d. Results 81
e. Discussion 83
f. Tables 85

PART IV

THEORETICAL CONSIDERATIONS

CHAPTER VIII

SPATIAL ORIENTATION, RFT PERFORMANCE, AND THE FIELD DEPENDENCE DIMENSION

1. Introduction 92
2. On defining orientation 94
3. The field dependence dimension 96
4. A first step towards a re-interpretation of performance in the rod-and-frame test 100

CHAPTER IX

THE ROD-AND-FRAME TEST AND ORIENTING PERFORMANCE

1. Introduction 104
2. The author's formulation on vertical orienting performance in the RFT 104
3. Three major functional types of information processing in vertical orienting performance 113
   a. Introduction 113
   b. The compensation principle 113
   c. The reconstruction principle 115
   d. The correction principle 117

CHAPTER X page

PERFORMANCE IN THE ROD-AND-FRAME TEST AND ITS INTERPRETATION IN INFORMATION PROCESSING TERMS AS A CASE OF VERTICAL ORIENTING PERFORMANCE

1. Introduction 120
2. On relating performance in the RFT to the three major functional types of information processing in vertical orienting performance 120
   a. The compensation principle and performance in the RFT 120
   b. The reconstruction principle and performance in the RFT 122
   c. The correction principle and performance in the RFT 123
      α. Compromise solutions 123
      β. Alternative solutions 130
      γ. Simultaneity solution 131
3. Two ways to interprete quantified performance in the RFT 132

CHAPTER XI

SOME FURTHER CONSIDERATIONS ON THE ROD-AND-FRAME TEST

1. Introduction 144
2. A developmental approach to the φ-parameter, the σ-parameter, and vertical orienting performance . 149
3. On population dependent and person-specific classifications 154

REFERENCES 166

SUBJECT INDEX 175

INTRODUCTION

1. QUESTIONS THAT INITIATED THE STUDIES

a. The question of the relative roles of visual information and "bodily" information for orientation relative to the vertical direction in space dates back to the studies of Wertheimer (1912). Theoretical as well as experimental studies led to contradictory views. After 40 years of controversy, Gibson (1952) argued that studies on the *interaction* between the relevant stimuli were more important than the debate about which mode is decisive.

Accepting Gibson's point of view we noted that no experimenter had sufficiently demonstrated the effect of changes of tactile stimulation on perception of the vertical. In fact Howard & Templeton (1966) explicitly omitted a discussion of the potential value of the tactile stimulation from their otherwise quite comprehensive survey on human spatial orientation.

Since we believed - mainly based on everyday experience - that the tactile modality plays at least some role for perception of the vertical, we set out to determine the potential effects of changing tactile stimulation on perception of the vertical.

Our point of departure was the frame of reference known as field dependency - field independency (*Witkin et al.*, 1954, 1962/1974). The main proponent of this frame of reference - Herman A. Witkin - had, however, rejected the hypothesis that "bodily sensitivity" plays a role for performance in the rod-and-frame test (RFT) with which we intended to work. On the other hand *Culver et al.* (1963) had shown that people do in fact differ in tactile sensitivity. Especially interesting to us in this connection was that *Culver et al.* (ibid.) demonstrated that field dependent subjects were less sensitive to tactile stimuli than field independent persons. On the basis of this conflicting evidence we decided to reexamine whether changing tactile stimulation effects perception of the vertical in the RFT.

b. During this work, another question soon arose. We found considerable individual differences in susceptibility to changes in the tactile stimulation which did not conform to our expectations. Thus, our next task was to determine why the performance of some persons deviated from our hypothesis.

c. A third question was why did a number of authors obtain contradictory results with the RFT. According to *Mann* (1952*a*) the contradictory observations might at least in part be explained by the use of too "weak" a frame in some of the apparatuses. As light intensity was a variable that differed radically from study to study, we wondered whether light intensity could cause the contradictory results. We thought that a frame with a high level of light intensity (in Mann's terminology: a "strong" frame) might influence the perception of the vertical more in a completely darkened room than a less "leading" ("weaker") frame. The possible effects of light intensity on RFT performance were of interest for other reasons as well. We planned to study what influences "frames" of different geometrical structures might exert on RFT performance. The experimental means for testing this variable inevitably involved considerable changes in light intensity. We therefore wanted definitely to settle the question of the effects of light intensity because changes in the light intensity in the RFT might interfere uncontrolably with the possible effects of changing the geometrical structure of the frame, thereby making such experiments meaning less.

d. The next question was whether the traditional ways of scoring the RFT were satisfactory to our purposes. We needed a method that took the complexity of the RFT performance into account. We wanted of course first of all a method that was sensitive to all the most important variables in the RFT situation. Secondly, the method should be devoid of variable contamination. Thirdly we wanted to use the method to obtain an estimate of the response consistency of subjects. Finally we wanted a technique that enabled us to relate the estimate of response consistency to the other variables in such a way that it could be determined whether the scores for the variables were due to random fluctuation. The traditional method of scoring the RFT did not fulfill our needs. Therefore, we created a method that conformed to our needs.

e. The next question was to determine whether the statistical method behind our method of scoring the RFT was valid.

f. Next, we had to determine whether the conclusions arrived at earlier about the meaning of light intensity changes should be re-formulated when the new method was applied to the original data.

g. We had on the basis of a statistical model claimed to have "isolated" the φ-parameter values as an indication of a subject's degree of "frame dependence". We then saw that we had to provide empirical evidence that the φ-parameter - and only this - was sensible to changes in the frame structure.

h. In a recent book, Nielsen, Nyborg & Dahl (1976) presented the results of studies on girls who lack sex chromosome material (the so-called Turner girls). The girls were studied with the RFT as well as by other means. One of the main findings with the RFT in this study was that these girls - considered as a group - performed much more field dependent than any other group studied so far. The study was initiated a number of years ago and the method of scoring the degree of field dependence in the RFT was accordingly the traditional one as prescribed by Witkin & Asch (1948). We wondered whether the extremely field dependent performance of these girls according to the old method needed re-evaluation when the new method was applied to the original data. Such re-analysis could as we saw it attain three major goals: 1) a *practical* one by obtaining a deeper understanding of what has been called "cognitional deficit" in Turner girls; 2) a *theoretical* one by studying in more detail a possible relation between sex chromosome abnormalities and cognitive functioning; and 3) finally a *methodological* one by learning more about the new method of scoring the RFT.

In short, through a re-analysis, we hoped to determine whether the previously observed high degree of field dependence in girls with Turner's syndrome was equivalent to a high φ-parameter value; and also to see how the new method of scoring the RFT worked for a greater number of subjects than previously studied.

i. During this work several serious questions arose centered mainly about the interpretation of the RFT. What is "really" field dependence? What is implied in the term "field" and what is meant by the term "dependence"? What is "frame dependence"? Is field dependence an unequivocal "perceptual dimension existing in its own right? Is it the only and unique dimension that may explain RFT behavior?

It was apparent that the concept of field dependence had appealed to an amazingly great number of researchers as a valuable heuristic concept, but we wondered whether performance in the RFT could be better interpreted without implying the so-called field dependence dimension?

We considered the answers to such questions to be vital for an understanding of the subject's performance in the RFT. It must, however, be made quite clear that we certainly do not - directly or indirectly - by these critical questions suggest the non-existence of consistent individual modes of responding to the RFT situation. We also do not deny possible relations between such consistent individual modes of responding in the RFT and the observer's level of "differentiation", or between his characteristic organization of personality.

What interested us was the possibility of considering the RFT performance in a much broader context than the field dependence frame of reference, namely as a complex expression of a subject's approach to maintain spatial orientation to the vertical as intact as possible. One of the main questions was whether it was necessary to implicate a special perceptual dimension such as the field dependence dimension in order to handle the data from the RFT. In order to find out, we used the new method of scoring the RFT in order to reinterpret the data. Our approach required radical re-thinking about what is measured in the RFT and pointed towards the end of the long era of field dependence.

The last part of this treatise, Part IV, presents a general introduction to those aspects of human spatial orientation that have special relevance for an understanding of RFT performance. We also addressed the question of how a specific subject functions in the RFT situation. In our approach, we tried to embrace distal, proximal and phenomenal aspects in one and the same consideration. Our approach to these questions was something between the neural-discharge level and the verbal-phenomenological level. We focused mainly on some hypothetical central-nervous mechanisms assumed to be involved in the perceptual performance in the RFT. We tried to consider these hypothetical neuro-psychological mechanisms in a system-analytic frame of reference. In Part IV of this treatise, the approach of Bischof (1966) is followed closely by applying some principles of human spatial orientation he has adapted and in some aspects reformulated from earlier studies of this area.

We thereby hoped to provide an overview of how the important variables in the RFT situation might be related to each other, i.e. how they function together. In order to facilitate the understanding of such a functional approach we presented a cybernetic model for the RFT performance. Such models seem especially suitable when highly complex mechanisms are under consideration. With the help of "flow-diagrams" we obtained a more clear understanding of the subject's performance in the test situation.

As a secondary aim we also hoped by such an approach to be able to relate the multitude of specific responses - measured by the new method for analysing the RFT performance - to an understanding of *how* the perceiver solved his task in the RFT.

Clearly the question of "*Why*" the subject responded as he did is also in focus. In Part IV we try to provide some answers to this question in a *developmental perspective* which seems so important for an understanding of individual differences in RFT performance.

2. AIMS AND METHODS

Part I of this treatise outlines the background, the development, and the application of the traditional concept of field dependence as related to the RFT. Part I also presents our attempts to obtain answers to some questions on the effect of tactile stimulation and light intensity on perception of the vertical, within the traditional field dependence frame of reference.

Part II presents an overview of traditional ways of measuring performance in the RFT situation, followed by a discussion on some problems encountered working with these methods of scoring the RFT. As a consequence of the problems encountered we substituted the old methods with a new. Some aspects of the new method are discussed and compared to old methods.

We put emphasis on individual or person-specific performance in the RFT. Finally, we studied the validity of the statistical basis of the new method.

Part III deals with studies in which the new method was applied. Reevaluation of the data from our earlier experiment on the effect of changes in light intensity was done in chapter V. In chapter VI we tried to answer questions such as "Has the new measure sufficiently high validity as a measure of frame dependence?" and "Do the traditional and the new method give equal results when applied on the same material?".

The RFT data from an extensive six-year study on girls who lack sex chromosome material were reanalyzed in Chapter VII. The girls had been found to perform in a very field dependent way in the RFT as measured by the traditional measures. We studied whether the new method gave results different from those previously obtained.

In Part IV of the treatise we incorporated the RFT performance into a more general theoretical context. We did this by first presenting in chapter VIII some broad viewpoints on matters relevant to the theory. In the following chapter we related these viewpoints to a more specific discussion of the content of the concepts of "field" and of "dependence" as traditionally applied in connection with the RFT. Drawing on this material we reinterpreted RFT performance.

The RFT test situation is very complex. In order to facilitate an understanding of RFT performance we present in Chapter X a cybernetic model. The model takes into account the complexity of the test situation while at the same time it keeps an overview of the important variables as well as their possible relations.

In the reinterpretation we considered the organism as an information processing system. We outlined some major functional types of information processes and discussed what possibilities a subject may have to keep her orientation to the upright intact while exposed to an experimental created "conflict" between optic and vestibular/somesthetical cues in the RFT.

Chapter XI ends with a discussion on the differences between the use of population-dependent estimates of RFT performance and person-specific estimates. The response consistency parameter (σ), and at the φ-parameter are considered with respect to chronological age in Chapter XI.

Experimental method plays a prominent role in RFT studies. We used a variety of *common statistics*. In one case, however, we had to *develop a statistical model* convenient to our purposes. In Part IV of the treatise a *cybernetic model* is used to illustrate how the postulated information processes may solve the RFT task. We focused on hypothesized neuro-psychological mechanisms that might operate in spatial orientation performance.

PART I

FIELD DEPENDENCE, THE ROD-AND-FRAME TEST, AND OUR FIRST EXPERIMENTS

CHAPTER I

THE EMPIRICAL BACKGROUND FOR THE DEVELOPMENT OF THE ROD-AND-FRAME TEST AND THE CONCEPT OF "FIELD DEPENDENCE"

CHAPTER I

THE EMPIRICAL BACKGROUND FOR THE DEVELOPMENT OF THE ROD-AND-FRAME TEST AND THE CONCEPT OF FIELD DEPENDENCE

1. INTRODUCTION

This chapter gives a brief history on the empirical basis for the rod-and-frame test (RFT), followed by an account of the traditional concept of "field dependence", and its relation to the "psychological differentiation" hypothesis (Witkin et al., 1962).

In the RFT the subject is required to adjust a rod within a tilted frame to a position which appears to her to be upright while her body is restrained in a certain position (usually gravitational upright). As perception of verticality takes a prominent place in the RFT, we give a short account on how accurate subjects usually react in a test situation in which they are required to adjust a rod or their own body to an upright position without a visually presented frame.

2. PERCEPTION OF THE VERTICALITY

a. <u>of a "rod"</u>

Most people are able to adjust a luminous rod to a vertical position with an accuracy of about ± 2 degrees in an otherwise completely darkened room with the body in a gravitational vertical position (for review: see Howard & Templeton, 1966). In most studies the deviation of the rod from gravitational vertical were recorded unsigned, i.e. without taking into account whether the rod deviated to the right or to the left of gravitational vertical. In a study in which the direction of deviation was recorded, Cohen & Tepas (1958) found a constant deviation of 2.3 degrees to the left of gravitational vertical. This observation of a counter clock-wise tendency for all subjects can be explained. The rod always started from the same position, and under this condition the "rod-starting-position effect" is demonstrable (see: Nyborg, 1974).

Small discrepancies between head- and body-axis may result in systematic deviations from gravitational vertical in settings of a rod (Neal, 1926). Inadequate head adjustment apparatus and asymmetrical conditions in the experimental situation can affect a subject's adjustment of the rod (Nyborg, 1971*a*; Rosman, 1960). Constant deviations of the rod to one side for all subjects probably are experimentally induced and not person-specific. On the other hand, Gibson and Radner (1937) and Naylor (1965) found consistent small individual differences in constant error for ± 2 degrees in the final position of the rod while there was no systematic deviation for the group as a whole.

In the RFT situation we have observed constant errors as great as 12 degrees in the subject's settings of the rod (Nyborg, 1974, p. 122). Errors of this magnitude are, however, quite unusual. Often the constant error in the RFT will be in the range of ± 2 degrees.

A number of other factors influence perception of the vertical with the body gravitationally upright. Besides the previously mentioned "rod-starting position effect" (Werner & Wapner, 1952; Schneider & Bartly, 1962; Morant & Aronoff, 1966; O'Connel *et al.*, 1967) there are *adaptation* (Morant & Aronoff, ibid; Cohen & Tepas, 1958), *rod adjusting method* (O'Connel *et al.*, ibid.), and *stimulus complexity of the "rod"* (Weiner, 1955).

The meaning of individual differences in the rod-starting position effect and of the constant error (subjective vertical) for the final adjustment of the rod to an apparent vertical position in the RFT is discussed in Nyborg (1974; see also: Chapter IV in this treatise). The effect of the structural complexity of the "frame" is discussed in Chapter VI in this treatise.

Unilateral stimulation by heat, noise, mild shocks and muscular asymmetry (see e.g. Kleint, 1937) together with body asymmetry (unilateral brain damage, unilateral amputations) (Werner, Wapner & Chandler, 1951; Teuber & Mishkin, 1954; Comalli, 1963) can influence perception of verticality. The meaning of unilateral tactile stimulation in the RFT is discussed in Chapter II of this treatise and by Nyborg (1971*a*, 1971*b*). Taylor (1963) has reviewed most of the evidence for a preference for stimuli oriented in the vertical and horizontal plane.

b. Perception of verticality of one's own body

If a subject is required to adjust his own body to a vertical position while blindfolded or in a dark room, seated and tilted passively, he can usually do so with an accuracy equal to that found in rod positioning (see: Howard & Templeton, 1966). The degree of initial tilt, speed of return from the tilted position, and duration of delay in the tilted position influence apparent vertical posture. These factors are not, however, considered in detail in the present treatise since the subjects studied were tilted only in the first experimental series, and since Nyborg (1971*a*, 1971*b*) discussed these experiments in detail previously.

c. Perception of the verticality of a "rod" by tilted subjects

The case of adjusting a rod to an apparent vertical position by tilted subjects deserves some attention in connection with our first experiments. In 1861, Aubert noticed that when he looked at a vertical ray of light and tilted his head to one side, the ray of light appeared to tilt to the opposite side. This phenomenon became known as the Aubert-effect (A-effect). Later Müller (1916) found that small tilts of the head caused the vertical ray of light to appear to tilt to the same side: the so-called E-effect. Sandström (1954) found, however, considerable individual differences in A- and E-effects. Wade (1968) suggested that the individual differences seen by Sandström resulted from his method. Some later studies found no A- or E-effects with body tilts up to 20 degrees, while E-effects occured with tilts from 20-70 degrees and A-effects predominated for tilts beyond 70 degrees. Schöne (1964) on the other hand observed only the A-effect for 180 degree body tilt.

Mainly due to the uncertain status of the A- and E-effects under body tilt, the subjects in our studies from series three onward were not tilted.

3. THE DEVELOPMENT OF THE ROD-AND-FRAME TEST

In the late nineteen-fourties Witkin and collaborators performed an extensive series of studies on space orientation. In some of the first reports they presented the results of experiments on perception of the upright with displaced visual fields (Asch & Witkin, 1948*a*, 1948*b*). In these studies the investigators required their subjects to adjust a rod to an apparent vertical position while at the same time they were exposed to a tilted scene. For technical reasons they could not easily change the experimental conditions in their first studies. Later, they developed a new technique (Witkin & Asch, 1948) in which a luminous frame measuring approximately one meter i square, with sides approximately 2.5 cm wide was used. This frame could be tilted to the left or to the right around its center. A rod, 95 cm in length, was mounted in the center of the frame. The rod could be tilted independently of the frame but within it in such a way that the rod did not collide with the sides of the frame. The task of the subject was simply to adjust the rod to a position which she considered to be vertical. The deviation of the final rod settings from gravitational vertical was measured in degree. The authors called the test the "rod-in-frame".

Since the publication of these studies, it became a standard procedure to tilt the frame 28 degrees either to the left or to the right off gravitational vertical and to keep the frame at this position.

The subject was usually tested either (1) with her body tilted 28 degrees to the same side as the frame, (2) with her body tilted 28 degrees to the opposite side of frame tilt, or (3) while sitting upright. Witkin concluded on the basis of these experiments that perception of the vertical was influenced by visual as well as postural factors, but that the visual factors usually *dominate* (for critical discussion see: Gibson & Mowrer, 1938; Gibson, 1952; refered to in Nyborg, 1971*a*, p. 1). Witkin found extraordinarily large individual differences in the subjects' performance (see e.g.: Witkin & Asch, ibid.). Some subjects considered the rod to be vertical when it was in fact tilted as much as the frame, i.e. 28 degrees from gravitational vertical, while other subjects could easily adjust the rod to perfect or nearly perfect gravitational vertical. Most subjects adjusted the rod somewhere between these extremes. Witkin and coworkers found it difficult to interprete the considerable individual differences in a general and simple manner that accounted for the determinants of perception of the vertical for the group of subjects as a whole. The estimation of some of the subjects appeared to be highly influenced by the tilted visual field while other subjects could "overcome" this influence.

4. FORMULATION OF THE CONCEPT OF FIELD DEPENDENCE IN RELATION TO THE RFT

As a preliminary hypothesis to explain individual differences in RFT performance, Witkin first suggested, that some subjects were simply "inaccurate" in their judgements. This hypothesis was soon rejected. Then Witkin hypothesized that the individual differences in responses were reflections of differences in "body-sensitivity"; this hypothesis was also rejected (for discussion, see: Nyborg, 1971*b*, p. 136). As a third hypothesis Witkin suggested that his observations could be explained by differences in the subjects' capacity to "overcome an embedding context". This hypothesis became the basis for the development of the concept of "field dependence".

In the book "Personality through Perception", Witkin *et al.* (1954) postulated the existence of a bipolar perceptual dimension: the "field dependence - field independence" dimension. Field dependence was defined as incapacity to "... overcome the influence of the surrounding field or to separate an item from its context." Its counterpart was described as capacity "... to distinguish an item from its context" (see also: Witkin *et al.*, 1962).

A subject's position on the field dependence - field independence continuum was decided on the basis of her performance in one or more of the tests that measure this dimension. The subject's performance in the tests is said to reflect "... the quality of the person's experience of his surroundings, his way of perceiving and using his body, the nature of his relations to other people, and aspects of his controls and defences." (Witkin *et al.*, 1962, p. 3). The degree of field dependence was claimed to be related to perceptual, intellectucal, emotional, motivational, defensive, and social aspects of a given subject." Thus, investigations that dealt with individual differences in a seemingly narrow perceptual acticity developed into a study of broad differences among people in what seemed to add up to a "style of life" (ibid., p. 4).

The concept of field dependence appealed to researchers all over the world. Many accepted it on face value, while some were sceptical. The concept has been applied broadly in clinical and experimental psychology. Personality researchers have also used it. Nearly two thousand reports dealing with the concept have been published, and the number of publications increases every year.

In experimental psychology,field dependence has been related to such topics as the effect of instruction, "set", effects of training, perceptual development, sensory deprivation, arousal, illusions, constancy, intelligence, creativity, sensory-motor discrimination, and much more.

In clinical psychology, the concept has been studies in relation to alcohol abuse, stress, different forms of therapy, sex differences, chromosome abnormalities, mother-child interaction, degree of similarity between twins or between adopted children and their families, the effect of medicaments, physiological responsivity and so on. Furthermore, groups with paranoia, with obsessive or compulsive symptoms, people with brain damage or with ulcers have been studies as have psychopathic, schizophrenic, or manio-depressive persons. In later years students of cross-cultural research have made extensive use of field dependence terminology as have researchers in educational psychology.

5. A DEVELOPMENTAL PERSPECTIVE ON FIELD DEPENDENCE AND PSYCHOLOGICAL DIFFERENTIATION

In a book entitled "Psychological differentiation" (Witkin *et al.*, 1962) and in later publications (e.g. Witkin & Berry, 1975) Witkin discussed his theory of *psychological differentiation*. This theory was important for the concept of field dependence.

In Witkin & Berry's words, the "... typical progression in psychological development is from less differentiated to more differentiated. A salient identifying characteristic of greater differentiation is specialization. Subsystems emerge within the general system which are capable of mediating specific functions. This implies a measure of separation of psychological functions - as perceiving from feeling, thinking from action; it implies as well specificity in the manner of functioning within an area. Greater differentiation also carries implications about relations with the environment; a more differentiated system is characterized by separation of what is identified as belonging to the self from what is identified as external to the self. Finally, differentiation carries implications for the way in which a system is integrated. Integrations have two aspects: complexity ... and ... effectiveness ... To the extent that greater complexity of integration is possible in a system with many components, complexity of integration is related to differentiation. Effectiveness of integration, however, bears no direct relation to differentiation." (p. 6).

"Progress toward greater differentiation during development involves the organism as a whole, rather than proceeding discretely in separate domains." "... among the tests used to assess differentiation in perception is the rod-and-frame test (RFT)." (p. 7).

"As might be expected from the differential framework, a characteristic developmental progression toward increasing field independence has been observed up to the period of early adolescence, when a leveling off occurs..." (Witkin & Berry, 1975, p. 8). A tendency, beginning in adolescence, for males to be significantly more field independent than females, has been observed. Evidence from cross-cultural studies suggests that socialization variables are associated with the achievement of a relative field-dependent or field-independent style, or more broadly, with a relatively less developed or more developed level of differentiation (Witkin & Berry, 1975, p. 13). Thus, "... encouragement of autonomous functioning as an emphasis in child rearing is associated with the development of a more field-independent style and greater differentiation; and that, on the other hand, field dependence and limited differentiation tend to be associated with demand for adherence to parental authority" (Witkin & Berry, ibid., p. 13). It is clear that 1) Witkin's "differentiation theory" is a developmental theory, 2) the field dependence-independence dimension is the main component within the theory, and 3) that field dependence can be assessed by the RFT. Thus, according to Witkin, studies on field dependence with the RFT are developmental studies and can indicate a subject's level of psychological differentiation.

The subject's level of differentiation is according to Witkin influenced by her earlier experiences: "The commonplaceness of the perceptual function at the heart of the field-dependence-independence dimension (disembedding part of an organized field from the field as a whole) makes this cognitive style a particularly valuable indicator of socialization effects" (Witkin et al., 1974, p. 12).

A number of procedures can be used to measure field dependence. The present treatise is concerned primarily with the RFT. This test is according to Witkin a main indicator of field dependence: it is "... the only one of our tests of field dependence which seems to show no practice effect" (Witkin, 1965). Bloomberg (1967) found that the RFT is considered as "... the barometer of field dependence in which researchers have greatest confidence".

In the following chapter we present our works carried out within Witkin's frame of reference.

CHAPTER II

OUR OWN EXPERIMENTS WITHIN THE TRADITIONAL FIELD DEPENDENCE FRAME OF REFERENCE

CHAPTER II

OUR OWN EXPERIMENTS WITHIN THE TRADITIONAL FIELD DEPENDENCE FRAME OF REFERENCE

This chapter represents some aspects of our studies on field dependence. Further details of our studies are in the relevant publications.

1. SERIES I

"Tactile stimulation and perception of the vertical I. Effects of diffuse vs. specific tactile stimulation"
(Nyborg, 1971*a*)

a. Introduction

Gibson (1952) pointed out that *studies of interaction* between relevant stimuli are important for learning more about optical-vestibular conflict situations. We noted from everyday life experiences and from animal research (Magnus, 1924) that tactile stimulation may contribute to human spatial orientation. However, we found contradictory results in the literature on tactile stimulation. Witkin claimed that "bodily sensitivity" could not explain individual differences in RFT performance. Later, Culver et al., (1963) demonstrated that field dependent subjects were not as "sensitive" as the field independent in their response to tactile stimulation.

But neither Witkin nor Culver studied the effect of tactile stimulation in a RFT situation. Accordingly it was not known to what extent tactile stimulation influenced the interaction of stimuli in the RFT. We therefore decided to study this problem.

Earlier studies on the effects of stimulation on perception can be classified in two main groups: 1) experiments aimed at studying the effect of changes in tactile stimulation in concert with input from other modalities, and 2) experiments in which the influence from all modalitites except tactile was restrained.

The results of these studies were as mentioned contradictory. We suggested that some of the contradictory findings might be due to lack of sufficient control of the relevant variables. We proposed a number of experimental criteria which we considered necessary in order to study tactile stimulation. An experimental apparatus was designed to reduce and control the input from a number of modalities other than tactile stimulation. The apparatus was used to study effect of changes in the "specificity" of the tactile stimulation on the degree of field dependence in the RFT as measured in final adjustment of the rod.

The question of whether field dependent and field independent persons differ in sensitivity to tactile stimulation was already answered in the affirmative by Culver et al. (ibid.). Our main question was whether changes in tactile stimulation effect RFT performance. If so, then individual differences in "bodily sensitivity" to tactile stimulation might actually explain some individual differences in RFT performance. The answer to this question is of particular theoretical interest because Witkin claimed that RFT performance was a question of "extracting" the rod out of its context, and that this extracting process had nothing to do with differences in "bodily sensitivity". But Witkin may have rejected the "body sensitivity" hypothesis prematurely. If tactile stimulation can be shown to play a role in RFT performance, then it would be necessary to consider tactile stimulation to be a relevant variable for perception of the vertical.

We did not use terms like "increased" versus "reduced", but finally chose "specific" versus "diffuse" tactile stimulation; neither did we present a quantitative definition of the tactile stimulation, mainly because "specific" tactile stimulation as defined operationally in the experiment cannot be separated from general stimulation of the tissue (see Gibson, 1966, p. 106). Receptors in and near the surface of the skin can be stimulated by pressure, stretching, rubbing, and so on. "The definition of stimuli in these terms, however, can be useful without its having to be a quantitative definition, a magnitude" (Gibson, ibid.). We agree with Gibson who remarked that it is possible to study the relations between perception and stimulation in a meaningful way without first having to establish a *metric* psycho-physics (Gibson, 1948).

The traditional "unsigned error" method of analyzing the RFT performance (Witkin & Asch, 1948; see chapter III) was used in this work.

b. Results and discussion

Our observations made clear that when the general level of sensory input was lowered and the tactile stimulation was then made more "specific" the subjects - considered as a group - adjusted the rod nearer to gravitational vertical. The hypothesis that specific tactile stimulation gave a more adequate basis of estimation for perception of the apparent vertical than "diffuse" tactile stimulation was thus confirmed for the group as a whole. Although the effect of tactile stimulation was not great, it was evident that the subjects' degree of field dependence in general was lowered experimentally under the specific tactile stimulation conditions.

The reduction in field dependence was, however, not characteristic for all subjects. On the contrary, some subjects had a higher field dependence score when the tactile stimulus changed from diffuse to specific. This observation led to the following analysis.

2. SERIES II

"*Tactile stimulation and perception of the vertical II. Effects of field dependence, arousal, and cue function.*"
(Nyborg, 1971*b*)

a. Introduction

As consequence of the considerable individual differences in the effect of changes in tactile stimulation on RFT performance, we decided to study further the cause of the individual differences. We postulated *a priori* that field independent subjects would make much use of changes in the tactile stimulus conditions towards the more specific, while the field dependent persons would not. In other words, our hypothesis was that field dependent subjects would not adjust the rod nearer to physical vertical under specific tactile stimulation relative to diffuse tactile stimulation conditions while the field independent subjects would.

b. Results and discussion

Our results did not support our hypothesis. We then attempted to interpret our results in terms of individual differences in level of arousal and corresponding differences in "cue-function". Partly because a relatively detailed report on the relevant aspect of our study is presented in Nyborg (1971*b*), partly because of the somewhat speculative interpretation, and finally because of the critique that can be directed toward the traditional method applied in analysing the RFT performance, we will not discuss this report further here.

3. SERIES III

"*Light intensity and perception of the vertical. Two experiments with the Rod-and-Frame Test.*"
(Nyborg, 1972)

a. Introduction

In the study on the meaning of light intensity on perception of the vertical we applied the "tilting stand" device used in series I. To secure homogeneous, exact and stable conditions of light intensity we constructed a modified version of the classical RFT set-up (see, Nyborg, 1972). By means of this apparatus we could vary separately in well defined steps the light intensity level in the frame and in the rod. Before the experiment a subjective equidistant scale of light intensity was established in order that the physically defined level of light intensity were optimal for the experiment. Contrary to series I and II our subjects were not tilted in this or in the following experiments. But as in the foregoing series of experiments, we also applied the "unsigned-error" scoring method in this series III.

b. Results and discussion

Our data showed that level of light intensity play no or only very little role for perception of vertical in the RFT. This holds true regardless of whether the subject was field dependent or field independent, and regardless of whether the change in light intensity was actual all over the total visual field or only in part of it. On this basis we discussed a number of implications for use of RFT apparatusses with differing level of light intensity. We also discussed an experiment (Curran & Lane, 1962) the result of which was only apparently contradictory to the result we obtained.

At this time we began to suspect shortcomings in USD scores due to variable contamination. We therefore performed a methodological study of the RFT, the results of which are presented in part II.

SUMMARY OF PART I

Chapter I presented the basis for the traditional interpretation of RFT performance considered from empirical, theoretical and developmental points of view.

Chapter II then shortly discussed some studies performed within the traditional field dependence frame of reference.

PART II

MEASURES OF FIELD DEPENDENCE IN THE RFT

CHAPTER III

TRADITIONAL WAYS OF MEASURING FIELD DEPENDENT PERFORMANCE IN THE ROD-AND-FRAME TEST

PART II

MEASURES OF FIELD DEPENDENCE IN THE RFT

CHAPTER III

TRADITIONAL WAYS OF MEASURING FIELD DEPENDENT PERFORMANCE IN THE ROD-AND-FRAME TEST

CHAPTER III

TRADITIONAL WAYS OF MEASURING PERFORMANCE IN THE ROD-AND-FRAME TEST

1. INTRODUCTION

This chapter concentrates on traditional ways of scoring the RFT. Critical analysis of how the data in the RFT is handled is important because the final results are usually the only basis for reaching conclusions about the person tested and final results might mask some important information about the person.

The specific reason for the present critical evaluation of the scoring method of RFT data was that during our own studies we began to suspect that the scoring method we had applied - the common unsigned deviation method - confounded a number of important variables. At the same time, we found the other methods at hand for scoring the RFT to be incomplete in one or more respects.

In the book entitled "Human spatial orientation", Howard & Templeton (1966) remarked that "one of the disturbing features of research in this field is the lack of consistency in the statistics used by different workers to summarize their data." (p. 241). We consider this remark to be especially true for field dependence as measured with the RFT.

There are four main types of methods for scoring the RFT. The four types will be termed (1) the unsigned deviation, (2) the constant deviation, (3) the variable error, and (4) the standard error.

2. METHODS OF SCORING THE RFT PERFORMANCE

a. Unsigned deviation

The unsigned deviation method is recommended by Witkin, and most researchers within the field have followed his advise. The terms "absolute error", "crude average error", and "unsigned error" have been used as synonymous for "unsigned deviation". Mean unsigned deviation is calculated in the following way:

> "The direction, in which the setting (... of the rod ...) was off - that is, whether it was clockwise or counter clockwise from the true vertical and horizontal - was not taken into account. The scores for all trials given the subject under a given condition were then averaged, the results representing his mean error for that condition. Finally, to obtain the mean error for the group as a whole, the mean errors of the individual subjects were simply averaged."
>
> (Witkin & Asch, 1948*b*, p. 764)

Later the means from trials under "given conditions" were converted to standard scores and finally to a "total RFT index" (see, Witkin et al., 1962, p. 37)

Mean unsigned deviation ($\bar{Y}$) can mathematically be written

$$\bar{Y} = \frac{1}{N} \Sigma Y_i$$

where Y_i (unsigned deviation) is the rod position measured in number of degrees (numerically) from gravitational vertical in the i_{th} trial, i.e. without regard to the direction of the deviation; N = number of trials. The formula simply expresses the mean of summed scores over N trials.

b. <u>Constant deviation</u>

Constant deviation is sometimes called "subjective vertical", "point of subjective verticality", "response set", and "constant error". The constant deviation can mathematically be written

$$\bar{X} = \frac{1}{N} \Sigma X_i$$

where X_i (signed deviation) is the rod position measured in number of degrees off gravitational vertical in the i_{th} trial (measured positively for clockwise deviations and negatively for counter-clockwise deviations). The formula expresses the algebraic mean of final rod positions around gravitational vertical.

The constant deviation reflects the tendency of a subject to adjust the rod either to the right or to the left of gravitational vertical.

c. Variable error

The variable error can be calculated in several ways. Common to all ways is that the calculations are independent of the constant deviation. Some authors calculate variable error as

$$(1)\ \frac{1}{N} \Sigma |Y_i - \bar{Y}|$$

which expresses the average of deviation between *unsigned* deviation and mean *unsigned* deviation.

Other authors calculate the variable error as

$$(2)\ \frac{1}{N} \Sigma |X_i - \bar{X}|$$

which signifies the average of deviations between signed deviation and constant deviation.

Variable error reflects the precision with which the subject adjusts his response to the stimulus-conditions.

Formula 1 gives a measure of response consistency without regard to the side of vertical to which the rod is adjusted, while the measure of response consistency provided by Formula 2 does reflect the side to which the subject tended to adjust the rod.

d. Standard error

Standard error reflects the range within which the scores can be expected to be found. The formula for standard error can be written as

$$s = \sqrt{\frac{\Sigma(X_i - \bar{X})^2}{N - 1}}$$

where X_i is signed deviations under comparable experimental conditions, and where

$$\bar{X} = \frac{1}{N} \Sigma X_i$$

Standard error gives an estimate of the consistency of the scores. Given that RFT scores show an approximation to a normal distribution, 95 per cent of the scores can be expected to be found within an interval of 4 s symmetrical around $\bar{X}$.

3. DIFFICULTIES WITH THE TRADITIONAL MEASURES OF RFT PERFORMANCE

a. Review of the literature

Witkin *et al.* (1954) wrote that "Some of the measures we developed are avowedly crude, in relation to the complexity of t phenomena to which they refer" (p. XXIII). In addition, they assumed that "Fresh measures, as well as improved versions of the measures developed here, are sure to follow the first step taken in this study".

Witkin and his collaborators certainly knew that "There are a number of possible alternative scoring methods for the RFT..." and remarked in this connection, that "These alternatives may be useful for specific research problems, but we have not foun a scoring method that has greater construct validity as a measure of field dependence than does the absolute error" (Witkin *et al.*, 1962, p. 37).

Kurtz (1969) supported the statistical treatment applied by Witkin. In an analysis of Witkin's work, Kurtz noted that "He [Witkin] has used adequate controls, the mathematical assumptions underlying the statistical treatment of the data were usually met with a degree of precision sadly lacking in much psychological research" (p. 522).

But a number of authors have been sceptical about the scoring method advocated by Witkin. Most notably among these are Gruen (1957), Lester (1968), and, Fine & Danforth (1975).

Gruen focused on "... the role of Witkin's method of scoring perception ..." and found that "... this simple method obscures what may be actually happening in these situations" (ibid., p. 81). The unsigned error score appeared to give no indication of how deviations from vertical in the adjustment of the rod were arrived at by the subjects in the RFT. In a replication of Witkin's experiment, Gruen found that some subjects did not accept the frame as upright on either side, while other subjects did view the frame in this way. Nevertheless, the unsigned error score treated all subjects as though they viewed the frame in a similar fashion and thereby could be ordered along the same continuum. Gruen noted that 90 per cent of the men and 96 per cent of the women moved the rod in the direction opposite to the tilt of the frame at least once during the test, and that such events are not reflected in the unsigned error score. These observations caused Gruen to conclude, that "... the complexity of behavior emanating from these space-orientation tests is not given expression in Witkin's presentation of data. It fails to reflect phenomenologically different events by lumping different kinds of behavior along one continuum. This not only reduces the validity with which his data purports to give us a picture of what the subjects' perceptual performances were, but cuts off from consideration of the full implications of actual behavior in these situations. It results in unjustified simplifications which may bear limited relationships to what people really do ..."

(ibid., p. 85). Neither is Gruen satisfied with the fact that the only data for variability that Witkin presents are those which are concerned with variability of the averaged scores from series to series. Gruen stated that "Obviously any intra-individual variability within a series if present gets lost in the process of averaging the trials. Nevertheless Witkin proceeds as if the score for any one series can be taken to represent some consistent function of a person's perceptual behavior." (ibid., p. 86). Gruen also pointed out that Witkin's method of scoring "... covers up initially wide variability in performance and may be averaging different factors along one continuum. We suggest 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." (ibid., p. 91).

In agreement with Gruen, Lester (1968) wrote that "...errors made by the subjects (in the RFT) were apparently then analyzed without regard to their direction. No control readings were taken; error scores were calculated with respect to objective rather than to the individual's subjective vertical." He concluded that "... as long as ... doubts exist about the test, it seems very much worth the while of personality researchers to improve methodology, with the hope of improving the accuracy of measurement and finding some trustworthy answers to the existing questions." (p. 1312).

Fine & Danforth (1975) also criticized the traditional way of scoring the RFT. They 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". (p. 685). Fine & Danforth were "... forced to conclude that rod-and-frame performance is considerably more complex than available theories would lead us to believe." (p. 691).

Thus, Witkin had dismissed a number of ways of scoring the RFT in favour of the unsigned deviation scoring method which a number of researchers characterized as inadequate to measure performance in the RFT.

b. Our own problems

According to Witkin et al. (1962) what is required of the subject in the RFT is "... straightforwardly ... separation of an item (rod) from the context or field in which it is embedded" (p. 45). Witkin claimed that "For succesfull performance in this task the subject must "extract" the rod from the tilted frame through reference to the body position" (p. 36). Witkin considered all trials in which the subject adjusted the rod far from the vertical to indicate "adherence to the visual field", while small deviations in the adjustment of the rod to vertical were considered to indicate independence of the field and "reliance on the body".

According to Witkin, the subject mobilizes information from his own body with regard to position in order to overcome the "embedding" effect of the tilted frame. But information of "uprightness" from the upright positioned subject's body can be erroneous (Gibson & Radner, 1937; Naylor, 1965). Consequently, a subject that normally "receives" erroneous information on "uprightness" from his own body would be considered frame dependent on the basis of unsigned deviation scores, even though he may not be influenced at all by the frame tilt. It is evident that the method of scoring the RFT on the basis of unsigned deviation has some serious shortcomings.

Since Werner & Wapner (1952) demonstrated that the starting position of the rod may have a significant effect on its final position, a number of authors have confirmed this phenomena (Davies & Laytham, 1964; O'Connell et al., 1967; Lester, 1968; Girotti & Beretta, 1969; Groberg, Dustman & Beck, 1969; and others). The rod-starting-position effect also can contribute to frame dependence scores using the unsigned deviation method, even though it has nothing at all to do with the frame. This is another reason why the unsigned deviation method is unsatisfactory for analyzing RFT performance.

An additional shortcoming of the unsigned deviation score is that it gives no indication of response consistency. It is to be noted that tremendous variability in the response consistency of subjects in the RFT has been reported (Gruen, 1957; Nyborg, 1974). Witkin & Asch (1948*b*) tried to account for the variability in response consistency by claiming that "... the luminous frame has a very simple structure (and) it provides a rather "weak" frame of reference. This is additional reason to expect that judgements made in its presence will not be very consistent" (p. 773). Witkin & Asch calculated the consistency with which their subjects responded to the RFT situation and found values "... sufficiently high to indicate that a tendency to be influenced by the tilted frame, or to remain independent of it characterizes a person's perception of the upright under the several conditions employed". (Witkin & Asch, 1948*b*, p. 768). But they calculated response consistency on the basis of mean scores from a series of trials. Their method failed to reflect the type of variations in response consistency that occured during the trials. It is to be noted that Gruen (1957), for example, found that some subjects started the RFT with field independent scores and ended up with field dependent scores, or vice versa. He commented that if the mean score of series are taken as basis for estimations of response consistency one may be "...averaging what may not be component along one behavioral continuum. Yet performance that include field-dependent and field-independent solutions is simply averaged." (Gruen, 1957, p. 87).

Summarizing the shortcomings of the unsigned deviation method of scoring the RFT we concluded, that this method does not unequivocally reflect the subject's degree of frame dependence. It gives results that are *variable-contaminated* to an unknown extent. The variables which are indiscriminately lumped together in the unsigned deviation score are 1) the subject's constant deviation, 2) his rod-starting-position effect, 3) his effect of the tilted frame, and finally 4) his degree of response consistency.

If field dependence in the RFT (unsigned deviation score) is taken to reflect "dependence on the frame" as has been suggested by Witkin (Witkin et al., 1962), then the method of scoring the RFT advocated by Witkin cannot be considered to have great construct validity.

We consider the RFT to be a very usefull test- and research instrument. We therefore undertook the task of developing a new method for analyzing RFT performance. We required of the new method that it takes at least the four above-mentioned variables into account. The next chapter presents a brief account of this work.

At this point attention should be given to the terms "deviation" and "error". In the following we discriminate between these terms. The advantage of making a discrimination between these terms came rather late to us, and therefore it was not made in all our publication. In the following, however, we use the term "deviation" to characterize the discrepancy between the information about the vertical as delivered by the perceptual mechanisms and the true vertical. On the other hand, we use the term "error" to refer to the statistical variation of the perceived vertical (such as the standard- and variable error) which may be related to the amount of precision of the mechanisms in question.

CHAPTER IV

DEVELOPMENT OF A NEW METHOD FOR ANALYSING PERFORMANCE IN THE ROD-AND-FRAME TEST

CHAPTER IV

DEVELOPMENT OF A NEW METHOD FOR ANALYSING PERFORMANCE IN THE ROD-AND-FRAME TEST

1. SERIES IV

"A method for analysing performance in the rod-and-frame test. I."
(Nyborg, 1974)

a. Discussion

In the foregoing chapter it was emphasised that a simple arithmethic averaging of the data on the behavior of a subject in the RFT does not give an adequate account of the complexity of the subject's response. A number of variables influence the subject and these variables are not taken into account properly by the traditional ways of scoring the test. In addition, the importance of measuring inter-individual differences is to be stressed. The traditional method of scoring the RFT measures neither the variables nor inter-individual differences.

A more adequate account of the RFT performance can be obtained when the subject's performance is scored in such a way, that the unique values of her response parameters can be related to localized sources in the test situation, and then estimated in relation to the response consistency with which she obtained these values.

A more adequate method of scoring the RFT would allow for unequivocal and separate measures of the perceptual variables while at the same time giving basis for an estimation of the subject's response consistency. We wanted to develop such a method. Furthermore, we wanted a method which enables us to consider the subject's parameter-values in light of his own response consistency and not primarily by comparison to a group mean score.

An important aspect in the data collection by the new method is that the final position of the rod is noted signed, i.e. a record is kept on whether the rod deviates to the right or to the left of gravitational vertical. A record is also kept on whether the rod deviates to the same or to the opposite side of the frame tilt; this is important because rod deviation opposite frame tilt cannot sensibly be considered as an indication of the effect of frame tilt equivalent to deviations to the same side as the frame tilt.

The new method is based on the assumption that the effect of tilting the frame to the left equals the effect of tilting the frame to the right; the effects so to say counterbalance each other symetrically. This balancing effect is assumed also for the rod-starting-position effect; thus starting the rod from a left tilted position has the same effect on final adjusted position as when started from the right tilted position, but of course with sign reversed.

For details on the practical application of the method and for comparison of results obtained with the traditional and the new method the reader is refered to Nyborg (1974; see also series VII and VIII in this treatise).

In the new method of scoring the RFT, a number of important variables in the test situation are now registered and their values are measured separately for every single observer. It is also possible by the new method to indicate how specific the individual subject's responses are to the stimuli presented, because the values of her parameters can be estimated on the basis of the response consistency with which the subject reacted to the experimental variables given.

In the new method the focus is not so much on general *differences in field dependence* but rather on the single person in order to learn what her *specific response pattern* looks like. We believe that attention to the specific response pattern of an individual is of particular importance in studies on the relation between perception and personality. Unsigned deviation scores cannot be used to study the specific response pattern of a subject. For example, a very inconsistently responding subject as well as a very consistently responding subject can obtain identical unsigned deviation scores. As a result, important differences between the subjects are overlooked by the use of unsigned deviation scores.

We agree with Gruen (1957) that it is essential to investigate what the perceptual responses mean in relation to the subject who makes them. Although the new method does not give direct information about *why* the subject scored as she did, it does allow for a person-specific estimation of the relative role of test variables on her response. Thus, the new method can be used to study an individual's specific response pattern in the RFT. This cannot be done by any other single method presently available for scoring the RFT.

2. SERIES V

"A method for analysing performance in the rod-and-frame test. II. Test of the statistical model."
(Nyborg & Isaksen, 1974)

a. Discussion

The new method for analysing performance in the RFT is based on a two-ways analysis of variance and on the assumption that scores in the RFT are normally distributed or near-normally distributed. The assumption of normal distribution is important for the sensitivity of the analysis of variance to non-normality, and the extent to which non-normality can be expected to be actual in the RFT scores. With regard to the sensitivity of the analyses of variance, Edwards (1960, p. 128) pointed out that "The F test for means is, like the t test, remarkably insensitive to nonnormality of the population distribution, provided the departure from normality are of the same kind for the various populations sampled. Thus, for example, if the population of observations represented by one treatment is skewed and if the populations for the various other treatments are skewed in the same direction, the F test will be primarily sensitive to differences in means and not to the skewness." Edwards also remarked that "...since the F test is very insensitive to nonnormality and since with equal N's it is also insensitive to the variance inequalities it would be best to accept the fact that it can be used safely under most conditions. The F test of the analysis of variance, in other words, remains a robust test under a variety of violations of the assumptions on which it is mathematically based."

It would be desirable to present empirical evidence to show that the assumption of normal distribution of RFT scores is reasonable. But an attempt to attain empirical evidence for this has several difficulties. A test for normality would for example require many repeated measurements under identical conditions. In such a series of repeated measurements it cannot be excluded that for effects such as adaptation and variations in the subject's motivation affect the results to an incontrolable extent. Thus, although the normality of RFT scores has not been proven conclusively, data from several hundred subjects do not give reason to assume that the scores are skewed.

An expression of the subject's response consistency must of course be obtained in the analysis of scores obtained under highly comparable conditions.

Two methods for estimation of response consistency were used to test the new method (Nyborg & Isaksen, 1974, p. 125). Thus testing the model presented in Nyborg (1974) two measures of response consistency (σ_1 and σ_2) were calculated so that they are comparable in the sense, that except by chance they have the same size and both express the consistency of the subject. σ_1 gives a measure of consistency independently of the model of scoring, while σ_2 presupposes the model. These two measures were used by Nyborg & Isaksen (ibid., p. 125) to determine whether the model gives a reasonable description of the "reality" in the experimental situation for a given subject. If σ_2 is great relative to σ_1 this would be reason to doubt the applicability of the model. The χ^2-values obtained for the comparison of σ_1 and σ_2 supported the model. Table 1 in Nyborg & Isaksen (1974) shows that there are many small values of F, indicating that the model fits better than could be expected.

The model is based on the assumption that the subject's response to the RFT can be partitioned into three additive components. μ, φ, and ρ, which all separately have been shown to be relevant for different subjects to a different extent. The model would be inadequate if for example the effect of the tilt of the frame and that of the rod-starting-position interfered so that the mean score, η, could not be written as a sum of single effects. It is important in this connection to stress that the assumption of additivity *does not* imply that interactional effects between the components are inconceivable or just not observed. Rather it means that the interactions are of so small importance that in practice they can be neglected (see Chapter VI). This point of view is also supported by the fact that the model "fits" the data so well.

SUMMARY OF PART II

An overview of the most common ways of scoring performance in the RFT was given in Chapter III. We discussed some difficulties connected to the use of these methods and concluded on this basis that there was a need for a new method of analysing data in the test. The new method should provide separate measures of the constant deviation, the "genuine" frame tilt effect, and the rod-start-position effect. Furthermore the method should give an adequate measure of the subject's response consistency, and it should be possible to relate the response consistency to the values of the other parameters in such a way that they could be checked for chance variations. In Chapter IV a method that conformed to these requirements was presented and some aspects were discussed. Also the importance of focusing on the specific response pattern of a subject rather than on general measures of field dependence scores in groups was emphasized.

PART III

OUR OWN EXPERIMENTS WITH THE NEW METHOD

CHAPTER V

THE LIGHT INTENSITY STUDY RECONSIDERED

1. SERIES VI

"Light intensity in the rod-and-frame test reconsidered." (Nyborg, 1974*b*)

a. Discussion

An earlier publication (Nyborg, 1972) on the effect of changes in light intensity of the frame and rod in the RFT indicated that such changes do not influence perception of the vertical. However, the unsigned deviation scoring method used in that study was later shown to be faulty (Nyborg, 1974; Nyborg & Isaksen, 1974). Therefore, the data were reanalysed by the new method of scoring the RFT in order to see whether the original conclusion that changes in light intensity have practically no influence on perception of verticality in the RFT could be maintained. The answer to this question was important for us because the next study we had planned involved inevitable changes in the level of light intensity in the visual field. If changes in light intensity were in fact important in RFT performance, then they could interfere to an unknown extent with the effects of changing the structure in the visual field in our next experiment, and thereby invalidate our study.

The results of the reanalysis confirmed fully our previous conclusion that even extreme changes in the level of light intensity have negligible effects on perception of the vertical in the RFT. The hypothesis that changes in the level of light intensity affected frame dependent persons more than frame independent observers was also rejected.

On this basis we concluded that the inevitable changes in light intensity in our next experiment could be considered to be unimportant for its outcome.

CHAPTER VI

THE GEOMETRICAL STRUCTURE CHANGE STUDY

CHAPTER VI

THE GEOMETRICAL STRUCTURE CHANGE STUDY

1. SERIES VI

"The effect of geometrical structure on perception of the vertical in the rod-and-frame test."

a. Introduction

In the present chapter we study whether the frame dependence parameter value (φ) obtainable by our method of analysing performance in the RFT is sensitive to variation in the geometrical structure of the frame. We furthermore test empirically the additivity assumption behind the method by determining whether the constant deviation (μ), the rod-starting-position effect (ρ), and the response consistency of the subject (σ) are affected by changes in the structure of the frame. We compare the validity of the φ-score with the validity of the traditional unsigned deviation measure of field dependence (frame dependence) in the RFT.

b. The problem

The rod-and-frame test (RFT) (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 RFT is used in pedagogical, clinical and cross-cultural psychology. But despite its widespread use, there is still doubt about what is "really" measured in the RFT. Witkin, the originator of the RFT, claimed that is 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 RFT "...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 RFT to be more complex than the traditional scoring methods can account for.

Our studies support the notion that both the RFT 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 all affect the outcome of the RFT (Nyborg, 1971a; 1971b; 1972). We constructed a model to separate the effects of these variables on RFT performance (Nyborg, 1974) 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 failed to 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 the outcome of the RFT in frame dependent and frame independent subjects tested under varying conditions of geometrical structure of the frame. Evidence against our model would be obtained if there were 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 RFT (Nyborg, 1974; 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 RFT. 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 RFT.

c. Material and methods

Eleven males and nine females were selected from 150 freshmen psychology students on the basis of their unsigned deviation scores (USD) in the RFT. Ten of the students were field dependent (USD > 8 degrees) and the other ten were field independent (USD < 2 degrees). The subjects were retested in the RFT and scored by the new method (Nyborg, 1974; Nyborg & Isaksen, 1974). 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 configuration 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 appears to them to be a vertical position. Several describtive 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 degrees to the right or left of the gravitationel vertical. The rod starting position was 28 degrees 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. In 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 sixteen 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 one hour 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 linearely related to the degree of ambiguity (incompleteness) of the frame-figure configurations. The slope of the regression lines was then examined.

d. Results

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 nineteen of the twenty 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 thirteen 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 thirteen subjects with unsloped regression lines were "frame independent" according to the φ-values obtained when they were shown the "completed" frame. 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 figure-frame completeness versus φ-values. Table 1 also shows data on the effect of frame-figure configuration on the values for μ and ρ in the RFT. The slope of regression lines for frame-figure configuration versus μ was significant in only 2 of 20 subjects; the slope was positive in one subject and negative in the other. The slope of regression lines for frame-figure configuration versus ρ was significant in only 1 of 20 subjects; in 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 in the RFT. 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 degrees (field independent groups), [1] 4 were predominantly frame dependent, 4 were characterized by constant deviation while the remaining subject was predominantly influenced by the rod-starting-position in the RFT. Of the 7 subjects with USD scores between 2 degrees and 8 degrees (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 degrees, all were predominantly frame dependent.

1) Upon retesting, one of the field independent subjects from our previous study obtained a USD score greater than 2 degrees.

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 Chi-square test showed that the difference in the distribution of significant and insignificant φ-values was significant ($p < 0.01$). Inspection of the data show that the frequency of significant φ-values tended to be higher in field dependent and moderately field dependent subjects than in field independent subjects.

e. Discussion

Three of the assumptions of our model for analysing RFT 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 subject more than frame independent subject, 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 failed to 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 artefact 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 in the light intensity in the visual field in the RFT. 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 in the RFT (Nyborg, 1972; Nyborg, 1974b). No other artefacts can be found that could have led to the present findings.

The traditional method of scoring the RFT 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 in the RFT and whether USD scores provide an adequate measure of RFT performance. The present findings show that USD scores do not represent the effects of any particular aspect of the RFT, 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 failed to discriminate between effects of the components of the RFT (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 RFT 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 the RFT 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 RFT can be used to specify the source of individual differences in perception of the vertical.

Figure 1. Configurations of the frames shown to subjects in the RFT. 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.

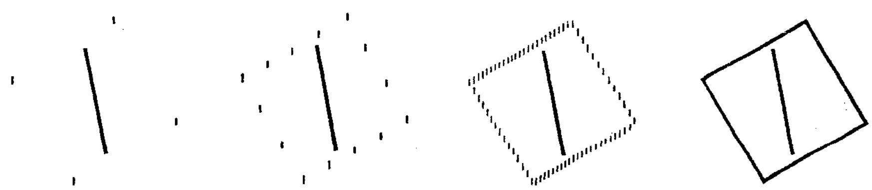


Table 1.

The frequency of significantly sloped regression lines ($\beta \neq 0$) and unsloped regression lines ($\beta = 0$) for frame-figure configuration versus φ, μ and ρ-values in frame dependent [1] and frame independent subjects in the RFT.

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

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

Table 2.

A comparison between USD scores calculated by the traditional method of scoring the rod-and-frame test and values for φ, μ and ρ calculated by the new method of scoring the test. The dominant parameters calculated by the new are underlined. 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.

Subject number	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 ($p < 0.05$).

Table 3.

The frequency of frame independent ($\varphi = 0$) and frame dependent ($\varphi \neq 0$) scores in field independent (USD $< 2^{o}$) and field dependent (USD $\geq 2^{o}$) subjects.

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

CHAPTER VII

SEX CHROMOSOME ABNORMALITIES AND COGNITIVE PERFORMANCE II. FIELD DEPENDENCE FRAME DEPENDENCE, AND PERCEPTUAL INSTABILITY IN GIRLS WITH TURNER'S SYNDROME

CHAPTER VII

SEX CHROMOSOME ABNORMALITIES AND COGNITIVE PERFORMANCE II. FIELD DEPENDENCE, FRAME DEPENDENCE, AND PERCEPTUAL INSTABILITY IN GIRLS WITH TURNER,S SYNDROME

1. SERIES VIII

"Sex chromosome abnormalties and cognitive performance II. Field dependence, frame dependence, and perceptual instability in girls with Turner's syndrome.

a. Introduction

In this series we administered the rod-and-frame test (RFT) to Turner girls, their normal sisters, and to nonsiblings with primary amenorrhoea and growth retardation as seen in Turner girls. The test was scored by the traditional method that gives a measure of "field dependence" as well as by a new method that gives a measure of frame dependence and response inconsistency. We wanted to study whether "field dependence", frame dependence, or response inconsistancy is a characteristic of RFT performance in Turner girls.

b. <u>The problems</u>

In 1938 Turner (9) described a group of women with short stature, webbed neck, cubitus valgus, and undeveloped secondary sex characteristics. The triad of short stature, webbed neck, and cubitus valgus became known as Turner's syndrome and young women with these characteristics became known as Turner girls. Only short stature seems, however, always connected with Turner's syndrome (3).

Turner girls have abnormalities in their sex chromosomes. Karyotype 45,X is found in approximately half of the Turner girls with other chromosome aberrations such as lack of certain parts of a sex chromosome or lack of a sex chromosome in only some cells appears in the other half (1, 2, 6, 8). Nielsen, Nyborg, and Dahl (3) have estimated the prevalence of Turner girls in a normal population to .004 per cent.

The full-scale intelligence in Turner girls is slightly below normal, due mainly to poor performance IQ. "Perceptual organization" and "freedom from distractibility" are also lower than normal in Turner girls (cf. 3). Shaffer (7) concluded that Turner girls have a "cognitional deficit".

In 1969 we began developmental studies on selected cognitive functions in Turner girls to learn more about the nature of their so-called "cognitional deficit". The rod-and-frame test (RFT) was used in our studies because it is a nonverbal test correlated with performance IQ subtests (10). It soon became apparent to us that the traditional method of scoring the RFT described by Witkin and Asch (11) had some serious shortcomings; it failed to provide measures of an individual's characteristic performance in the test. Consequently, we developed a new method of scoring the test.

In the present study, the results of the RFT in Turner girls and in control groups were analyzed by the traditional method and by the new method. The outcome of the two methods are discussed with special emphasis on obtaining a better understanding of the "cognitional deficit" in girls with Turner's syndrome.

c. Material and methods

Forty-five girls with Turner's syndrome were studied. Twenty-one of them had a karyotype of 45,X while the others had other chromosome abnormalities as described by Nielsen, Nyborg and Dahl (3). Their age ranged from 7^{1} to 38 years with mean age of 20^{9} years. 23 of the girls lived in Copenhagen while the others lived in smaller towns and rural districts in Denmark.

Twenty-one of the Turner girls had a sister that was less than 5 years older or younger than she. Nineteen of these sisters consented to be tested and were studied (Sister control group). The mean age in the Sister control group was 22^{9} with a range of 14^{5} to 39 years. Also included in the study was a control group of 15 girls with growth retardation and primary amenorrhoea as in Turner girls but without chromosome abnormalities (Nonsibling control group). The mean age in the Nonsibling control group was 19^{7} and ranged between 9^{3} and 32 years.

The RFT apparatus used was a transportable model from DARRO. It consisted of a table top sized box. The subject put her head in one end of the box so that her view was restricted to the inside of the box. A square frame with a moveable rod inside it was visible at the other end of the box. The frame was tilted 28 degrees to the right or to the left of gravitational vertical. The subject's task was to adjust the rod to apparent vertical within the stationary tilted frame.

The traditional method of scoring the RFT gave an unsigned, unweighed deviation score (USD) for each subject. The USD mean score was calculated by dividing the arithmetic sum of measured deviations of the rod, in degrees, from gravitational vertical by the number of trials as described by Witkin & Asch (11). This parameter gave a measure of how much the subject's judgement of the vertical depended on the tilt of the frame. This parameter is called field dependence. It is to be noted, however, that field dependence scores calculated by the traditional method neither gives information about the direction of the deviations nor estimates the response consistency of the subjects.

The new method of scoring the RFT was carried out for each subject using the procedure described in details by Nyborg (4) and Nyborg and Isaksen (5). The direction of deviation of the rod from gravitational vertical was recorded to calculate a "signed deviation" score. An account was kept of whether the rod was adjusted to the same side to which the frame tilted or to the other side. The "pure" effect of tilt of the frame on the final position of the rod (frame dependence parameter, φ) was calculated from the data on signed deviation of rod setting, in degrees, from gravitational vertical. The tendency of a subject to adjust the rod consistently to one side of gravitational vertical (constant deviation, μ) was noted. The tendency of a subject to see the rod as vertical even though it was still inclined towards its original tilted position (the "rod-starting-position effect", ρ) was recorded. Thus, the new method of scoring the RFT enabled the source of each subject's deviation to be traced and also gave an estimate of each subject's response consistency (σ), which was a measure of the "stability" with which the subject responded to comparable conditions of initial rod and frame tilt.

In order to assess the significance level of the φ -values, each subject's calculated φ-value was related to her estimated response consistency (σ) by the formula presented by Nyborg (4). If the φ-value was found to be significantly different from zero ($p < 0.05$), then the subject was classified as "frame dependent". The value obtained by this procedure was called the "weighed φ-score"; it provided an index of the degree of significant frame dependence with respect to the subject's response consistency.

d. Results

Table 1 shows the results of the RFT based on the traditional method of scoring the test. The scores of Turner girls with karyotype 45,X (11.82 ± 8.58) and Turner girls with other chromosome abnormalities (11.16 ± 7.62) were very similar and were therefore combined for statistical analysis. The USD score of Turner girls was significantly higher than that of their sisters. The USD score of the Nonsiblings was not significantly different from that of the Turner girls or of their sisters. The standard deviation (SD) of scores in Turner girls and in the Nonsiblings was approximately twice as high as the SD in the Sister group.

The groups were subdivided on the basis of their USD scores in Table 2. Scores greater than 8^o are considered to indicate extreme "field dependence" while scores less than 2^o indicate "field independence". 49 per cent of the Turner girls showed extreme field dependence while only 11 per cent of their sisters and 27 per cent of the Nonsibling control group had USD scores greater than 8^o. On the other hand, less than 1o per cent of the Turner girls showed field independence while more than 25 per cent of their sisters and of the Nonsiblings had USD scores below 2^o. Chi-square tests showed that the difference between Turner girls and their sisters were statistically significant ($x^2 = 9.34$, $p < o.ol$), while the differences between Turner girls and Nonsiblings or Sisters and Nonsiblings were not statistically significant.

Table 3 shows the unweighed scores for frame dependence (φ) and for response consistency (σ) in the RFT calculated by the new method of scoring the test. The φ scores of Turner girls with karyotype 45,X (1o.23 $\pm$ 8.99) did not differ significantly from the φ-scores of Turner girls with other karyotypes (9.5o $\pm$ 7.29), so the data were combined for statistical analysis. The mean unweighed φ - score of Turner girls was significantly higher than that of their sisters. The mean unweighed φ -score of the Nonsiblings was not significantly different from that of the Turner girls or of their sisters. It is to be noted that frame dependence scores obtained by the new method of scoring the RFT were smaller than the USD scores for frame dependence obtained by the traditional method because in the new method constant deviation (μ) and rod-starting-position effect (ρ) are subtracted from the φ - values (4).

Borderline statistical significant differences were found for mean σ-scores between Turner girls and either their sisters or nonsiblings, while the mean σ-scores for the sisters and the nonsiblings were nearly identical.

Table 4 shows the distribution of weighed φ-scores in the groups. 51 per cent of the Turner girls had weighed φ - scores that were greater than zero on five per cent level, i.e. they were significant frame dependent. 37 per cent of the sisters and 60 per cent of the nonsiblings were significantly frame dependent. None of the differences in significant frame dependence between the groups were statistically significant.

e. Discussion

An important aspect in studies on Turner girls is establishment of appropriate control groups so that the effect of the abnormal karyotype in Turner girls on their perception and performance can be determined. It must be noted that Turner girls typically have primary amenorrhoea and growth retardation in addition to an abnormal karyotype (3). Control groups should be established to permit the effect of the abnormal karyotype in Turner girls to be distinguished from the effects of retarded growth and abnormal sexual development. This was done in the present study by the use of two control groups. One was composed of sisters to the Turner girls. They had normal karyotypes and showed no abnormalities in growth or sex characteristics. Since Turner's syndrome is, to the best of our knowledge, randomly distributed in a given population, the sisters of Turner girls represent a random sample of normal subjects. The other control group was made up of unrelated girls with normal karyotypes but with primary amenorrhoea and growth retardation as seen in Turner girls. This group served as controls for the effects of abnormal sexual development and retarded growth on perception and performance in the RFT. All groups were of comparable age, so that possible effects of age on the outcome of the RFT were ruled out in the present study.

The main purpose of the present study was to obtain a better understanding of the "cognitional deficit" in Turner girls. This was accomplished by comparing the results of the traditional method and the new method of scoring the RFT. The outcomes of the analyses of the RFT data for Turner girls, their sisters, and nonsiblings by the traditional method of scoring the test and by the new method were quite different. Based on the traditional method, Turner girls appeared to be extremely field dependent compared to control groups. The new method of scoring the RFT showed, however, that Turner girls were not significantly more frame dependent than the controls. Evidently, field dependence in girls with Turner's syndrome measured by the traditional method does not represent significant effects of frame tilt on their behavior in the RFT. On the contrary, the new method of scoring the RFT indicated that Turner girls show high response inconsistency that leads to their high field dependence scores. Thus, a characteristic feature of the "cognitional deficit" shown by Turner girls in the RFT was response inconsistency rather than significant frame dependence or field dependence.

Our findings show that the traditional method of scoring the RFT is inadequate mainly because it fails to pin-point the source of the deviations in the test and mistakenly treats all deviations as though they were due to frame dependence. The new method of scoring the RFT differentiates between errors due to "pure" frame dependence, constant deviation, rod-starting-position effect, and response consistency, and thereby provides a more accurate account of the factors responsible for a subject's performance in the test. It is obvious that RFT performance can only be fully understood on the basis of multidimensional considerations.

TABLE 1

FIELD DEPENDENCE SCORES (USD) IN THE ROD-AND-FRAME TEST IN TURNER GIRLS, THEIR SISTERS, AND NONSIBLINGS, (AFTER NIELSEN, NYBORG, & DAHL, 1976)

Group	USD	
	Mean	SD
Turner girls	11.47	7.9o
Sisters	4.59*	4.7o
Nonsiblings	7.67	8.14

* = significantly different from Turner girls at p < o.o5.

TABLE 2

DISTRIBUTION OF FIELD DEPENDENCE SCORES (USD) IN THE ROD-AND-FRAME TEST IN TURNER GIRLS, THEIR SISTERS, AND NONSIBLING CONTROLS. SCORES GREATER THAN 8° INDICATE EXTREME FIELD DEPENDENCE WHILE SCORES LESS THAN 2° INDICATE FIELD INDEPENDENCE

GROUP	USD SCORE					
	$\leq 2^{o}$		$> 2-8^{o} <$		$\geq 8^{o}$	
	N	%	N	%	N	%
Turner girls	4	9	19	42	22	49
Sisters	5	26	12	63	2	11
Nonsiblings	4	26	7	47	4	27

TABLE 3

UNWEIGHED SCORES FOR FRAME DEPENDENCE (φ), AND RESPONSE CONSISTENCY (σ) IN THE ROD-AND-FRAME TEST IN TURNER GIRLS, THEIR SISTERS, AND NONSIBLINGS

Group	φ - scores		σ -scores	
	Mean	SD	Mean	SD
Turner girls	9.84	8.o4	7.35	8.13
Sisters	3.97**	5.o9	3.93*	2.o5
Nonsiblings	6.73	8.61	3.43	2.25

* = Borderline significant difference compared to Turner girls ($0.1 > p > 0.05$)

** = Significantly different from Turner girls at $p < 0.05$.

TABLE 4

DISTRIBUTION OF SIGNIFICANT FRAME DEPENDENCE ($\varphi \neq o$) AND FRAME INDEPENDENCE ($\varphi = o$) SCORES IN THE ROD-AND-FRAME TEST IN TURNER GIRLS, THEIR SISTERS, AND NONSIBLINGS

Group	$\varphi \neq o$		$\varphi = 0$	
	N	%	N	%
Turner girls	23	51	22	49
Sisters	7	37	12	63
Nonsiblings	9	6o	6	4o

SUMMARY OF PART III

In part III were presented works applying the new method. In the first experiment material from a previous experiment on the meaning of light intensity for perception of verticality was re-analysed; the re-analysis gave no reason to change the original conclusion, namely, that changes in light intensity within a wide range do not influence adjustments of a rod to an apparent vertical position.

In the next experiment was demonstrated that the frame *is* the effective stimulus for the φ-parameter value because changes in the frame structure were followed by corresponding variations in the φ-value. The constant error (μ), and rod-starting-effect (ρ) were shown to be independent of changes in φ-values. It was finally shown that the "unsigned error" scoring method and the new method give different measures of frame dependence; the differences were discussed.

In a six year study on girls lacking sex chromosome material it was found - using the "unsigned deviation"scoring method - that such girls, generally speaking, scored extremely field dependent (Nielsen, Nyborg & Dahl, 1976). Analysis with the new method demonstrated that the girls lacking sex chromosome material are not significantly more frame dependent than could be expected by chance; on the other hand their response consistency measure (σ) seems to indicate a remarkable perceptual "instability" in their performance in the RFT. The different results obtained with the "unsigned deviation" scoring method and the new method were ascribed to artifacts of the former.

PART IV

THEORETICAL CONSIDERATIONS

CHAPTER VIII

SPATIAL ORIENTATION, RFT PERFORMANCE, AND THE FIELD DEPENDENCE DIMENSION

CHAPTER VIII

SPATIAL ORIENTATION, RFT PERFORMANCE, AND THE FIELD DEPENDENCE DIMENSION

1. INTRODUCTION

In previous chapters we have discussed the effect of changing tactile stimulation, light intensity and the geometrical structure of the frame on perception of the vertical in the RFT. Furthermore, a RFT study on girls lacking sex chromosome material (Turner girls) was presented in which a possible effect of this chromosomal condition on perception of the vertical was observed. Finally, we presented some methodologically works, and gave examples of applications of the newly developed method for analyzing performance in the RFT.

Generally speaking, up to the study on Turner girls, we had been loyal to the field dependence frame of reference. We had accepted the basic ideas of the Witkin group as relevant for interpreting RFT performance. We had not commented directly on the theoretical status of the field dependence dimension as such, although we had modified its quantitative basis. Instead of using the USD scoring method we operationalized field dependence in the RFT as frame dependence measured by the φ-parameter values. We also weighed the φ-parameter with respect to the response consistency (σ) of the subject, thereby being able to classify our subjects into persons whose RFT behavior was significantly influenced by frame tilt and persons whose behavior was not so influenced.

The theoretical basis for this weighing procedure has not yet been discussed in detail. This will be done in the present part of the treatise.

The study on Turner girls clearly showed us that RFT performance is multi-dimensional and cannot be adequately described in terms of frame dependence alone. Such recognition necessarily have serious consequences for the theoretical status of the one-dimensional field dependence interpretation of the RFT behavior. In the following, we present a multi-dimensional approach as basis for interpreting the RFT performance.

In so doing, we hope to be better able:

1. to interprete complexity of measured RFT performance.

2. to incorporate the subject's response parameters in a more general frame of human spatial orientation.

3. to apply a more individual-centered research strategy.

4. to further an understanding of "*how*" the single subject functions in the RFT, i.e. to actualize a functional approach, and finally,

5. to enlight from a new point of view some etiological factors that can be considered as important for an understanding of "*why*" the subject functioned as she did.

These aims are - to put it mildly - ambituous. On the other hand we can see no better way to a better understanding of the intricate RFT performance than an attempt to widen the basis provided by Witkin and his coworkers.

Our attempt to change the approach to RFT behavior has four points of departure: 1) we consider performance in the RFT as a case of vertical orienting performance; 2) we consider the subject as an information processing system; 3) we consider the subject's RFT performance with the help of a cybernetic model, and finally, 4) we accept the paradigm that the proper study of individual persons is the study of single individuals each considered as a total universum not only to be studied in the light of group means.

We are partly indebted to Bischof for our approach to RFT performance. He has thoroughly discussed various aspects of human spatial orientation, and especially the vertical constancy performance (Bischof, 1966*a*; 1966*b*; 1966*c*; Bischof & Scheerer, 1970; Bischof, 1974). Our approach differs from Bischof's however on some theoretical points that will also be discussed in the following.

2. ON DEFINING ORIENTATION

The capacity for orientation is common for most living organisms and it is a basic precondition for survival (Gibson, 1966). Without orientation it would be impossible for an organism to search for food, to avoid danger, or to mate.

It is difficult, however, to give a general definition of orientation because the concept can be applied in many quite different connections. One can be oriented in time as well as in space or in ways that are not primarily related to time or space (e.g. "reality contact" in psychiatric patients). Thus, the term "orientation" is most meaningful in a particular context.

The context for the present treatise is perception in space and we will therefore focus on spatial orientation. More specifically we are interested in perception of verticality, and our subject is accordingly perceptual orientation to the vertical.

Regarding distinctions between orientation and localization Sandström (1951) remarks that a number of authors use the term "orientation" where "localization" would be more adequate and vice versa. Thus in a study of verticality Neal (1926) speaks about visual localization of the vertical while Asch & Witkin (1948) speak about orientation. Sandström himself prefered the term "orientation" to "localization" on account of the stronger affective character of the former (Sandström, ibid. p. 182); he recognized the fact that orientation presupposes quite a different, more intense and more vital personal commitment, and argued that disorientation can hardly be experienced without concomitant strong emotions and affects. Since some subjects show quite intense personal commitment to their responses in the RFT situation, we chose the term "orientation".

Sandström furthermore stresses that to be oriented is a state while orienting oneself implies a process (ibid., p. 177). We will be especially interested in orienting.

As mentioned in Chapter I, most upright persons can easily adjust a rod to or near to a gravitational vertical position in the absence of a frame in their field of vision. Addition of an upright frame in their field of vision usually makes rod adjustment even more exact. If the framework tilts, as in the RFT situation, the accuracy of the verticality estimation deteriorates for most persons, as demonstrated in Chapters II to VII. It might be said that the optic information from the contours of the tilted frame are inadequate information for perception of the vertical; for so-called "frame dependent" subjects, the information is directly misleading. In such situations some subjects apparently become disoriented.

However, according to Sandström (ibid.) one "... cannot speak of disorientation until the individual is conscious of this" (p. 155); very often this state is experienced with a remarkable suddenness and "break down" of the orientedness, caused by the fact that the continual stream of stimuli which preserves orientedness has been cut off or that the frame of reference has become so complicated or unusual that it exceeds the ability to maintain orientedness. Defined this way disorientation is said to be accompanied by a vigorious experience of uneasiness. Some subjects in the RFT report total loss of their spatial frame of reference, i.e. they can no longer tell what is "up" from what is "down" and feel considerable discomfort thereby. This experience is uncommon, however, at least with the transportable RFT apparatus used in some of the present studies. Consequently, Sandström's definition of "real" disorientation finds little application in the present context. On the other hand, Sandström cites Angyal (1930) for a useful discrimination between "real disorientation" and "illusion of orientation"; the latter pertains to the situation where one's perception of a spatial relation does not correspond to realia. This is often the case in the RFT situation. Illusion of orientation in the RFT can be defined as non-veridical perception of the vertical caused by the tilted frame, and the extent of "illusion" can be measured by the new method and can be tested for significance. Accordingly, the term "illusion of orientation" rather than "disorientation" is used as a counter concept to orientation in most cases in the present treatise. The illusion of orientation can convincingly be demonstrated in subjects, even if they "know" that the frame tilt influences their rod adjustments (Nyborg, unpubl.).

To be quite clear on these points, Sandström defines orientation ability as the "ability to resist stimuli that exercise a disintegrating effect on the state of being oriented", disorientedness expresses the mental state which arises when the frame of reference has lost its validity, *and* a characteristical feature of this state is, that the organism ceaselessly strives to regain a state of being oriented. In contrast to "real disorientation", when "illusion of orientation" occurs one might expect that the subject shows no sign of "ceaselessly striving to get a more veridical perception". As will be seen later, such distinctions are in some compound cases difficult to make.

3. THE FIELD DEPENDENCE DIMENSION

The following discussion will be concentrated on the two components mainly responsible for perception of the vertical in the RFT, namely, the optical and the vestibular component. First we discuss how Witkin and collaborators consider these two components.

The optical component is most important to Witkin. Theoretically, his approach stems from gestalt-inspired considerations about field structures. Parts in a perceptual field are considered as narrowly related to the field structure as a whole. Parts are usually defined as a rod, a geometrical figure, or one's own body, and the "field structure as a whole" in the RFT is to be understood as the surrounding *visual* field (Witkin et al., 1975, p. 5-7).

Since Witkin uses the term "field" in the RFT to mean the surrounding *visual* field, "field dependence" must be taken to mean "visual field dependence" in Witkin's work.

Of course Witkin and collaborators also were aware of the information from the "felt position of the body" (p. 5), and they saw RFT performance also as "... the consequence of the conflict created between the standards of uprightness *derived from the surrounding field* and the standard *derived from within* the body" (our underlinings). But there were serious problems with Witkin's concept of "field dependence" due to his separation of "out-there"-visual standards and "within"-bodily standards. According to Witkin, gravitational forces acting on the vestibular and the somesthetic systems are the basis for the *standard derived from within the body*, while optical forces acting on the visual system are the basis for the *standard derived from the surrounding field*. It is evident, however, that gravitational forces and optical forces both act on the body from "without" while neural activity in the vestibular and somesthetic systems as well as in the visual system act "within" the body. It is therefore incorrect to speak of visual standards as arising "out-there" and of gravitational field forces arising "within" the body as Witkin did (Witkin et al., 1962).

Furthermore, Witkin and coworkers wrote that field independent subjects "... seem able to apprehend the body as an entity discrete from the surrounding field, which, in people at the other extreme, exerts a profound effect on their perception of body position" (Witkin et al., 1975, p. 6). The gestalt-view is thus also generalized to the "felt body". Thus, according to Witkin et al. (1975), the body can be separated from the surrounding visual field in the field independent case by reference to "information from within". Mainly due to the somewhat unclear status of information from "within" and "without", one may also wonder how this "body-separation-performance" should be understood.

Problems also arose due to the term "dependence". According to the field-dependence school-of-thought, field dependent people are dependent on the "surrounding visual field" while field independent people are independent of the visual field. So far so good. But the field independent person in the RFT is of course "dependent" on the gravitational "field" as she is said to disregard the visual field and thus necessarily takes reference to the force of gravity. She simply has no other choice in order to maintain her orientation. We are thus logically forced to speak now of "visual field dependence" and "gravitational field dependence" unless it can be shown that the field independent person is a person that is independent of the gravitational field as well as of the visual field. Quite aside from the difficulties of proving this the problem must be considered that the conflict postulated by Witkin to occur between the visual and the bodily standards completely looses its meaning. In any case the field dependence terminology runs into trouble.

Furthermore the general statement that the surrounding visual field exerts in field dependent subjects a "profound effect on their perception of body position" must according to our protocols be questioned. A number of our very "field dependent" subjects could not report of any profound "surrounding field effect" on their perception of body position. Although such subjects *can* be found, our point is here that they are not characteristic for all field dependent subjects.

One reason for the remarkable "weak" interpretation of the "bodily" side of the RFT performance in the field dependence school-of-thought may be found in some early considerations of the Witkin group. As already mentioned, Witkin had rejected the hypothesis that the field dependent - independent responses could be explained by differences in "body-sensitivity". Instead he prefered an idea which later became *the* basis for understanding field dependent performance . This idea was that such performance should be interpreted as lack of capacity to "overcome an embedding context", thereby meaning a visual surrounding context. Accordingly field independence was defined as capacity to "...overcome the surrounding field or to separate an item from its context" (Witkin et al., 1954). Witkin's idea put special emphasis on the visual aspects of the test.

Rejection of the "body-sensitivity" hypothesis led considerations away from the role of the vestibular information and from interaction between visual and vestibular information. Witkin's poorly formulated notion of person-specific "conflict" between "body-standards" and "visual uprightness-standards" did, however, leave the door open for considerations of the interaction between the visual and vestibular systems. These examples of problems pertaining to Witkin's school-of-thought are by no means exhaustive. We consider it more important, however, to turn now to a constructive attempt to overcome the difficulties inherent in the works of the Witkin group. We will therefore in the following attempt to interpret performance in the RFT more precisely than has been done previously.

4. A FIRST STEP TOWARDS A RE-INTERPRETATION OF PERFORMANCE IN THE RFT

In the following an attempt will be made to interpret performance in the RFT without taking recourse to field dependence terminology. Thus the capacity for overcoming "Embeddedness", so important for the whole concept of field dependence, will not be in the focus of the discussion. Instead performance in the RFT will be considered as a case of vertical orienting performance. Vertical orienting performance can be understood as the processes by which the organism can compensate for disturbances in object-related stimulus parameters in order to maintain or establish adequate vertical orientation, i.e. where subjective vertical and the gravitational vertical merge.

Important factors in vertical orienting performance are optical and gravitational cues. In the RFT situation the optical factors are defined by the rod and the frame; the tilted contours of the latter give potential illusory information about physical vertical and horizontal axes in space. Gravitational factors are defined by the direction and the force of gravity acting on the vestibular and the somesthetical systems.

As the frame contours are tilted 28 degrees off physical vertical and horizontal in the RFT, a non-correspondance with regard to direction in space between optical and gravitational cues is to be found. This non-correspondance can have different effects for different subjects because the problem of incongruence between the information about physical vertical from the optical and the vestibular somesthetical perceptual systems can be solved in different ways; some subjects may put much emphasis on optical information, and thus suffer "illusion of orientation", while other subjects may put emphasis on the vestibular-somesthetical information, and thus show complete correspondance between subjective and gravitational upright. As will be apparent later a number of other solutions to the problem of handling incongruent information are also possible, making for multi-dimensional considerations.

When behavior in the RFT is considered as a case of vertical orienting performance, optical information based on the tilted contours of the frame may be seen as a "disturbing" factor, and the "disturbance" is somehow to be opposed by the subject if her vertical orientation is to be maintained. It can also be said that the extent to which the subject "weights" the visual afference against the vestibular afference with regard to direction determined to a great extent how successful her vertical orienting performance will be in the RFT.

Defining behavior in the RFT this way has several advantages. First of all, we avoid the difficulties of defining "inner" and "outer" *fields*; we simply talk about information and specify the perceptual system in which they arise. Secondly, the term "dependence" in the sense of passive attachment to the "outer" visual structure or field can be converted into more functional and dynamical considerations of *how* a given subject weights the visual afference relative to the vestibular-somesthetic afference. By doing so the vestibular information may be better represented in the considerations of RFT behavior. By focussing on *different* conflict solutions in different subjects in the RFT, it also becomes possible to get a better understanding of the complexity of the performance in the RFT, as will be demonstrated later.

Bischof (1966*a*; *b*; *c*; Bischof & Scheerer, 1970; Bischof, 1974) emphasised and to some extent re-formulated a number of principles for how the subject may handle spatial information. The following interpretation of performance in the RFT relies heavily on Bischof's painstaking analyses. In some aspects we will, however, deviate from Bischof's approach. We will thus not define performance in the RFT as vertical constancy performance, but as mentioned previously as vertical orienting performance (for discussion of ambiguity of the concept of "perceptual constancy", see Poulsen, 1972, p. 73 ff.). Bischof also consider ontogenetic changes or interindividual variability as less interesting to study than general characteristics (Bischof & Scheerer, 1970, p. 105). We will concentrate primarily on interindividual variability and also consider ontogenetic changes, although the latter aspect will receive more attention elsewhere (Nyborg & Nielsen, 1976*b*).

Besides considering interindividual variability we also aim at incorporating some aspects of intra-subject variability into the interpretation of RFT performance as a case of vertical orienting performance.

We have found it advantageous to develop our interpretation with the help of biocybernetics. We will therefore in Chapter IX give a brief introduction to some general cybernetic aspects and also present a short introduction to the organism considered as an "information processing" system. In these ways we hope to further a more precise understanding of the RFT vertical orienting performance.

CHAPTER IX

THE ROD-AND-FRAME TEST AND VERTICAL ORIENTING PERFORMANCE

CHAPTER IX

THE ROD-AND-FRAME TEST AND VERTICAL ORIENTING PERFORMANCE

1. INTRODUCTION

In this chapter we aim at a more precise formulation of performance in the RFT. We will present a number of functional types of information processing. We also present a cybernetic model for understanding performance in the RFT.

Cybernetics is according to Ashby (1971) a "theory of machines". A "machine" is - to avoid misunderstanding by people hypersensitive to man-machine analogies - to be understood essentially as a system "...whcse behaviour is sufficiently law-abiding or repetitive for us to be able to make some prediction about what it will do" (p. 225). In cybernetics one does not ask "what *is* this system, machine, or thing?" Rather the question is "what does it *do*?"

"Cybernetics is thus functional. In cybernetics special attention is given to the flow of information" (Ashby, ibid. p. 110).

Cybernetics is particularly well-suited for considerations on large and complex systems such as those that underly behavior. Cybernetics can be used to ask "what determining and controlling factors are *the important* ones for how the "system" works." Cybernetics can also be used to consider all the possible behaviors specific to a certain system. We will use cybernetics to study the possible behaviors to keep vertical orientation intact. It will be used to ask about how a particular individual conforms to her restrictions and controls in the RFT. Attention to individual performance is of special importance in the present treatise.

2. THE AUTHOR'S FORMULATION ON VERTICAL ORIENTING PERFORMANCE IN THE RFT

Systematic changes in object-related stimulus parameters often can be compensated for in such a way that we still have a veridical perception of the object: in the RFT the subjective verticality estimation usually does not change at random with systematic variations in frame tilt indicating that the organism is somehow able to compensate for such systematic variations. In case the subjective and the gravitational vertical coincide we speak of adequate or veridical orienting performance. On the other hand if the rod adjustment is completely influenced by systematic changes in frame tilt we say that non-veridical orienting performance occurs.

We will now take a closer look at vertical orienting performance in different situations starting with a relatively simple one. An upright positioned subject is required to adjust a luminous rod by remote-control to what appears to be upright in an otherwise darkedned room without touching it. As seen in Chapter I most subjects can perform this task with surprising accuracy, i.e. within $\pm$ 2 degrees. This is apparently so because 1) the physical tilt of the distal object (the rod) is causally related to the tilt of its perceived contours in its retinal representation, and 2) because the nervous system somehow takes into account the angle between the tilt of the distal object and that of a retinal coordinate.

We have then two aspects of vertical orienting performance as symbolized graphically in *Figure 1*. The first is the rela-

Insert Figure 1 about here

tion between the physical tilt and its retinal representation: in our case the only causal bridge between the distal object and its phenomenal correlate. The second aspect is the vertical orienting performance to be accounted for by central-nervous mechanisms to be considered later. In our case the subjects' head position was gravitational upright. In everyday life such ideal conditions are not always present. Very often

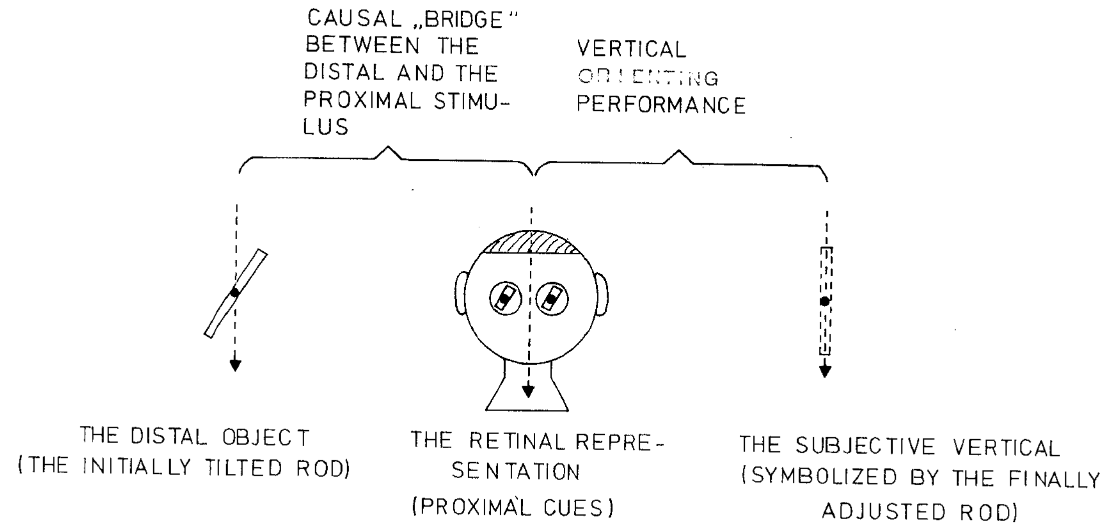


FIG. 1 The vertical orienting performance of adjusting a rod to an apparent vertical position in a dark room without touching it.
(Punctuated line = direction of gravity)

we perceive the surrounding world with our head tilted but nevertheless with considerable accuracy.

In *figure 2* is depicted a situation in which a tilted subject attempts to adjust a rod to apparent vertical.

Insert figure 2 about here

Her head is in our case tilted exactly the same number of degrees as the distal object (the rod) is tilted off gravitational vertical, say 28 degrees. Considered in retinal coordinate terms it can be seen from *figure 2* that this situation corresponds to that in *figure 1* where the upright-positioned subject was confronted with the gravitationally vertical rod (for the sake of simplicity we will not here consider the compensating effect of the counterrolling of the eyes). The analogy can be generalized: If the subject takes into account only the proximal stimulus contours in estimations of vertical, then the causal bridge between the distal object and its retinal representation would be equivocal. This is so because if all possible distal object tilts were compensated by an equal tilt of the head (i.e. retinal tilt) the organism would be unable to decide what was up and down; and this is so for all possible head-object tilts. Any given proximal stimulus contour tilt relative to the retinal coordinate system can appear for a given physical object contour tilt. Thus, optical information alone clearly is not sufficient to enable a person to adjust a rod to gravitational vertical. Since people can in fact adjust a rod accurately or nearly accurately to a gravitational vertical position, there must be other information that they make use of. We think that this information arises mainly from the vestibular and somesthetic systems.

Thus gravity affects a number of sensory systems; and for example tilting the head causes information to arise from the

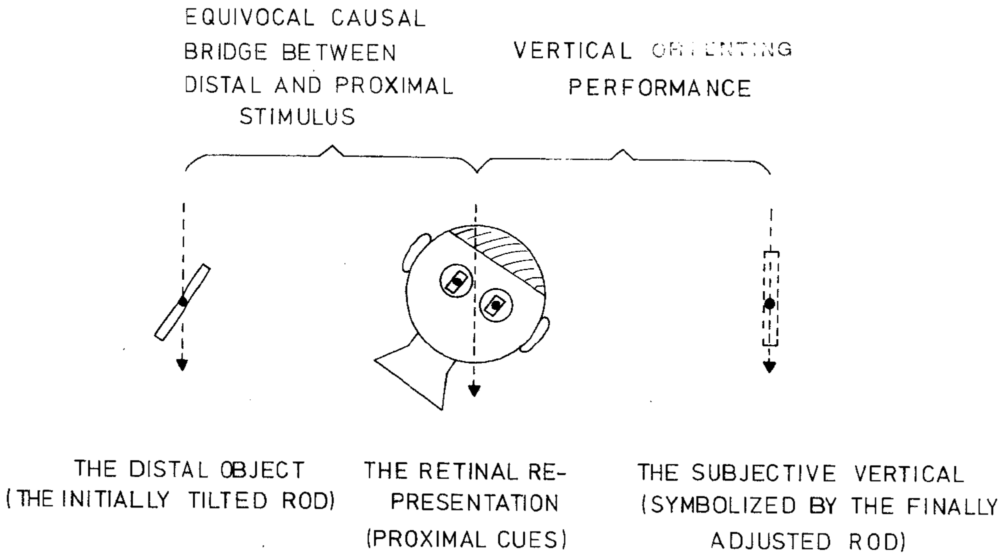


FIG. 2 The vertical orienting performance of a tilted subject adjusting a rod to an apparent vertical position in a dark room without touching it.

vestibular organs, from the skin senses, from muscles, and from joint receptors and so on.

In this way the organism, whether tilted or upright, learns about body position (and thereby also about the position of the retinal coordinate relative to gravitational vertical) from senses other than vision. Due to this process the organism can distinguish between "body upright - line tilted" conditions and "body tilted - line upright" conditions. The ability to make such distinctions is important for the vertical orienting performance, because thereby the equivocality of the optical information can be overcome.

The general problem of the vertical orienting performance is according to Bischof "how to analyze the veridical correspondance between the distal object and its phenomenal correlate despite the fact that the only causal bridge betweem them is disturbed unpredictably by the interference of a further variable?" This problem is schematized in *figure 3*.

Insert figure 3 about here

In the before mentioned example the variable to be compensated for was head tilt. We have already in Chapter I reviewed some of the evidence on effects of tilting the subject's body for accurate estimation of the vertical. Since the subject's body was kept gravitationally upright in most of our experiments, we will pay no detailed attention to body-tilt conditions in the present context. But it is important to note that while the independent disturbance in the before mentioned example was body tilt this variable may not have quite the same "disturbing" effects in RFT studies in which the subjects are upright, such as the studies to be discussed in the following.

Insert figure 4 about here

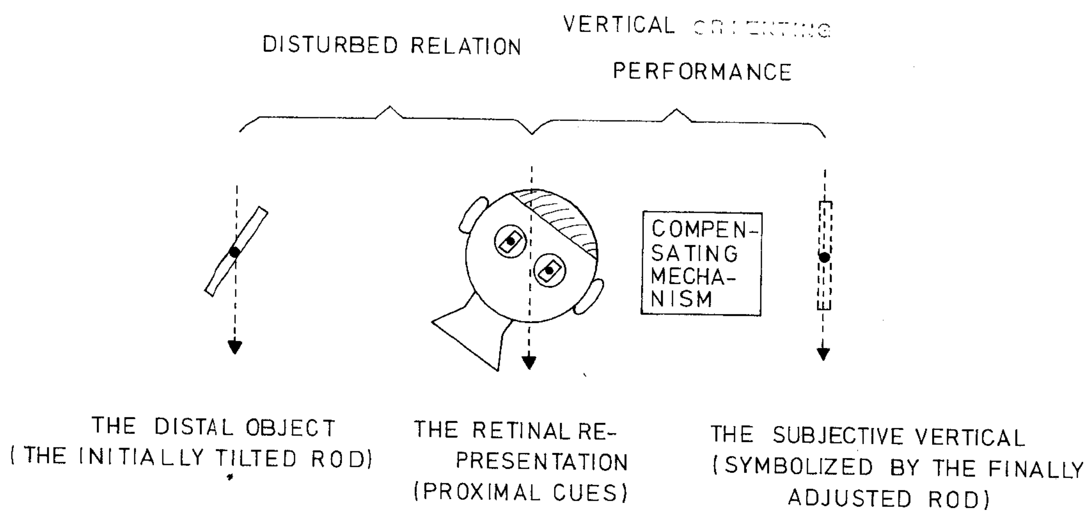
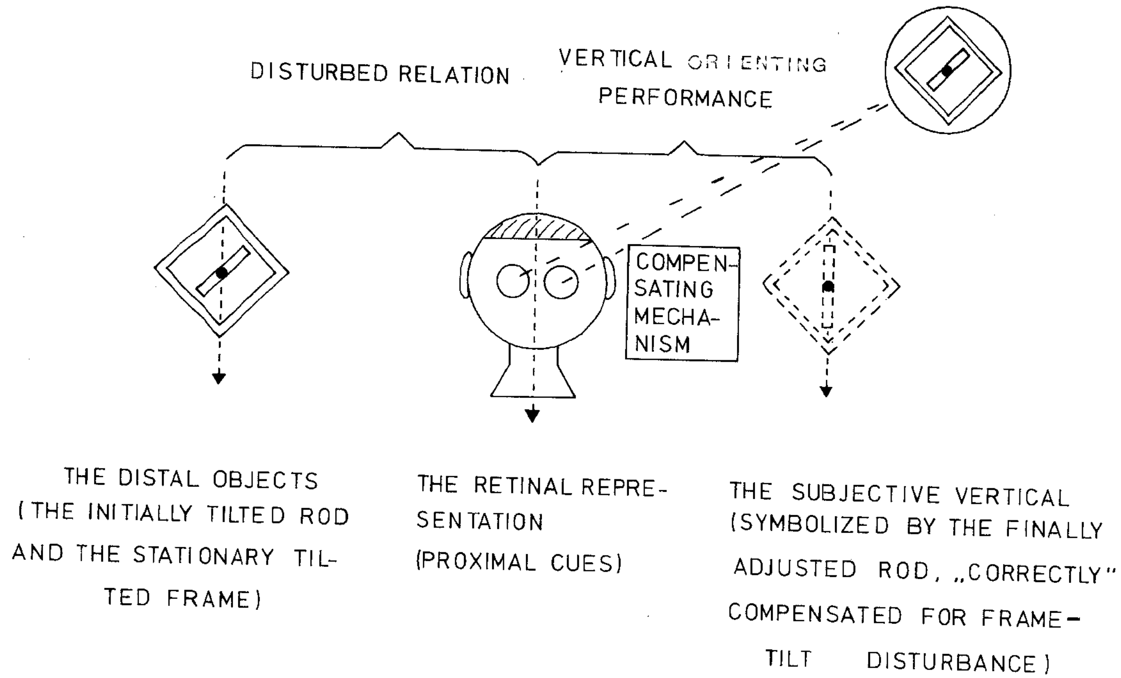


FIG. 3 The vertical orienting performance.

A postulated central-nervous mechanism compensating for body tilt disturbance; allowing for distinction between „head-up" and „head-tilted" and able to compensate for disturbances (in this case: head tilt).



<u>FIG. 4</u> The vertical orienting performance. A postulated central-nervous mechanism compensating for proximal frame tilt disturbance.

The primary disturbance to concern us here is the effect of the frame tilt. As seen in *figure 4* instead of tilting the subject we in the example tilted the main axis of the optical stimulus pattern in such a way that they no longer coincided with gravitational vertical or with horizontal. It will be remembered that the vertical orienting performance was defined as the capacity to establish a close correspondance between the objective and the subjective vertical despite unpredictable disturbance from a further variable; this definition can be extended to cover also performance in the RFT as a special case.

But before going into detail about this we first point to a very important difference between Witkin's interpretation of the performance in the RFT and our interpretation. Thus although the unpredictable disturbance in the example in *figure 4* is in Witkin's as in our interpretation caused by the tilted contours of the frame we differ radically in where the "disturbance" arises. Witkin considered the "disturbance" to arise in the distal area in form of "embedding field forces" exerted by the frame on the rod "out there" in the visual field to be overcome by the subject by "separating" the rod from the visual context, i.e., the frame. In contrast, we consider the disturbance to arise within the subject. Our interpretation is as follows: if the subject shows poor orienting performance in the RFT, it may be due to a "failure of calculation" in the compensatory mechanism. The *retinal representation* of the contours of the tilted frame, i.e., the *proximal* cues, is mistakingly taken as basis for the physical upright and horizontal axes. A subject doing this fails to adjust the rod to gravitational vertical. To be discussed later is *how* such a mistake will lead to calculation of a compensatory variable that will be insufficient to correct for the *proximal* frame tilt disturbance.

3. THREE MAJOR FUNCTIONAL TYPES OF INFORMATION PROCESSING IN VERTICAL ORIENTING PERFORMANCE

a. Introduction

We have earlier pointed out that it might be advantageous to study "how" the single subject performs as she does in the RFT. But if we want to study "how" the subject maintains an adequate orientation to the gravitational vertical despite the disturbing frame, we have to "go inside" the subject, i.e. to consider what information processing may be responsible for her specific vertical orienting performance.

Bischof has discussed some functional principles assumed to underly vertical orienting performance. Although the main emphasis in his discussion has not been on interindividual variability as such we believe that the principles can succesfully be applied in the study of individual differences.

We will review three of the principles. The first two will be presented only in those aspects that seem especially relevant for an understanding of behavior in the RFT, while the third principle will receive a more detailed treatment because of its direct focus on optic-vestibular interactional processes.

The three principles have been termed 1) the "compensation principle", 2) the "reconstruction principle", and finally, 3) the "correction principle" None of the principles presupposes logically each other as they pertain to different problem-aspects in the vertical orienting performance. Normally they co-operate, however, in securing adequate vertical orientation.

b. The compensation principle

The compensation principle has been discussed by Bühler (1922); Kardos (1928); Brunswik & Kardos (1929), and was later re-formulated by v. Holst & Mittelstaedt (1950) as the "re-afference principle". It can be connected to the vertical orienting performance in the following way. The perception of the verticality of a rod is dependent on the physical contours of the rod (the stimulus characteristics of the distal object) and also on the object-related stimulus parameters (the systematic disturbing variables which in our example on p.107 was body tilt).

The problem here is "how does the subject succeed in perceiving the distal object's stimulus characteristics correctly if the only information she has at hand is a joint product of the stimulus characteristics of the object AND the systematic disturbing stimulus variables?" The answer to this problem is that the organism "neutralizes the interference by repeating it with reversed sign." (Bischof, 1974, p. 158). The compensation thus implies two operations: 1) a representation of the interfering variable i tracked down (the compensatory variable), and 2) is fed into the afferent information in such a way that it ideally cancels out the interference.

A number of possible ways of tracking down a representation and feeding it into afferent information have been suggested. Of these we will only be concerned with the two afferent types. The first type is exemplified on p.107. When the body (head) tilts to the right the visual field appears in retinal coordinates turned to the left. By means of information from the vestibular apparatus (and somatoreceptors) the extent of head tilt can be decided and added to the retinal tilt in order to "turn the object representation" exactly so far back as the disturbance amounted to. Besides this function the compensatory variable can of course also serve as indication of head position as such. This is, of course a very simplified account of highly complicated central-nervous processes. Thus, experiments have for example shown that the statolith information seems most "reliable" with head-upright, the reliability decreasing as a function of head tilt and with minimal reliability in the area of 120-180 degrees (Schöne, 1964). In so far as the vestibular component is concerned, the reliability of the statolith information is important for an understanding of vertical orienting performance. If we accept the paradigm that the organism hunts for the most relevant information it follows that if the vestibular information becomes less relevant, the optical information takes over. This aspect will be discussed in more details later.

The other type of afferent compensation principle to be sketched here is assumed to take place when the disturbance cannot be "traced" directly. In such case the disturbing component might be "filtered out" due to object redundancy by means of a postulated filter system. If for example the subject's body (head) is tilted to the right, the retinal representation of the optical field goes to the opposite side. Through vectorial addition (see 125 ff.) of the tilt tendencies of all contours in the optical field a value is obtained that corresponds to body tilt but with sign reversed. The object redundancy expectation comes into play partly because the few contours that in a natural scene usually deviate from the gravitational vertical will not influence the tilt-mean considerably. And as will be seen from the discussion of the following vertical orienting principle the most prevailing optical axis in natural scenes coincide with the gravitational vertical and horizontal.

c. The reconstruction principle

The idea that the eye *itself* can mediate information about head position relative to gravity was not accepted in classical experimental psychology since neither the subject's own head nor the field of gravity is portrayed on the retina. According to Bischof (1974, p. 166) modern psychology (Gibson, 1950, 1955, 1966; Attneave, 1954; Kohler, 1961; Metzger, 1968) had, however, established that perceptual phenomena are not necessarily identical to the proximal stimulus configuration; it is sufficient that the proximal stimulation correlates to a certain extent with the distal object.

How close the correlation should be to assure adequate perception is difficult to say, but it is generally accepted that the number of stimulus characteristics of an object is usually considerable greater than the number of apparent stimulus characteristics with which they correspond. That this discrepancy normally does not disturb the perception of objects as such is possibly due to the fact that most objects regularly appear in certain "typical" contexts. The organism may react to a certain stimulus characteristic of the object while at the same time it makes use of "typical" object-related stimulus characteristics. According to information theory the principle can be described so that "...the perceptual system takes advantage of the *redundancy* within its physical surroundings in a manner that could be compared to the way one reconstructs the text of an abbreviated or distorted telegram." Bischof (1966*b*) therefore proposed the term "reconstruction processes" to characterize this kind of stimulus elaboration.

Formulated more plainly the reconstruction principle says that objects usually appear in certain regular contexts and that the subject can make use of this regularity. Gibson (1966) has given a number of examples. He argued that if a wide, almost plane expance is to be found in a natural scene it is most probably horizontal; the direction in which the texture density of sufficiently large retinal units changes is greatest is most probably corresponding to the direction of the pull of gravity. Koffka (1935) took point of departure in the conception that equilibrium-states can be observed with higher probability than any other comparable states in natural scenes. Oblong objects most probably stand upright, hang down or lie horizontally.

When the outline of a composition of such positioned objects is projected in the retina its retinal projection exhibits two main axis perpendicular to each other, the one corresponding to the gravitational vertical the other to the physical horizontal.

Besides redundancy expectations of the general nature sketched above one can also find more specific types. For example, smoke from a fire can be expected to go opposite the pull of gravity, while rain-drops fall according to it. Thus experiences in concrete situations may contribute to build up redundancy expectations.

A type of redundancy expectation that may have relevance for behavior in the RFT, is what Metzger calls "unwahrnehmbar vorhanden" (Metzger, 1954). This term refers to the fact that one can easily orient oneself in a dark room if the room is wellknown from previous stays under lightened conditions. Even in the dark one can without difficulties walk directly to the previously wellknown position of, say, a light contact, avoiding furniture without seeing it and so forth (see also Sandström, 1951). The room with its content is phenomenologically "imagined", "conscious", or just "at hand". If this "unwahrnehmbar vorhanden" shows up to deviate considerably from reality total disorientation may occur (Kleint, 1940).

These and numerous other examples illustrate the point that a number of "regularities" may be found under natural conditions; the reconstruction principle says that the organism relies upon such regularities to a certain extent in its perception. The meaning of this for performance in the RFT will be apparent in the next section.

According to Bischof the reconstruction principle contributes to most orienting performance but alone cannot explain it. Therefore, other principles probably are needed to explain behavior in the RFT in terms of vertical orienting performance.

d. The correction principle

The correction principle seems to be relevant for an understanding of the vertical orienting performance in the RFT. Under the name of "convergent detection", this principle has been considered in detail by Brunswik (1934, 1940, 1956).

The principle is based on the use of redundancy on the level of the sensory messages that refer to distal objects. Bischof (1974) has expressed the correction principle in the following way: "...the organism tries to keep on the safe side by seeking information from different "warrantors". The organism hunts for equivalent signals." The correction principle is related to the vertical orienting performance because of the high degree of equivalence between the messages from the optical and the vestibular systems. For any vestibular output there can be found an equivalent visual output, and any known motor or perceptual effect elicited by the vestibular organ can also be elicited by optical excitation (Bischof, 1974, p. 177), but more vice versa.

Our special interest in the correction principle is focused on those cases where the organism gets incongruent information from the vestibular and the optical system. Under these circumstances, differenct reactions are possible. Knowledge of different reactions to situations where incongruent information is at hand in sensory systems may provide a better understanding of the complexity of performance in the RFT.

At least three reactions are possible in situations to which optical and vestibular information are incongruent: a compromise solution, an alternative solution, or a simultaneity solution. These three possibilities will receive detailed treatment in the next chapter.

But first we will turn our attention to how the performance in the RFT can be interpreted in terms of the above mentioned functional information processes terminology. Later two ways of quantifying performance in the RFT will be suggested.

CHAPTER X

PERFORMANCE IN THE ROD-AND-FRAME TEST AND ITS INTERPRETATION IN INFORMATION PROCESSING TERMS AS A CASE OF VERTICAL ORIENTING PERFORMANCE

CHAPTER X

PERFORMANCE IN THE ROD-AND-FRAME TEST AND ITS INTERPRETATION IN INFORMATION PROCESSING TERMS AS A CASE OF VERTICAL ORIENTING PERFORMANCE

1. INTRODUCTION

In this chapter performance in the RFT is related conceptually to three types of information processing in vertical orienting performance.

2. ON RELATING PERFORMANCE IN THE RFT TO THE THREE MAJOR FUNCTIONA TYPES OF INFORMATION PROCESSING IN VERTICAL ORIENTING PERFORMANCE

a. The compensation principle and performance in the RFT

The compensation principle can account for the fact that "field dependence" scores increase when subjects are tilted (Witkin et al., 1954, 1962). Here, the compensation principle refers to the use made of information from the statolith apparatus which enables the tilted subject to determine the extent of head tilt and to "turn the object representation" as far back as is necessary to compensate for the degree of tilt. In that statolith information is maximally reliable with head-upright and decreases in reliability as the tilt of the head is increased (Schöne, 1964), the failure of tilted subjects to compensate fully for the tilt of their body as the degree of tilt of their head increases is to be expected. As the statolith information becomes less valid with increasing body tilt, the subjects probably rely more upon optical information (Gibson, 1966). Thus, a higher "field dependence" score for the tilted subject than for the same subject while upright may at least partly be explainable in terms of the compensation principle by assuming that the compensatory variable arising from the statolith apparatus is not sufficient for full compensation for body tilt. Of course, this assumption does not exclude other explanations as well. A number of important somatoreceptor variables also probably change with body tilt.

The effect of body tilt on scores in the RFT determined by the new method of scoring the test is not exactly known. However, preliminary analysis of data from experiments I and II in this treatise show that response consistency (σ) is lower in subjects tilted 28 degrees than in the subjects while upright for 45 of the 48 subjects tested. 17 of these subjects showed significantly lower response consistency while tilted than while upright, buth the results do not permit firm conclusions to be made about the possible relation between body tilt and response consistency in the RFT.

Expectations due to object-redundancy also come into play in the RFT. Most contours in natural scenes coincide with vertical and horizontal axes. Through vectorial addition of the optical axes, a mean value can be caluculated in the central-nervous system and a few contours deviating from the mean might be "filtered out". In the RFT situation, however, vectorial addition of the optical axes gives a mean value that deviates considerably from the values normally obtained in everyday life. In this way, the frame axes provide information that departs from what would be established in everyday life. The filter mechanism is deceived because the mean value does not coincide with what used to be gravitaionally upright and horizontal. Consequently, the value of the compensatory variable will be inadequate.

Some information on the speed at which the compensation mechanism can operate (can be "retuned") was obtained in our study on Turner girls. In that study we asked subjects that seemed to be responding "strangely"to take their head out of the transportable RFT apparatus and then to adjust the rod to a gravitational vertical position. With their head out of the box, and thereby with all the usual gravitationally vertical contours such as edges of windows, doors and walls in view, they could promply adjust the rod to a perfect or nearly perfect vertical position. However, as soon as they placed their heads in the test apparatus again and thereby had their vision restricted to the tilted frame, they were no longer able to adjust the rod to a vertical position. Thus, the compensatory mechanisms were affected ("retuned") in a matter of seconds. We do not know, however, whether the changes in the compensatory mechanisms affected primarily the frame parameter (φ) or response consistenc (σ) in the Turner girls.

b. <u>The reconstruction principle and performance in the RFT</u>

Objects usually appear in "typical" contexts and when these are "known" to the subject (the redundancy expectations) a few of the stimulus characteristics of the object suffice for the subject to orient properly to the object. The reconstruction principle applies particularly in situations where information is i complete and/or ambiguous such as in the RFT.

Thus, the frame is an incomple and ambiguous substitute of a natural scene. We nevertheless find that most subjects' verticality estimations are influenced when this simple configuratio is tilted away from the gravitational vertical. From Gibson we learned that if in a natural scene is found a wide, almost plan expance, it is most probably horizontal (Gibson, 1966); from Koffka (1935)we learned that oblong objects in retinal projection most probably exhibit a gravitational vertical axis and a horizontal axis perpendicular to it.

Thus, when only the tilted frame is presented, its axes may be mistakenly "reconstructed" by some subjects as "correct" representations of vertical and horizontal. In such subjects the reconstruction principle may be very strong, since, as seen in some Turner girls, the subjects may know that the frame is not upright but they nevertheless cannot adjust the rod to an upright position.

According to the reconstruction principle the frame can be thought of as providing stimulus characteristics of the axes of a natural scene that some subjects use to reconstruct the complete scene with regard to the misleading optical components of the scene. We might accordingly expect to find individual differences in "strength" of redundancy expectations behind the observed differences in RFT performance. Considerations of some possible reasons for differences in strength of redundancy expectations will be given in Chapter XI.

c. The correction principle and performance in the RFT

The following discussion is based on three propositions.

1) According to the correction principle the organism hunts for equivalent information from different perceptual systems in order to relieve the doubt.
2) There is a high degree of equivalence between vestibular and optical information.
3) In the RFT situation, optical and vestibular information are incongruent.

In the following, we consider the response possibilities available to a subject in the RFT. We agree with Gibson (1968) that a subject"must either accept the visual information and reject the postural, or accept the postural information and reject the visual, or alternate between the two, or compromise between the two. Of course, he may sometimes be just confused. All of these outcomes show up in the results..." (p. 297).

α. Compromise solutions

A compromise solution is one in which the organism composes a mean between incongruous (in our case optical and vestibular) information.

Depending on the situation and the organismic conditions, the mean can be put toward optical or vestibular information. Clear-cut examples of compromise solutions have been found in experiments carried out in fish (v. Holst, 1950). Some fish species swim with their body tilted, instead of swimming with the dorsal side upwards, when light reaches them from a side instead of from above. In these fish orientation is a compromise between optical and vestibular information. Surgical removal of the vestibular system leaves the fish entirely dependent upon optical information for orientation.

Examples of compromise solutions can also be found in humans in the RFT. Thus, when optical and vestibular information no longer coincide with regard to gravitational vertical, some subjects seem to "compose a mean between the two incongruent informations". Here, the phrase "subjects seem to compose a mean between the incongruent informations" is intentionally abstract. It is used to refer to a highly hypothetical conceptualization of a large unknown process by which the organism may be able to decide veridically on directions in space. V. Holst (1950) made a vectorial model of how a fish may "compose a mean" between incongruent optical and vestibular information. Later Bischof & Scheerer (1970) presented a more sophisticated model by which the principle of "composing a mean" in the vertical orienting performance in human beings was illustrated. Their model is used here, modified to the purpose of illustrating performance in the RFT.

Insert figure 5 about here

In *figure 5a* the square signifies the retinal representation of the tilted frame, and the broken lines indicate the retinal meridian. We will now require of the system that it can estimate pair-wise - "the one depending on the other" - indications for direction of verticality and that it can weigh the different visual "suggestions" on the basis of their probable reliability. Each side of the frame in question is identical to the other three, and accordingly they have the same directional weight as symbolized by vectors I-IV having the same length. At this stage, the system probably establishes a provisional indicator of verticality. In our system the vector V is a representation of the "pure" vestibular vertical, i.e. here defined operationally as the final rod adjustment in a trial where the frame was not presented.

The length of V symbolizes its relative weight and is of course dependent on the arbitrarily chosen length of the other vectors.

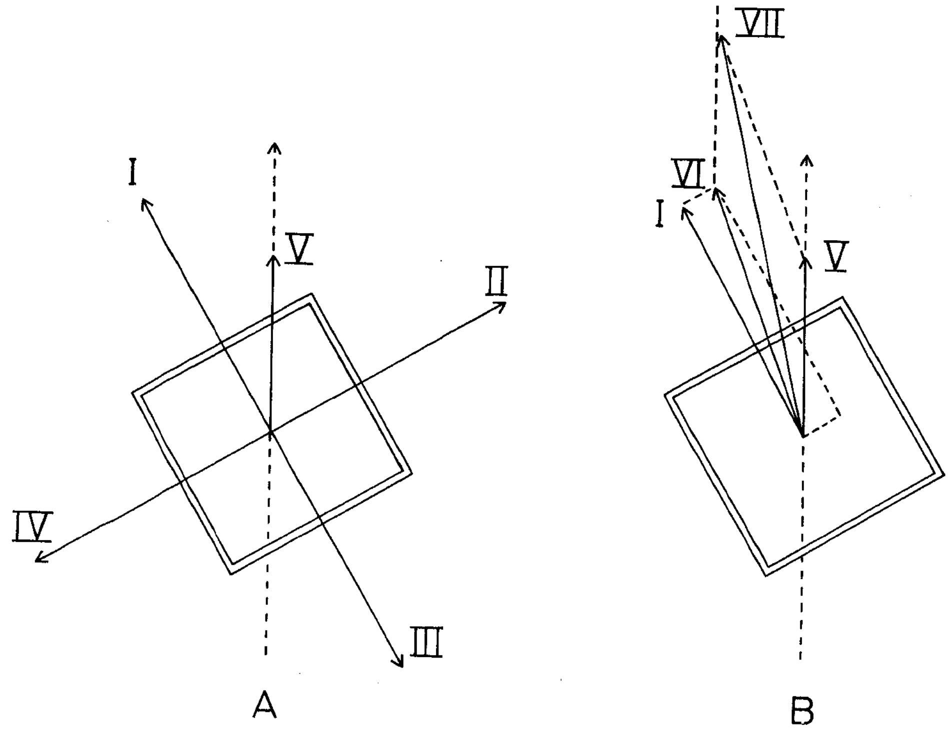


FIG. 5 A POSTULATED VECTORIAL MODEL FOR „COMPOSING A MEAN" BETWEEN INCONGRUENT OPTIC AND VESTIBULAR INFORMATIONS.

(For explanation: see text; adapted from Bischof and Scheerer, 1970, and modified)

On the basis of the "pure" vestibular vertical it is decided which of the four visual "suggestions" is to be followed. According to *figure 5b* this is done in the following way: based on the fact that the four pronounced visual "suggestions" have different angles to the vestibular upright (V) and on the assumption that the length of the optical vectors are dependent on the angle with which each of them deviated from the vestibular vertical - then the further away the optical vector is from the vestibular vertical the more it is shortened. The resultant vector (VI) symbolizes the most favorable final "suggestion" from the optical system regarding the vertical direction. The last performance of the system is now to calculate the apparent vertical direction (vector VII) by extracting the resultant between the final optical "suggestion" (VI) and the vestibular vertical (V): this resultant symbolizes final rod adjustment position reflecting the "subjective vertical".

The principles in Bischof & Scheerer's model (ibid.) should only be taken as a description of qualitative connections; the vectorial addition only serves an illustrative purpose. The model depicted in *figure 5a* and *5b* is based on a "feed-forward" principle as demonstrated in *figure 6*.

Insert figure 6 about here

The model can also be considered as functioning according to a "feed-back" compensation principle where the apparent vertical itself *could* serve as the provisorial indicator of verticality instead of the vestibular vertical. This principle is illustrated in *figure 7*. Bischof & Scheerer (1970) consider the last principle as the most probable, and presented evidence to support this hypothesis. *Figures 6* and *7* illustrate the difference between feed-forward and feed-back principles graphically. The functions of such models will be described in detail in Chapter XI.

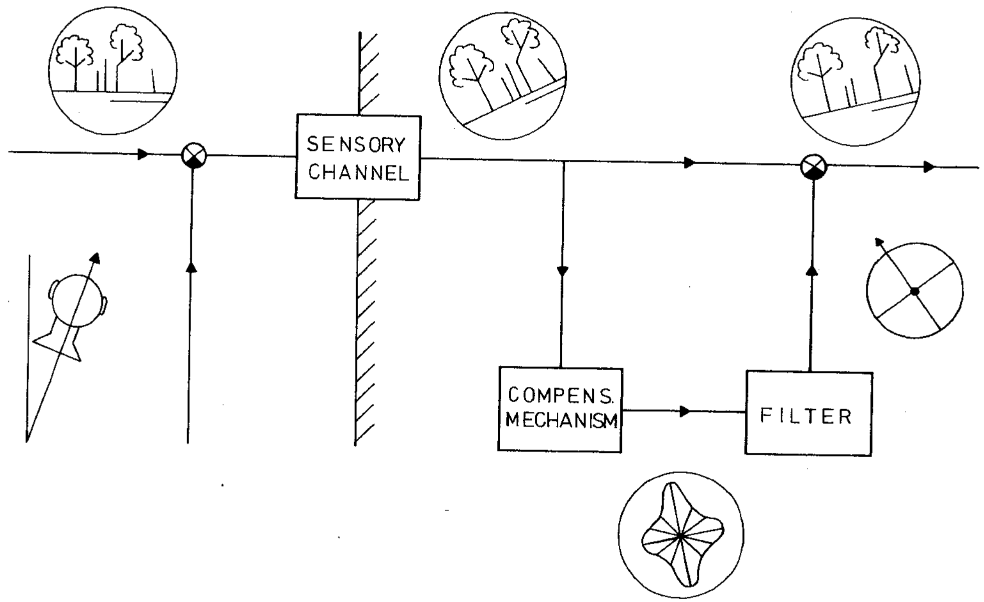


FIG. 6 An exemplification of the feed-forward compensation principle under head tilt. The distal stimulus contours are represented in oblique orientation on the retina. The filter „computes" the tilt angle which via the compensatory system will be fed into the visual afference with sign reversed. (Adapted with permission from Bischof, 1974).

Insert figure 7 about here

With the models in mind - and on the assumption that they depict some aspects of performance in the RFT - one may conceptualize what happens in a subject in the RFT who takes the final "suggestion" from the optical system seriously. In such a subject, vector VI increases and by vectorial addition the apparent vertical (vector VII) becomes tilted close to the final "optical" suggestion. This would be mirrored in the subject setting the rod close to the degree of tilt of the frame. On the other hand, another subject may put much emphasis on the vestibular upright information and the vectorial representation of this becomes accordingly longer (V), so that the apparent vertical (vector VII) is near to the vestibular upright.

Bischof & Scheerer (ibid.) observed a close relation between the weight a tilted subject put on optical information and the degree of counter torsion of the subject's eye-balls. Bischof & Scheerer assumed that the degree of counter-torsion corresponded closely to the output of the statolith apparatus. On this basis they suggested that individual differences in statolith information possibly might explain individual differences in the weight put on the optical information. It is interesting to speculate that individual differences in statolith information also might affect performance in the RFT.

A replication of the Bischof & Scheerer study is needed, however, because results of a study of Udo de Haes (1970) did not coincide with those of the former authors. Nevertheless it is possible that people differ in statolith sensitivity even while upright; some may have extremely finely tuned statolith apparatusses while other people may have poorly tunes ones. Such differences may at least partly ex-

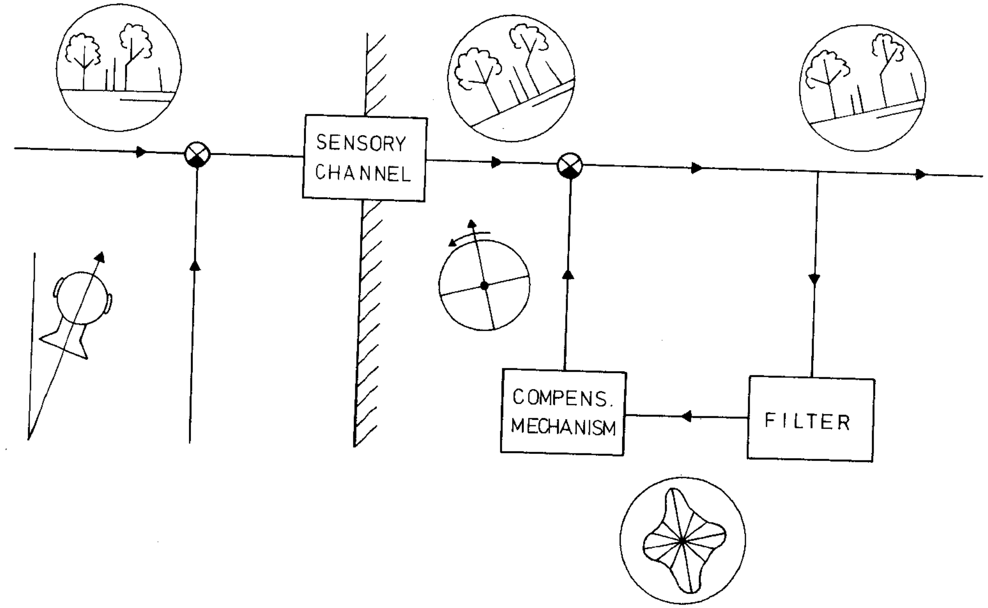


FIG. 7 An exemplification of the feedback compensation principle under head tilt. According to this principle the perceptual output itself undergoes the filtering procedure. The compensatory coordinate frame is rotated as long as the inclination of the main axis of the apparent contour distribution differs from zero. (Adapted with permission from Bischof, 1974).

plain why some people weighing heavely the misleading optical information in the RFT; perhaps they cannot establish a representative compensatory variable.

It is also possible that statolith information is adequate in most people, but that some for whatever reasons "block" it out. This possibility will be discussed in the following.

β. Alternative solutions

In compromise solutions a subject may put more emphasis on one of the two incongruent signals than on the other . In alternative solutions, the subject puts emphasis on only one type of signal and blocks the other . The type of signal that dominates depends on a number of factors.

In subjects in which one and only one type of signal dominates throughout the entire RFT, it is difficult to know whether the subject takes account of the other signals assumed to be blocked. One indirect way to detect the presence of incompatible, blocked tendencies in a subject is to investigate whether the dominant solution is accompanied by feelings of insecurity, uneasiness and lability. Thus Müller (1917) noted a "lokalisatorischen Unruhe" in some subjects that appeared to be caused "...durch eine nicht ganz unterdrückbare konkurrierende Lokalisationstendenz". We have also noted "lokalisatorischen Unruhe" in some subjects in the RFT. We have had subjects which said they experienced considerable doubt and uneasiness in the RFT, even though they adjusted the rod consistently and correctly to gravitational vertical.

We are now aware that the occurence of "lokalisatorischen Unruhe" was not related to φ-values; it was expressed by subjects with either high or low φ-scores. Unfortunately, during the studies we considered a lack of correspondence between the size of the φ-value and the subject's verbal reports as an indication of unreliable verbal reports. On the basis of the notion of alternative solutions, we now recognize that it might have been wiser to take such discrepant reports seriously. They might have enabled us to determine whether the behavior of a subject represented an "uncomplicated" compromise solution with extreme weight to one of the two incongruent signals or an alternative solution where one signal dominated the other by "blocking" it.

Another indicator of lability of performance in the RFT is response inconsistency, the σ-value. This measure together with the subject's verbal reports might provide a method for discriminating between "uncomplicated" compromise solutions and alternative solutions due to "blocking". It would be valuable in addition to determine whether GSR, EKG, EMG and other measures of stress-states differ in the RFT in subjects which report uneasiness and show lowered response consistency, compared to relaxed subjects with high response consistency.

Another alternative solution is of the flip-flop type. This type of solution can be conceptualized as analoguous to the reversible figures phenomena in which one interpretation of an ambiguous figure may alternate in succession with another interpretation, one interpretation excluding the other at a given moment. Possibly the flip-flop alternative solution describes the phenomenon studied by Kleint (1936) in which a person in a very tilted room experienced the room alternately as tilted and upright. Flip-flop alternative solution may take place in some subjects in the RFT. These subjects adjust the rod to and fro and have difficulty in deciding which of the two positions "really" appears upright to them. Unfortunately, we made no systematic studies on this phenomenon.

γ. Simultaneity solution

The phenomenon known as simultaneity solution has been illustrated in studies of Fisher (1930) and Udo de Haes & Schöne (1970). These authors found that, when asked to set a luminous line to apparent vertical under body tilt of 150 degrees in the absence of other visual information, some subjects experienced two positions of the rod which simultaneously appeared to be vertical. Simultaneity solution may indicate a conflict between the sensory information at hand. The simultaneity "solution" provides for an over-determination making it extremely difficult for the subject to react appropriately. It remains to be dertermined whether simultaneity "solutions" have explanatory power for performance in the RFT in upright or slightly tilted subjects. This ends the presentation of some of the types of solutions to the problem produced by incongruent optical and vestibular information in the RFT. The next section presents graphically two ways to quantify performance in the RFT, and two ways of interpreting the quantified performance.

3. TWO WAYS TO INTERPRETE QUANTIFIED PERFORMANCE IN THE RFT

The two interpretations to be suggested here have in common the assumption that the vectorial parameter (φ, σ) is the information necessary to describe the subject's performance in the RFT with regard to the processing of the incongruent optical and vestibular information.

Furthermore, both interpretations relate the *dynamic interplay* between the φ-values and the σ-values for each subject. We are at present primarily interested in finding out more about "how" the subject responded as she did to the conflict between the optical and the vestibular information in the RFT.

The first interpretation is based on the following way of quantifying performance in the RFT.

In *figure 8* a logically exhaustive overview on all possible response combinations measurable by our method is given. We used a simple "Yes-No"-procedure.

Insert figure 8 about here

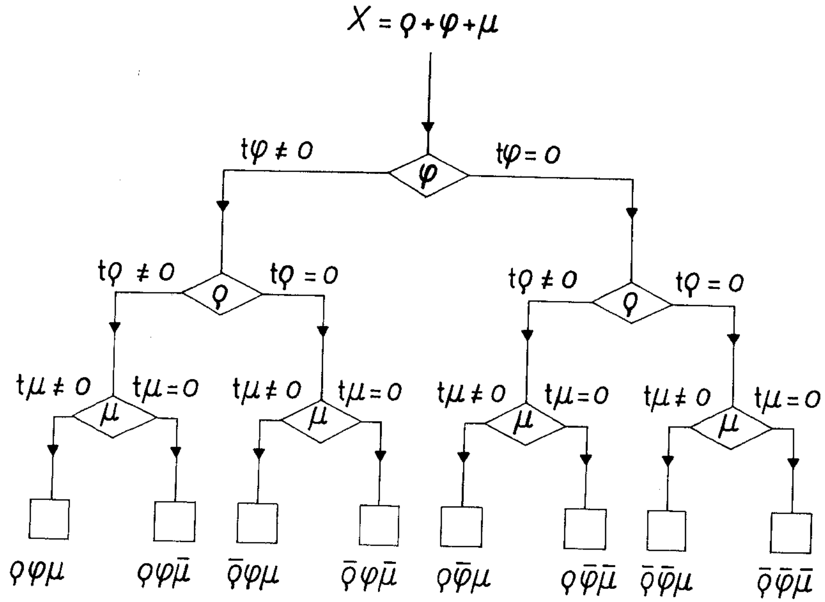


FIG. 8 Logically exhaustive classification of responses in the rod-and-frame test according to the new method. (For symbols: see text)

As will be seen from *figure 8*, the procedure started with the question: "Has this subject put significant weight on the optic information in the RFT, i.e., has she obtained a φ-parameter value significantly different from zero?" If the answer was yes, the next question was: "Has she been influenced to a significant extent by the rod-starting-position, i.e. has she obtained a ρ-value significantly different from zero?" If the answer was yes, we asked: "Has she obtained a significant constant deviation value, μ?" If the answer to this question also was yes, she could be localized at the extreme left end in the diagram with the designation φ, ρ, μ, signifying that she put much emphasis on the optic information (although to a not exactly determined degree), that she was markedly influenced by the initial starting position of the rod, and that there was considerable person-specific constant deviation in her settings. On the other hand, if the answer to all these questions was "No", then the subject was designated as $\bar{\varphi}$, $\bar{\rho}$, $\bar{\mu}$, meaning that she had not to any significant extent emphasized the optic information, and that she had neither a significant rod-starting-position effect nor a significant constant deviation.

The results quantified in this way can be handled as follows:

Insert figure 9 about here

Along the abscissa in *figure 9* are marked the φ-parameter values observed for each single subject in our 1971*a* study (series I); these values indicate the relative emphasis each subject put on the optical and the vestibular component in the test. Along the ordiante is marked each subject's estimated response consistency value (σ). φ-values below the oblique lines represent scores of subjects that put significant weight on visual information in the RFT; these subjects never adjusted the rod to a zero degree setting (i.e. a setting not deviating from the gravitational vertical position) during the RFT. φ-values above

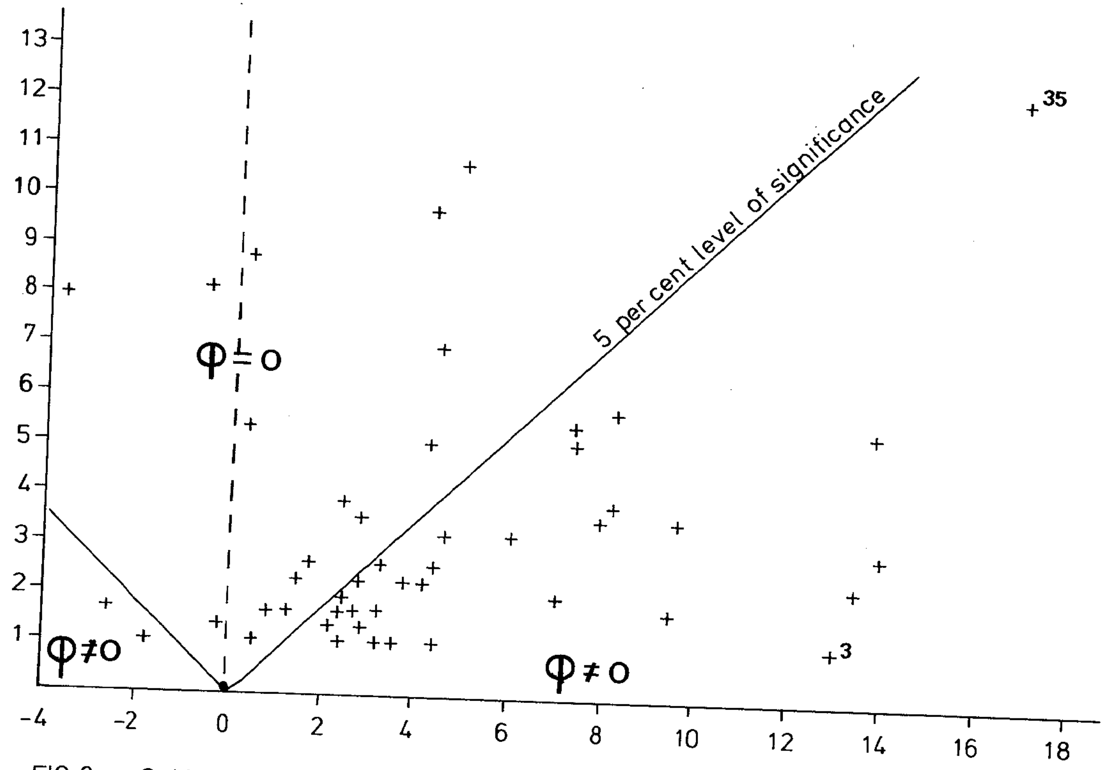


FIG. 9 Subjects classified 1) as persons significantly emphasizing optic tilt information (i.e. $\varphi \neq 0$ on 5 per cent level), and 2) as persons for whom the interpretation of the weight put on optic tilt information was rendered doubtful (i.e. $\varphi = 0$ on 5 per cent level). For explanation: see text.

the oblique lines belong to subjects that showed a low degree of response consistency (high σ-values), so that interpretation of their φ-values is unsafe.

Of course, different levels of significance could be used to calculate the "dividing lines"; but for our purpose the five per cent level was found to be convenient.

According to this first interpretation, we may say that despite different φ- and σ-values, all subjects in the areas of figure 9 called "$\varphi \neq 0$" have in common that they put significant emphasis on frame tilt information in their setting of the rod in the RFT.

On the other hand, subjects represented in the area called "$\varphi = 0$" cannot with certainty be considered to have emphasized frame tilt information in their setting of the rod.

Subject No. 35, for example, obtained a φ-value of 16.87 degrees, pointing to the possibility that she had put much emphasis on frame tilt information. Her σ-value of 12.04 tells us that her settings varied much under comparable conditions. In *figure 10a* we represent this subject's behaviour graphically by drawing a rather broad "response-fan" ($= \pm 1\ \sigma$) around her φ-value, signifying the variability in her rod settings.

Insert figure 10 about here

Compare her performance to that of subject No. 3,who also obtained a rather high φ-value ($\varphi = 13.0$) but on the other hand a relatively low σ-value ($\sigma = 1.12$). This subject is symbolized in *figure 10b* with a relatively narrow "response-fan". Common to both subjects is nevertheless that their response-fans do not cover settings of the rod to a gravitational vertical position.

Because of the "nature" of the statistic the response fan must be narrower in subjects with low φ-values than in subjects with high φ-values in order for them to be localized in the "φ ≠ 0"-category.

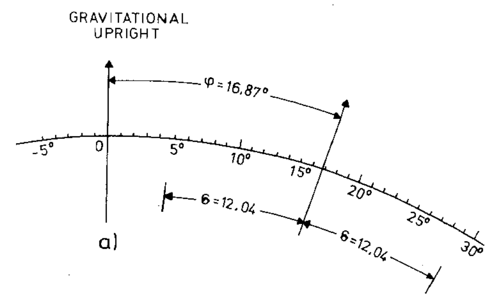
Thus, subjct No. 46 who obtained a small φ-value of .37 degrees and a σ-value of 1.17 (see *figure 10c*) was categorized in the "φ = 0"-category together with for example subject No. 7 (φ = 4.87;σ = 10.42; see *figure 8d*). Common to these two subjects and to all other subjects in the area "φ = 0" is that their "response-fan" include the gravitational upright position. In these subjects, the reason for deviation from perfect gravitational upright in their settings of the rod is uncertain; it may be due to random variation.

This first interpretation provides an answer to the question whether a given subject's φ-value can reliably be ascribed to her emphasis on the frame tilt information in the optic-vestibular conflict in the RFT.

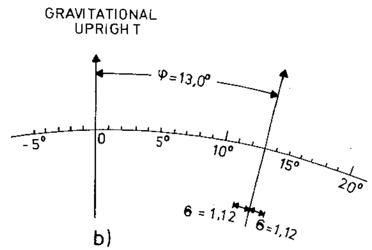
Mere registration that a subject has this or that significant parameter is probably not worth the time consumed in obtaining these measures unless we also manifest an interest in "*HOW*" she actually arrived at these values. Until we know the answer to "HOW", we have really not learned much worth knowing about the person we have troubled with our study. We therefore attempted in the following to relate the responses, not to just the weight put on the optical information as in the first interpretation, but to considerations about *how many* principles may be useful to incorporate in our attempt to obtain satisfactory answers to the question of "How".

To start, we relate the φ-parameter values and the σ-values of a given subject to the three major functional types of information processing in the vertical orienting performance.

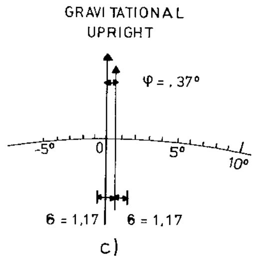
As shown in *figure 11* we begin with the same data used in *figure 9*, but operate now with another borderline for the σ-values.



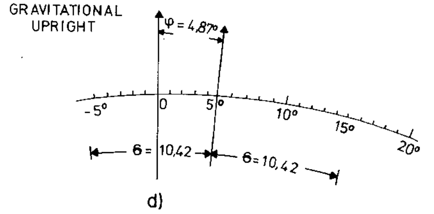
SUBJECT No. 35. THE HIGH φ-VALUE INDICATES MUCH EMPHASIS ON THE OPTIC INFORMATION WHILE THE RANGE OF THE σ-VALUE REPRESENTS A WIDE RESPONSE-REPERTOIRE TYPICAL OF THIS SUBJECT. (FOR EXPLANATION: SEE TEXT).



SUBJECT No. 3. MUCH EMPHASIS ON OPTIC INFORMATION WHILE A „NARROW" RESPONSE-REPERTOIRE (SMALL σ-VALUE) CHARACTERIZES THIS SUBJECT. NEITHER FOR HIM NOR FOR SUBJECT No. 35 ARE SETTINGS OF THE ROD TO A GRAVITATIONAL VERTICAL POSITION ACTUALIZED: BOTH ARE CLASSIFIED IN THE $\varphi \neq 0$-CATEGORY.



SUBJECT No. 46. LITTLE EMPHASIS ON THE OPTIC INFORMATION AND A NARROW RESPONSE-REPERTOIRE. CLASSIFIED IN THE $\varphi = 0$-CATEGORY.



SUBJECT No. 7. SOME EMPHASIS ON THE OPTIC INFORMATION COMBINED WITH A BROAD RESPONSE-REPERTOIRE. CLASSIFIED IN THE $\varphi = 0$-CATEGORY AS WAS SUBJECT No. 46 BECAUSE THE RESPONSE-REPERTOIRE OF BOTH INCLUDE THE GRAVITATIONAL UPRIGHT POSITION.

FIG. 10 Subjects classified according to size of φ- and σ-values into 1) $\varphi \neq 0$ (a and b) and 2) into $\varphi = 0$ (c and d). For explanation: see text.

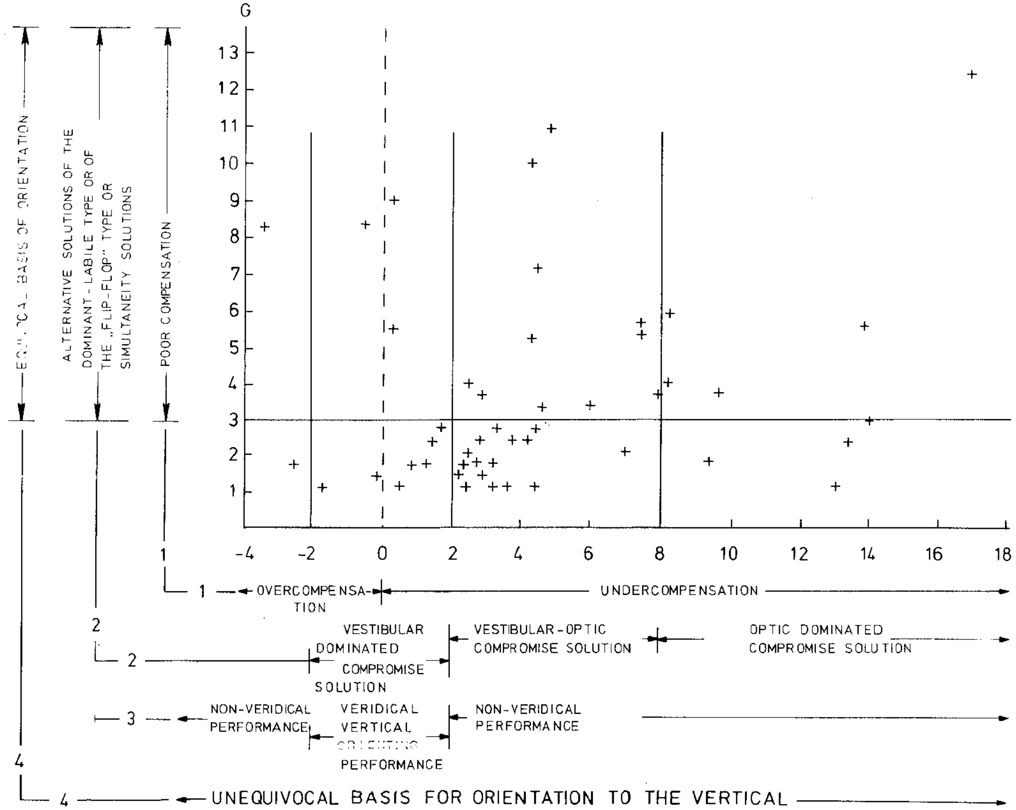


FIG. 11 Subjects classified according to certain criteria for vertical [illegible] performance and according to assumed types of solutions they practiced in solving the problem of incongruent optic-vestibular information.

Insert figure 11 about here

The horizontal line in *figure 11* represents a somewhat arbitrarely chosen cut-off point assumed to discriminate sensibly between persons that obtained "small" σ-values (below the line) because they responded *systematically* to the frame tilt information and persons that obtained "great" σ-values, due to their *unsystematic* responding.

In the present material we chose a σ-value of 3.0 as cut-off point on the σ-continuum. Of course, more than one line could be drawn for example dividing the σ-values into "small", "moderate", and "great" values;cut-off points other than the one we chose could be used. With this in mind, we present the second interpretation for performance in the RFT.

At the first level of description (1) we will assume that we have a case where the frame tilt information has been undercompensated if the subject's φ-value is both under the horizontal cut-off point line and greater than zero. If her φ-value turns out to be negative (and this sometimes occurs) but still below the line, we say that she has overcompensated for the frame tilt.

At the second level of description in *figure 11* (2) we say that if a subject's φ-value is near to zero (here defined somewhat arbitrarely as zero ± 2 degrees) and below the horizontal line she most probably made a stable compromise solution with predominant weight to the vestibular component, i.e. she solved the incongruence between the equivalent optic and vestibular information by systematically relying upon the vestibular. If her φ-score is below the line and within the range of 2-8 degrees (also an arbitrarely defined range) we may tentatively take this to signify that the subject made a stable compromise solution in which she took recourse to the optical as well as to the vestibular component and made a mean thereof. If her φ-value is above eight degrees and still to be found below the line she has probably made a compromise solution in which she systematically put heavier emphasis on optical than on vestibular information.

If one wants to describe the subject's performance in terms of "adequacy" (or veridicality) (3) we might say that the performance is adequate if the subject's φ-value is close to zero (say, 0 ± 2 degrees), since such performance gives a veridical or nearly-veridical vertical orientation. It would be a mistake, however, to conclude that a subject with φ-values outside this range but still below the line has an equivocal basis for orientation (4), although such a subject can be said to under-compensate (or over-compensate) for the optical tilt information, the relatively low response consistency score, σ, indicates that she responded systematically. In this sense her perception of the vertical is not veridical but is nevertheless unequivocal. Accordingly, φ-values along the abscissa but below the line do not necessarily symbolize optimal vertical orienting performance but nevertheless do indicate a systematic basis for orientation to the gravitational vertical.

It is quite another story with values above the horizontal line in *figure 11*. It is inappropriate to talk about over- and under-compensation in the same sense as for φ-scores below the line, because the subject's performance is so variable. For the same reason we cannot sensibly talk about an indication of *stable* compromise solutions in the same sense as we did about φ-scores below the line.

Rather the performance of subjects with values in this area of the diagram can be characterized as alternative solutions of the dominant type. These subjects probably also experienced lability and uneasiness in the RFT. We might also find the flip-flop alternative solutions here, as flip-flop adjustments of the rod may augment the σ-value considerably if measured adequately. In this aspect we deviate from the opinion of Bischof who mentions that compromise *and alternative* solutions will "...always provide an unequivocal basis of orientation..." (Bischof, 1974, p. 179). It might be expected that the blocking of all factors but one may cause so much corresponding insecurity (phenomenological as well as behavioral) in the subject that at least some of the subjects will respond less consistently in this situation than will subjects with an "uncomplicated" compensatory averaging between the signals. Thus, "blocking" may provide an equivocal basis for orientation.

Finally, scores above the line might represent subjects which practice simultaneity solutions representing paradoxical perceptions of the orientation of the rod due to over-determination. Since incongruous, optical and vestibular information are represented simultaneously in conscious perception in these subjects, the perceptual situation may be difficult for them to react to and we might accordingly expect such subjects to obtain an elevated σ-value.

Thus, scores above the line generally indicate poor and unsystematical orientation to the vertical. Dominant and flip-flop alternative type solutions, or simultaneity solutions - might come into play either singularly or in concert in order to cope with the problem of incongruity between equivalent, optical and vestibular signals in the RFT.

Of course, the cut-off lines drawn in *figure 9* and *figure 11* must not be taken literally. The lines represent only an *estimated* limit in a continuous distribution. The φ-value of each subject should be related to her σ-value in the ways prescribed above in order to fit the outcome into the interpretations represented. Regarding the second interpretation a number of subjects will most probably be found to use more than one principle in their performance in the RFT or to use different principles at different stages of development or just to change between prefered principles because the organism apparently hunts for what seems to be the most relevant information, and takes advance of any possible way of getting it. Therefore, besides looking for "clear-cut" types of solution one might also expect to localize "blended" types. Nothing in our approach speaks against such an expectation. In fact our data speak in favour of it.

CHAPTER XI

SOME FURTHER CONSIDERATIONS ON THE ROD-AND-FRAME TEST

CHAPTER XI

SOME FURTHER CONSIDERATIONS ON THE ROD-AND-FRAME TEST

1. INTRODUCTION

In the foregoing chapter we presented some principles to describe how subjects may try to solve the problem of incongruent information in the RFT where adequate vertical orienting performance is required. These principles are discussed in detail in the works of Bischof already cited. Bischof used terms and principles from information theory and biocybernetics. We have already made use of three major functional types of *information processing* in our attempt to interprete performance in the RFT, and we have discussed ways of arriving at an adequate orientation to the vertical. Common to these ways was that they were based on the assumption that optical and vestibular information are equivalent in all important aspects and that the organism can make use of both types of information. Under "natural" everyday conditions, optical and vestibular information are not normally incongruent. In the RFT, however, they are by experimental means deliberately made markedly incongruent.

In the following, we consider neuro-physiological systems thought to be responsible to integrating incongruent sensory information in order to arrive at an adequate orientation to the vertical. Although the functional system behind this performance is extremely complex a model for it has been proposed by v. Holst (v. Holst, 1950; v. Holst & Mittelstaedt, 1950) and by Mittelstaedt (1961; 1972). In 1970 Bischof & Scheerer presented a cybernetic model designed to account for dynamic, experimental conditions much more complex than those observed in the RFT. We will present this model in simplified form in order to further an understanding of how the organism may handle the "static" tilt conditions present in the RFT, and to be used as an implement to think about the complex systems behind this performance. The model is not considered to represent the entire system. Rather it is at best a roughly simplified version of the complex neuro-psychological system assumed to underlie vertical orienting performance in the RFT.

The model is symbolized graphically in *figure 12*. Boxes signifying a system defined as an extract whose borderlines can be chosen freely; anyone system can be presented any number of times and in any number of combinations. Lines between the boxes signifying "channels" for the information. Arrows on the lines signifying the direction of "flow" of the information and vectorial variables shown by double lines are without regard to whether two or more informations are involved. Lines coming from "nowhere" are free input. Circles with diagonals mean addition of two variables unless one of the quadrants is black in which case the meaning is subtraction. Squares with diagonals that if empty mean multiplication and if black mean division.

The meaning of the terms "variable", "signal", and "information" are not completely settled. In the present context by "variable", "signal", or "information" we mean that which changes the state in a given system, thereby in fact saying that a variable, signal or an information is a state in the system considered.

A variable is observable if we can specify the operations for measuring it. If we cannot specify the operations for measuring a variable we speak of an infered variable. The infered variable is to be considered at present as "imagined" and to be specified operationally someday when we have learned enough about neuropsychology. Most infered variables probable will turn out to be multi-vectorial rather than scalar and simple one-dimensional. Observable variables in the present model are frame tilt and rod tilt relative to gravitation as well as body tilt. The retinal representation of the frame and the rod tilt can at least in principle also be considered as observable. These observable variables are following Bischof & Scheerer (ibid.) symbolized by greek letters and subscript $_G$ for reference to gravitational direction and with subscript $_R$ for reference to the retinal meridian of the retinal representation of the tilted contours of the distal objects. The distal stimulus situation is the tilted contours of the distal objects defined according to the direction of gravity, while the proximal stimulus situation is the tilted contours of the distal objects defined according to the retinal meridian reference system.

We will now assume that the model symbolizes a system for perception of the vertical direction in space. In that the system thus has a defined purpose we can call it a "teleonome" system. The model is idealized partly because it has no "build-in errors" such as those common to biological systems, partly because it is assumed that perceptual processes can be separated from cognitive processes and partly because it is assumed to function independently of a number of methodological variables.

In the RFT, the subject has the following proximal "free" inputs; 1) the retinal tilt of the rod (λ_R); 2) the retinal tilt of the frame (β_R); and 3) body tilt (α). The visual proximal stimulation is thus (λ_R, β_R) with body tilt (α) subtracted componentwise, as shown in *figure 12*.

Insert figure 12 about here

α is zero in our upright subjects; therefore no counter torsion of the eyes is symbolized in the model.

The output of the system is the subject's adjustments of the rod to be understood as a negative backward coupling which (in co-operation with the rod-starting-position effect, called ρ, and a constant deviation, called μ, in our method for measuring performance in the RFT) determines the position of the distal rod (λ_G). These are the observable variables.

A number of other possible free inputs to the system will be discussed in the next section; they have highly interesting ontogenetic and phylogenetic aspects.

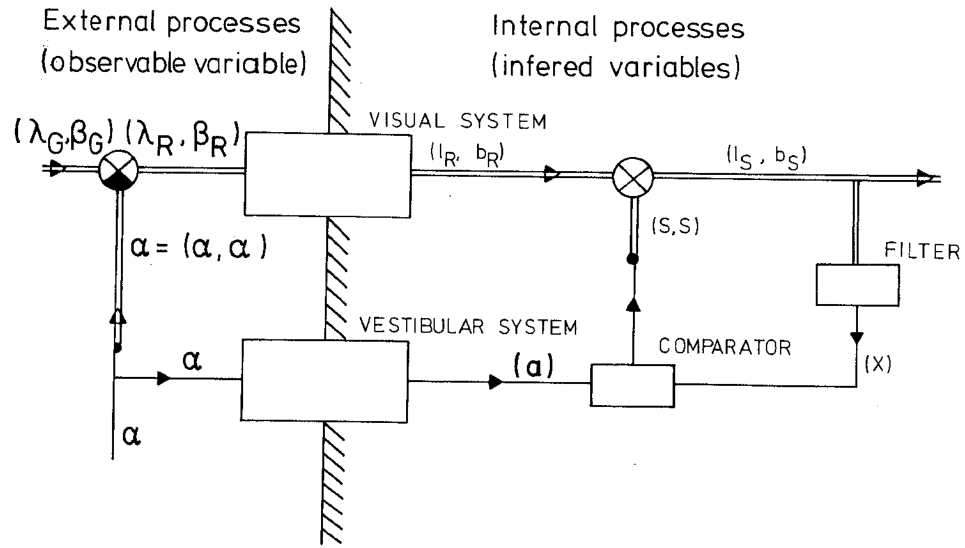


FIG.12 A cybernetic model for vertical orienting performance in the rod-and-frame test (Adapted from Bischof and Scheerer, 1970, and modified; with permission of the authors and „Psychol. Forsch." For explanation: see text.)

Inferable variables are: 1) (l_R, b_R) which are to be considered as the visual afference corresponding to a linear mapping of (λ_R, β_R); 2) (l_S, b_S) which signify apparent tilt of the rod and the frame. They are based on the visual afference by component-wise addition of a compensatory variable (s, s). According to Bischof & Scheerer they can also be understood to act as a subjective frame of reference (subscript $_S$) into which (l_R, b_R) is mapped to yield apparent contour inclination. This is the so-called feed-back compensation hypothesis.

According to the model, the tilt of the distal object contours $(\lambda_G, \beta_G$; where λ_G is the tilt of rod contours relative to gravity, and β_G is the tilt of frame contours relative to gravity) will, after subtraction of body tilt (defined as a vector (α, α)) represent the proximal visual information (λ_R, β_R). This information together with body tilt information (α) handled by the vestibular system will produce the corresponding infered afferent variables l_R, b_R and a to be understood as highly complex neuro-psychological (probably multi-vectorial) constructs.

As shown in *figure 12*, the variable (α, α) was subtracted from (λ_G, β_G) in order to signify the distortion effect of body tilt to be compensated for. The compensation will according to the model be performed so that the organism establishes a representative compensatory variable (s , s) for the distortion (α, α), and feed this compensatory variable additively, i.e. with sign now reversed, into the afferent flow. We then have a vector (l_S, b_S). In this vector l_S stands for "the apparent tilt of the rod" while b_S represents "apparent tilt of the frame".

But our description of the model is still insufficient because we have not demonstrated how the compensatory variable (s, s) is established. The following will remedy this insufficiency. From empirical evidence we know that the size of the compensatory variable (s, s) depends not only on body tilt (α, α), but also on frame tilt (β_G). Thus, when a subject adjusts a rod to an apparent vertical position without a frame, the adjustment may deviate as a function of body tilt, but if a tilted frame is now presented to the subject the rod deviates even more. What is now suggested is a comparator-system (C) by means of which the most favorable optical suggestion ((x) from the filter (F)) of the visual system is compared to the "pure vestibular vertical" (see *figure 5*). Such a comparator could assign weight to the optical suggestion on behalf of the vestibular suggestion and vice versa, causing corresponding changes in the compensatory variable (s, s).

The extent to which weight is put on a misleading optical suggestion from the filter (F) will impair the vertical orienting performance because the compensatory variable will be insufficient. Furthermore, the system proposed in *figure 5* is now partitioned into two systems: 1) the filter (F) by which a mean value of the four contour-directions components is derived to give the most favorable visual "suggestion", and 2) the comparator-system where the visual "suggestion" is weighed in relation to the vestibular "suggestion".

This sketchy account of a model for vertical orienting performance leaves out many interesting aspects discussed by Bischof & Scheerer. But our present aim was only to demonstrate that cybernetic models can be used to conceptualize a vertical orienting system. Such models may be useful to describe "how" a subject may orient herself to the vertical direction in the RFT.

Another question to be considered is "why" the subject arrived at the particular scores she obtained in the RFT, i.e. Why did the subject weigh optical and vestibular information as she did? We will discuss this question from the point of view of development of the individual and with the use of our postulated comparator system.

2. A DEVELOPMENTAL APPROACH TO THE φ-PARAMETER, THE σ-PARAMETER AND VERTICAL ORIENTING PERFORMANCE

Witkin and coworkers claim that the RFT measures the subject's general level of development, reflected in her "field dependence" score. (Witkin et al., 1962). The extent of field dependence has in fact been demonstrated to be functionally related to chronological age; it is greatest in prepuberty. Field dependence was found to decrease in a subject from the age of 8 to the age of 15, at which time the most field independent level was found.

In a study of developmental trends in Turner girls (series VII, and Nielsen, Nyborg & Dahl, 1976), we found that their φ-parameter values diminished as a function of age. Furthermore, when the fifteen year old Turner girls were compared to their sisters of about the same age, the difference in φ-value was highly significant, with the Turner girls scoring much higher. When the scores for the 20 year old Turner girls were compared to those of their sisters of the same age, the difference was still significant, but barely so.

At the age of about 25-30 years the difference was no longer significant (Nyborg & Nielsen, 1976, in progress). Also the difference in σ-values between Turner girls and their sisters decreased with age.

It seems probable that φ-values and σ-values may signify a certain developmental stage. The effect of development can be related to our re-interpretation of performance in the RFT in terms of a cybernetic model for vertical orienting performance.

Ashby (1971) discussed cybernetic models for the regulation of sensory information in survival of the organism. His argumentation was that the states M_1, ..., M_k, in a living organism can be defined as the states in which certain *essential variables* are kept within assigned ("physiological") limits. These essentiel variables, E, can be divided into two groups: 1) η = "good", or "alive", and 2) not-η = "bad" or "dead" (of course finer classifications can be made, but this is not essential for the argumentation here). One of Ashby's examples was of a bicycle rider. Ashby wrote that "E is chiefly the angle with the vertical. η is a set of small permissible deviations. D is the set of those disturbances that threaten to make the deviation become large. F is the whole machinery - mechanical, anatomical, neuronic - that determines what the effect of D is on E" (p. 199)

A similar line of reasoning can be applied to vertical orienting performance in the RFT. Here the essential variable, E, can be orientation to the vertical. η can be the set of small permissible deviations still allowing for adequate orientation to the vertical, and not-η can be the deviations that lead to severe disorientation in the sense of Sandström. D is the set of those disturbances that threaten to make the deviation become large, such as the effect of body tilt and of frame tilt in the RFT. F is the whole regulatory machinery (as for example symbolized by the cybernetic model of a system working for vertical orienting performance (see *figure 12*)) that determines what effect D, i.e. body tilt and frame tilt, may have on E, the state of being adequately oriented to the vertical. In so far as orientation has survival value, the better F is as a regulator of vertical orienting, the larger the organism's chance for survival.

Performance in spatial tests may be affected by gene effects. Support for this notion comes from studies on spatial performance in men and women. There are sex differences in performance in the RFT; the optical component is emphasized more by women than by men. The sex differences may at least in part be explainable by specific effects of the sex chromosomes. Our studies on girls with Turner's syndromen, men with Klinefelter's syndrome, and men with 47,XYY karyotype (Nyborg & Nielsen, 1977*a*, 1977*b*, both in progress) suggest that gene effects may play a role in spatial perfection. Of course, environmental influences probably also affect spatial perception markedly.

Further support for the role of genes in spatial perception comes from studies carried out on fish. v. Holst (1950) and Braemer (1957) observed that bottom-seeking fish species usually were not influenced when the incidence of light did not coincide with the direction of gravity, while fish species living near the surface were influenced by the relationship between light and gravity. Furthermore, individual differences within a species of fish were observed. It would be interesting to determine in addition whether the chronological age of the fish plays a role in its orientation in space, as appears to be the case in humans.

An answer to the question of *why* human beings differ in vertical orienting performance in the RFT is our major concern here. This question has unfortunately "...not yet been thoroughly investigated, partly because for years authors have engaged in a fruitless debate as to which of the two sensory channels , the optical or the vestibular, is "prior" or "more basis" to the perception of the vertical, instead of taking for granted that *both* are important and simply asking how they interact" (Bischof, 1974, p. 181; after Gibson, 1952; see also: Nyborg, 1971*a*).

The age of the subject plays a significant role in performance in the RFT. It is possible that the relative weight a subject puts on the optic component dimishes with age due to *maturational* changes. The maturational changes that take place in neuropsychological mechanisms could be responsible for the effect of age on performance in the RFT. The changes might occur in the central comparator system, in the vestibular system, in the optical system and/or in the overall degree of "differentiation" of the whole system of sub-systems (Witkin et al., 1962).

Environmental influences also could lead to sex differences in performance in the RFT. Witkin and coworkers noted that girls usually are raised in more "protected" ways than boys. As a result a girl may learn to rely more authoritatively on key persons in her social surroundings (a sort of "social field dependence"), as well as on the perceptual facts in her enviroment (the perceptual "field dependence"). Accordingly a girl may "learn" to behave in a "field dependent" manner.

Compared to a boy, a girl may not learn to trust her "internal bodily standard". Accordingly, a girl may behave more field dependent than a boy. It is also conceivable that the mothers of field dependent girls are field dependent for genetic reasons, and thus give genes disposing their daughters to field dependence. In addition, social and genetic effects might interact to produce field dependence. In fact, Dawson (1975) explained individual differences in field dependence in terms of a bio-cultural model where the endocrinological variables go together with cultural factors and have joint effects on human spatial orientation. Dawson's approach is interesting mainly because it is non-reductionistic. Dawson tested some of his notions in experiments carried out in laboratory animals. He found that repeated doses of oestrogen (a female sex hormone) impaired spatial learning significantly in castrated male and female rats. His findings support the notion that endocrinological variables play a role in spatial perception. In accordance with Dawson's findings, our findings show that Turner girls who received long-term oestrogen treatment scored significantly more field dependent in the RFT than Turner girls who had not received oestrogen. Some care must be taken in the interpretation of our data, however, because it was not possible for us to obtain certain information about the specific oestrogen preparation each Turner girl took, and we could not control whether they took the hormone in the prescribed doses. Furthermore, the unsigned error scoring method with all of its shortcomings was used to score the test. Nevertheless, our results suggest that it might be wise to consider the possibility that hormonally based differences between subjects might show up as measurable differences in vertical orienting performance in the RFT.

We believe that the particular optic-vestibular weight ratio arrived at by a subject in the RFT is multi-determined. In general, peoply rely on certain regularities to be found in the environment, but there are probably individual differences in their ability to detect and take advantage of the regularities. We think that the source of individual differences might partly be found by studying the extent to which people have opportunities to establish redundancy expectations. Boys probably have more opportunities than girls to obtain spatial experiences and to establish redundancy expectations due to rough play and use of tools. A simple correlation between these opportunities and performance in tests of spatial perception probably is not to be found because the optic-vestibular weight ratio appears to depend upon learning, hormonal, maturational, genetic and temporarily conditioned factors. All of these factors can be considered as "free" input variables in our cybernetic model (*figure 12*).

We belive that an inductive approach to vertical orienting performance is called for. In our opinion, the proper study of inter-individual differences in the RFT is to study each individual, and then to determine what is common to them all in order to make generalizations. The next section gives some of the arguments in favor of this point of view.

3. ON POPULATION DEPENDENT AND PERSON-SPECIFIC CLASSIFICATIONS

In Chapter IV it was mentioned that the interpretation of the unsigned deviation score is population dependent because its meaning is derived from a sample population mean. Skinner (1956) argued against the principles in such a procedure. His argument was that if one wants to study human behavior the point of departure must be the study of individuals. This approach is not used in psychometric methods that are concerned with *groups* of individuals. Skinner's remarks apply to the studies on the RFT carried out by Witkin and his coworkers. Their work rests heavily on group-centered techniques, i.e. on correlations between groups. Although studies based on group means may have some value, they cannot be used to describe and reflect on how and why a given individual responded as she did in the test. Up to now, one of the main problems with studies on perception and performance in the RFT has been the lack of statistics that can be used to describe the results of a single subject. As pointed out by Zubin (1955) contemporary statistics have been completely group-centered. There is a need for development of "individual-centered" statistics. In order to comply with this need, we developed the new method for analyzing the performance in the RFT; the parameter values obtained by this method are not dependent on the group mean because they are estimated in relation to the specific response consistency of the subject herself. Our method is "individual-centered".

In order to illustrate the differences between a "population-dependent" and an "individual-centered" approach we compared the method of Witkin with our own. We once more use the data from Nyborg (1971*a*, series I) analyzed accordingly to the interpretation demonstrated in *figure 11* and compare the results with those obtained when the data were analyzed by the unsigned deviation scoring method.

According to the usual procedure for the unsigned deviation scoring method, the subject's score represents deviations of final rod settings without taking account if the deviation was co-inciding with the tilt of the frame or ran counter to it. According to Witkin's one-dimensional bi-polar conception of the "field dependence" dimension the data are marked along the abscissa in *figure 13*; the number of subjects corresponds to the number of circles (containing an identification number) ordered along the ordinate. (Adapted from Nyborg, ibid., p. 8, *figure 3*; and modified.)

Insert figure 13 about here

With the data ordered in this way, one now has the problem of deciding which subjects belong to the "field dependent" group and which ones belong to the "field independent"group. We used what Witkin calls "natural breaks" or "natural cut-off points" in the data. The localization of such "natural" cut-off points depends, however, on two conditions: 1) on the mean score of the group, and 2) on how many subjects make up a "field depen-

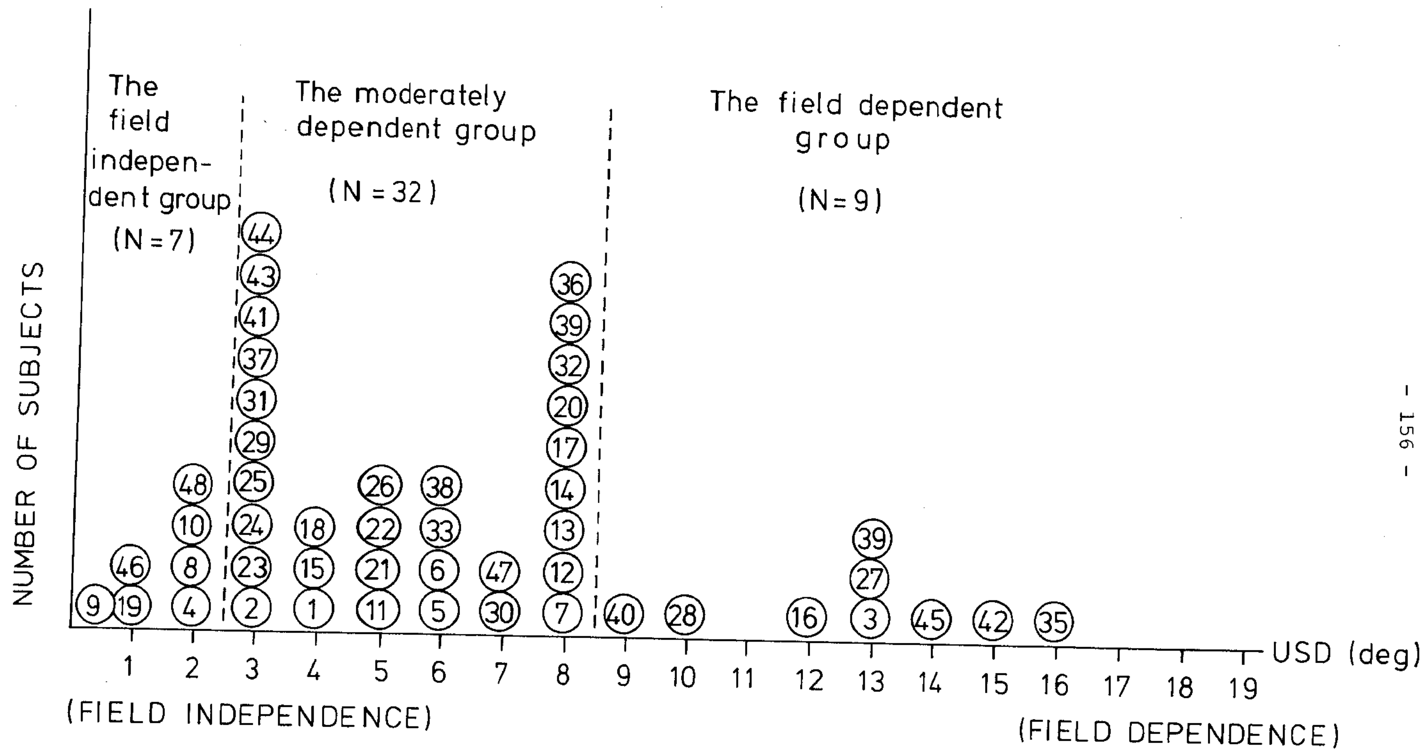


FIG. 13 UNSIGNED DEVIATION ERRORS (USD) IN DEGREES AD MODUM WITKIN
(Adapted from Nyborg, 1971a; and modified. With permission of Scand. J. Psychol.)
The numbers within the circles make identification in fig. 14 possible.

dent" group and a "field independent" group, again depending on the specific purpose of the study. If for example the group mean score is low, the probability is low that a reasonably large "field dependent" group can be established because probably only a few subjects obtained scores higher than ten degrees.

If this is the case, either the definition of field dependent is changed to all scores above eight degrees or the number of subjects studied is increased. The latter solution is, however, seldom applied. Thus, the decision as to whether a given person belongs to a field depdendent group or to a field independent group is quite arbitrary by the group mean method.

Applying the group mean method to the Nyborg (1971*a*) study, we found the "natural cut-off points" to be three and eight degrees, respectively, so that there were seven subjects in the field independent group and nine in the field dependent group. The "in-between" group is in most studies not of interest.

As seen from the identification numbers within the circles, we thus classified subjects 4, 8, 9, 10, 19, 46 and 48 as field independent while subjects 3, 16, 27, 28, 35, 40, 42 and 45 were classified as field dependent. The thirty-two other subjects were classified as moderately field dependent.

After such classification, nothing more is usually said about the subject's perceptual field dependence. This classification is used as the basis for determinations of correlations between personality traits or other traits and field dependence in the studies.

Figure 14 also shows how subjects can be classified according to the interpretational principle proposed in *figure 11*. The subject's score is ordered according to her φ-parameter value and also according to her σ-value. The φ-value indicates to what extent she emphasized the optical or the vestibular factors, while the σ-value indicates the consistency with which she did this.

Insert figure 14 about here

The "σ-cut-off line" is at $\sigma = 3$. In the comparison it can be seen that the two classifications differ in many aspects. *Table 1* gives an overview of some of the discrepancies.

Insert table 1 about here

Row A in *table 1* lists the subjects classified as systematically and markedly emphasizing the vestibular component, row B shows subjects that systematically made a compromise solution between the vestibular and optical components, row C presents the subjects that systematically and markedly emphasized the optical component, row D represents subjects responding unsystematically, while rows E, F, and G list subjects according to Witkin's classification of field independent, moderately dependent, and field dependent subjects.

It is particularly important to note that the subjects classified as field dependent by the Witkin method are not always those that systematically emphasized the optical component in the RFT. Thus, the notion that field dependence as measured by Witkin's unsigned deviation score provides an index of the subject's ability to "overcome embeddedness" due to the frame in the RFT does not appear to be generally correct. Evidently, classification of the complex spatial performance in the RFT along a one-dimensional perceptual scale (field dependence versus field independence) on the basis of a simple averaging of responses is not able to adequately describe a subject's behavior. The procedure not only leads the considerations away from the complexity of the human responses in the complex situation, but directly hinders the collection of valuable information necessary for a better understanding of the subject's behavior.

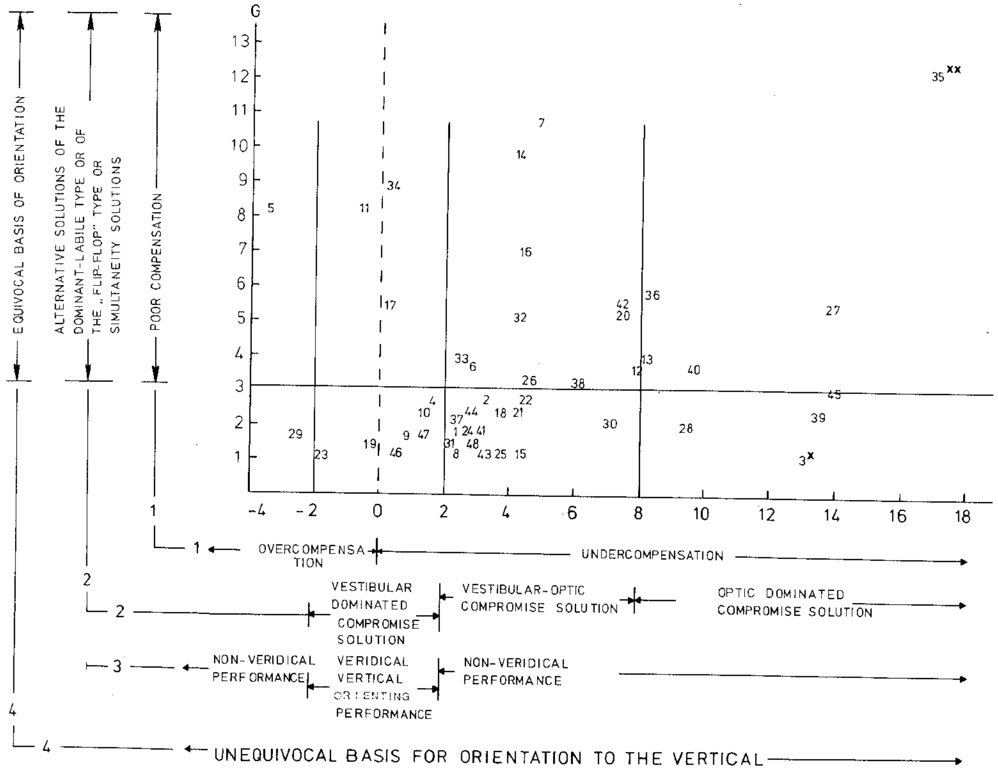


FIG. 14 As figure 11, except that identification numbers now allow to identify the subjects in order to compare results of the new interpretation of RFT performance to the traditional interpretation presented in figure 13. (See also table 1).

TABLE 1. Overview of the discrepancies between the traditional and the new interpretation of the RFT performance.

The new multidimensional method

Subject No.:	A	B	C	D
1		X		
2		X		
3			X	
4	X			
5				X
6				X
7				X
8		X		
9	X			
10	X			
11				X
12				X
13				X
14				X
15		X		
16				X
17				X
18		X		
19	X			
20				X
21		X		
22		X		
23	X			
24		X		
25		X		
26				X
27				X
28			X	
29		(φ = -2)		
30		X		
31		X		
32				X
33				X
34				X
35				X
36				X
37		X		
38				X
39			X	
40				X
41		X		
42				X
43		X		
44		X		
45			X	
46	X			
47	X			
48		X		
	7	17	4	20

Total N = 48

A = SYSTEMATIC VESTIBULAR DOMINATED COMPROMISE SOLUTIONS
$\sigma < 3$ AND $\varphi < \pm 2°$

B = SYSTEMATIC VESTIBULAR-OPTIC COMPROMISE SOLUTIONS
$\sigma < 3$ AND $2° < \varphi < 8°$

C = SYSTEMATIC OPTIC DOMINATED COMPROMISE SOLUTIONS
$\sigma < 3$ AND $\varphi > 8°$

D = UNSYSTEMATIC RESPONDING SUBJECTS
$\sigma > 3$

E = FIELD INDEPENDENT SUBJECTS
USD < 2°

F = MODERATELY DEPENDENT SUBJECTS
2° < USD < 8°

G = FIELD DEPENDENT SUBJECTS
USD > 8°

The traditional method

E	F	G	Subj. No.:
	X		1
	X		2
		X	3
X			4
	X		5
	X		6
	X		7
X			8
X			9
X			10
	X		11
	X		12
	X		13
	X		14
	X		15
		X	16
	X		17
	X		18
X			19
	X		20
	X		21
	X		22
	X		23
	X		24
	X		25
	X		26
		X	27
		X	28
	X		29
	X		30
	X		31
	X		32
	X		33
	X		34
		X	35
	X		36
	X		37
	X		38
		X	39
		X	40
	X		41
		X	42
	X		43
	X		44
		X	45
X			46
	X		47
X			48
7	32	9	

Total N = 48

The new approach considers performance in the RFT to be complex and it leads to multi-dimensional considerations on the individual's unique performance. The new approach allows for a functional and dynamic system-analytic approach in which each subject's performance can be considered without referring to group means.

A few examples may demonstrate this. Consider for example the score of subject No. 3 in *figure 14* (marked with x). Her φ-score indicates that she has given much weight to the optical component; her σ-value is low and far below the cut-off line, which means that she responded systematically to the optical information. Her scores indicate considerable and systematical under-compensation. Her compromise solution was unmistakenly optic dominated. She had "non-veridical" orienting to the vertical because she experienced "illusion of orientation". Her performance nevertheless gave an unequivocal basis for orientation as her under-compensation is consistent. The size of her response consistency estimation, σ, suggests that she did *not* use an alternative solution of the dominant-labile type or of the flip-flop type; neither did she use a simultaneity solution. What is lacking in the estimation of the subject's performance are reports on how she herself experienced the whole situation. This information in combination with psycho-physiological and other measures would enable her performance to be fully described. But even without the subject's verbal report, the differences between the description of the subject's performance by the new approach compared to a simple statement that she is "field dependent" (whatever this term means) is apparent.

As another example to illustrate the difference between the two methods for describing performance in the RFT, consider subject 35 in *figure 14* (marked as xx).

She had a φ-value even higher than subject No. 3 and she is according to Witkin's procedure classified as extremely field dependent. By taking into consideration the dynamic interplay be-

between her high φ-value *and* the extraordinarily high σ-value indicating a very unsystematic performance, we arrived at another conclusion. Her compensation was extremely poor. Accordingly, this subject's performance does *not* represent an "uncomplicated" predominantly optic dominated solution (as the φ-value alone seems to indicate). Rather she probably used one of the solution possibilities stated along the ordinate, and her basis for orientation to the vertical is equivocal. The next question is how it can be decided logically which of the solutions indicated at the ordinate may best characterize her performance? If she practiced an alternative solution of the dominance-labile type we would certainly expect that her responses would be accompanied with feelings of "uncertainty", "vagueness", "unrealness", "unconvincingness", and the like (Kleint, 1936; Müller, 1917; Metzger, 1965). If the subject had practiced a flip-flop alternative solution this could possibly be seen from a closer analysis of her raw data. Simultaneity solutions will possibly be indicated in the subject's verbal report in statements like: "The rod appears upright in this or that position, but not in other positions."

These examples show that the new approach can lead to a functional, individual-centered way of analyzing the subject's performance in the RFT. The new approach is dynamic because the interpretation of the subject's performance is most meaningful when the interaction between more different parameter-values are taken into account.

A question that comes to the mind when considering the multitude of possible dynamic interactions in the subject's performance is how to establish reasonable generalizations from this tangled web of individuality? As mentioned in Chapter IV, the way goes through the study of the individual and only the individual as a total universe in the RFT. On the basis of the results of such studies, it is possible to establish individual test profiles by studying the relative relevance of the factors for the single subjects in question. This procedure conforms to the requirements of Rasch (1960) who stated that individual-centered statistical models demand that each single individual can be characterized separately.

First when the ideographic test profiles for a number of persons are at hand the next step can be taken. This consists in comparing these individual test profiles to decide whether any of the relatively relevant factors can be shown to underlie the variation from individual to individual (Poulsen, 1972). The idea behind this approach is that by establishing the characteristics of the individual, the chance will be greater to find the "genuine" general. This procedure is much more sound than the correlational technique typically used in studies on the RFT (Witkin et al., 1962). The correlation techniques are weak because 1) the correlation coefficients obtained in these studies are too low to warrant the generalizations made from them (Fine & Danforth, 1975, p. 692), 2) correlation cannot prove a causal relationship, and 3) correlations do not provide insight into the mechanisms responsible for the relationships (Jensen, 1973, p. 231).

Our approach consists in estimating the predominant performance characteristics of each subject in order to determine whether one or more are representative of all or most subjects. The extent to which a characteristic is shown by subjects signifies how "genuinely" general the characteristic is. The extent to which an individual shows a particular characteristic determines her placement in the general trends. Our approach does not encapsulate the indivual in superfluous correlation coefficients but rather focuses on the subject under study. Our approach can expose the structures and mechanisms behind the subject's score. Finally, our approach can be used to study how an individual performs the complex task of keeping her orientation to the vertical within acceptable limits.

SUMMARY OF PART IV

1. SUMMARY

The last part of the treatise contained suggestions on a re-interpretation of performance in the RFT in terms of vertical orienting performance and discussed related aspects.

Chapter VIII gave some definitions of orientation followed by a critical discussion of the concept of "field dependence". Chapter VIII ended with a first step towards a re-interpretation of performance in the RFT as a case of vertical orienting performance.

In Chapter IX we discussed further the relation between the RFT and the vertical orienting performance. Three functional principles important for a deeper understanding of performance in the RFT were introduced.

Chapter X contained a logical exhaustive classification of behavior in the RFT and an attempt to relate the most important aspects of this classification to the three working principles presented in Chapter IX. The chapter was closed with some examples.

The Chapter XI gave some further considerations on the RFT. We presented a cybernetic model for understanding performance in the RFT. We then considered the φ-parameter and the σ-parameter from a developmental point of view in order to discuss some etiological factors important for an answer to the question of "why" the subject performed as she actually did. Possible genetic components in vertical orienting performance were discussed. The chapter ended with an example of differences in classification of subjects when population dependent and individual-centered approaches are used.

REFERENCES

REFERENCES

Angyal, A. (1930) Über die Raumlage vorgestellter Örter. Arch. ges. Psychol., 78, 47-94.

Asch, S. E. & Witkin, H. A. (1948a) Studies in space orientation: I. Perception of the upright with displaced visual field. J. exp. Psychol., 38, 325-337.

Asch, S. E. & Witkin, H. A. (1948b) Studies in space orientation: II. Perception of the upright with displaced visual field and with body tilted. J. exp. Psychol., 38, 455-477.

Ashby, W. R. An Introduction to Cybernetics. London: University Paperback, 1971.

Attneave, F. (1954) Some informational aspects of visual perception. Psychol. Rev., 61, 183-193.

Aubert, H. (1861) Eine scheinbare bedeutende Drehung von Objekten bei Neigung des Kopfes nach rechts oder links. Virchows Arch., 20, 381-393.

Bischof, N. Erkenntnistheoretische Grundlagenprobleme der Wahrnehmungspsychologie. In: Handbuch der Psychologie, Bd. 1/I, Bewusstsein und Wahrnehmung. W. Metzger und H. Erke, Eds. pp. 21-78. Göttingen: Verlag f. Psychologie (1966a).

Bischof, N. Psychophysik der Raumwahrnehmung. Ibid. p. 307-408 (1966b).

Bischof, N. Stellungs-, Spannungs- und Lagewahrnehmung. Ibid. p. 409-497, (1966c).

Bischof, N. & Scheerer, E. (1970) Systemanalyse der optisch-vestibulären Interaktion bei der Wahrnehmung der Vertikalen. Psychol. Forsch.,34, 99-181.

Bischof, N. Optic-vestibular orientation to the vertical. In: Vestibular system Part 2: Psychophysics, Applied Aspects and General Interpretations. H. H. Kornhuber, Ed., p. 155-190. Berlin: Springer-Verlag (1974).

Bloomberg, M. (1967) An inquiry into the relationship between field dependence-independence and creativity. J. Psychol., 67, 127-140.

Braemer, W. (1957) Verhaltensphysiologiske Untersuchungen am optischen Apparat bei Fischen. Z. vergl. Physiol., 39, 374-398.

Brunswik, W. Wahrnehmung und Gegenstandswelt. Leipzig: Deuticke, 1934.

Brunswik, E. (1940) Thing constancy as measured by correlation coefficients. Psychol. Rev., 47, 68.

Brunswik, E. Perception and the representative design of psychological experiments. Berkeley: University of California Press, 1956.

Brunswik, E. & Kardos, L. (1929) Das Duplizitätsprinzip in der Theorie der Farbenwahrnehmung. Z. Psychol. III, 315.

Bühler, K. Die Erscheinungsweisen der Farben. Jena: 1922.

Cohen, W. & Tepas, D. (1958) Temporal factors in the perception of verticality. Amer. J. Psychol., 71, 760-763.

Comalli, P. E. (1963) Body position and localization of a visual object. Percept. mot. Skills, 16, 86.

Culver, C. M., Cohen, S. I., Silverman, A. J. & Shmavonian, B. N. Cognitive structuring, Field dependence-independence, and the psychophysiological response to perceptual isolation. In: J. A. Wortis (Ed.) Recent advances in biological psychiatry, 6. New York: Plenum Press. 119-128, (1963).

Curran, C. R. & Lane, H. L. (1962) On the relations among some factors that contribute to estimates of verticality. J. exp. Psychol., 64, 295-299.

Dawson, J. L. M. (1969) Theoretical and research bases of biosocial psychology. Univ. Hong Kong Gaz., 16, No. 3, 1-10.

Davies, A. D. M. & Leytham, G. W. H. (1964) Perception of verticality in adult life. Brit. J. Psychol., 55, 315-320.

Eberhard, G. (1964) A serial Rod and Frame Test: a pilot study. Psychol. Res. Bull, 4, 11.

Edwards, A. L. (1960) Experimental design in psychological research. New York: Holt, Rinehart & Winston.

Fine, B. J. & Danforth, A. V. (1975) Field-dependence, extraversion, and perception of the vertical: Empirical and theoretical perspectives of the rod-and-frame test. Perc. Mot. Skills, 40, 683-693.

Fischer, M. H. (1930) Messende Untersuchungen über die Gegenrollung der Augen und die Lokalisation der Scheinbaren Vertikalen bei seitlicher Neigung des Gesamtkörpers bis zu 360°. II Mitt. Untersuchungen an Normalen. Graefes Arch. Ophthal. 123, 476.

Fisher, R. A. Statistical Methods for Research Workers. Edinburgh: Oliver & Boyd, 1970.

Ford, C. E., Jones, K. W., Polani, P. E., Almeida, J. C. de & Briggs, J. H. (1959) A sex-chromosome anomaly in a case of gonadal dysgenesis (Turner's syndrome). Lancet i., 711-713.

Fracarro, M., Kaijser, K. & Lindsten, J. (1959) Chromosome complement in parents of patient with gonadal dysgenesis (Turner's syndrome). Lancet ii., 1090.

Gibson, J. J. The perspective of the visual world. Boston: Houghton Mifflin Comp., 1950.

Gibson, J. J. (1955) Ordinal Stimulation and the possibility of a global psychophysics. Acta Jutlandica, 11, 178.

Gibson, J. J. (1966) The senses considered as perceptual systems. London: Allen & Unwin.

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.

Gibson, J. J. & Mowrer, O. H. (1938) Determinants of the perceived vertical and horizontal. Psychol. Rev., 45, 300-323.

Girotti, G. & Beretta, A., (1969) Apparent verticality following short-term sensory deprivation: Differential performances in young and old men. Cortex, 5, 75-87.

Groberg, D. H., Dustman, R. E. & Beck, E. C. (1969) The effect of body and head tilt in the perception of vertical: Comparison of body and head tilt with left and right handed, male and female subjects. Neuropsychologia, 7, 89-100.

Gruen, A. (1957) A critique and re-evaluation of Witkin's perception and perception-personality works. J. gen. Psychol., 56, 73-93.

Gurnee, H. (1931) The effect of a visual stimulus upon the perception of bodily motion. Amer. J. Psychol., 43, 26-48.

Haes, H. A. U. de & Schöne, H. (1970) Interaction between statolith organs and semicircular canals on apparent vertical and nystagmus. Acta Otolaryng, 69, 25-31.

Hellkamp, D. T. (1968) Perceptual response sets on the Rod-and-Frame Task in a college sample. Percept. Mot. Skills, 27, 591-594.

Holst, E. v. (1950) Die Arbeitsweise des Statolithenapparates bei Fischen. Z. vergl. Physiol., 32, 60-120.

Holst, E. v. & Mittelstaedt, H. (1950) Das Reafferenz-prinzip. Naturwissenschaften, 37, 464-476.

Howard, I. P. & Templeton, W. B. (1966) Human spatial orientation. London: Wiley.

Jensen, U. J. (1973) Videnskabsteori 1. København: Berlingske Forlag

Kardos, L. (1928) Dingfarbenwahrnehmung und Duplizitätstheorie. Z. Psychol., 108, 240.

Kleint, H. Versuche über die Wahrnehmung, Z. Psychol. 138, 1 (1936); 140, 109 (1937); 141, 9 (1937); 142, 259 (1938); 143, 299 (1938); 148, 145 (1940); 149, 31 (1940).

Koffka, K. Principles of Gestalt Psychology. London: Routledge and Kegan Paul, 1935.

Kohler, I. (1951) Über Aufbau und Wandlungen der Wahrnehmungswelt. Sitzber. Österr. Akad. Wiss. 227, Wien.

Kohler, I. (1961) Interne und externe Organisation in der Wahrnehmung. Psychol. Beitr. 6, 426.

Kurtz, R. M. (1969) A conceptual investigation of Witkin's notion of perceptual styles. Mind, 78, 522-533.

Lester, G. (1968) The Rod-and-Frame Test: Some comments on methodology. Percept. mot. Skills, 26, 1307-1314.

Magnus, R. Körperstellung. Berlin: Springer, 1924.

Mann, C. W. (1952a) Visual factors in the perception of verticality. J. exp. Psychol., 44, 460-464.

Metzger, W. Psychologie. Darmstadt: Steinkopff, 1954, 1968.

Mittelstaedt, H. (1961) Die Regelungstheorie als methodisches Werkzeug der Verhaltensanalyse. Die Naturwissenschaften, 8, 246-254.

Mittelstaedt, H. (1972) Kybernetik der Schwereorientierung. Heidelberg: Gustav Fischer Verlag, 1972.

Morant, R. B. & Aronoff, S. (1966) Starting position, adaptation and visual framework as influencing the perception of verticality. J. exp. Psychol., 7, 684-686.

Müller, G. E. (1916) Über das Aubertsche Phänomen. Z. Psychol. Physiol. Sinnesorg., 49, 109-246.

Müller, G. E. (1917) Zur Analyse der Gedächtnistätigkeit und des Vorstellungsverlaufs. Z. Psychol. Erg., 8.

Neal, E. (1926) Visual localization of the vertical. Amer. J. Psychol., 37, 287-291.

Nielsen, J., Nyborg, H. & Dahl, G. (see: Nyborg, 1975c).

Nyborg, H. & Nielsen, J. (1977) Sex chromosome abnormalties and cognitive performance III. Cognitive defect or maturational delay in girls with Turner's syndrome: a developmental study (in prep.)

Nyborg, H. (1971a) Tactile stimulation and perception of the vertical: I. Effects of diffuse vs. specific tactile stimulation. Scand. J. Psychol., 12, 1-13.

Nyborg, H. (1971b) Tactile stimulation and perception of the vertical: II. Effects of field dependency, arousal and cue function. Scand. J. Psychol., 12, 135-143.

Nyborg, H. (1972) Light intensity and perception of the vertical: two experiments with the Rod-and-Frame test. Scand. J. Psychol., 13, 1-13.

Nyborg, H. (1972b) Psykologi og genetik - En introduktion til psykogenetik. København: Munksgaard.

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

Nyborg, H. (1974b) Light intensity in the rod-and-frame test reconsidered. Scand. J. Psychol., 15, 236-237.

Nyborg, H. & Isaksen, B. (1974) A method for analysing performance in the rod-and-frame test. II. Test of the statistical model. Scand. J. Psychol., 15, 124-126.

Nyborg, H. (1975) Validity of two measures of field dependence in the rod-and-frame test. A comparative study. (in prep.)

Nyborg, H. (1975b) Adaption and temporal effects in the rod-and-frame test. (in prep.)

Nyborg, H. (1976) Turner's syndrome. A psychiatric-psychological study of 45 women with Turner's syndrome, compared with their sisters and women with normal karyotype, growth retardation, and primary amenorrhoea. (in collaboration with J. Nielsen and G. Dahl). Acta Jutlandica, Publ. Univ. Aarhus, Universitetsforlaget, Aarhus.

O'Connell, D. C., Weintraub, D. J., Latrop, R. G. & McHale, T. J. (1967) Apparent verticality: Psychophysical error versus sensory-tonic theory. J. exp. Psychol., 73, 347-353.

Polani, P. W., Hunter, W. F. & Lennox, B. (1954) Chromosomal sex in Turner's syndrome with coarctation of the aorta. Lancet ii, 1205.

Poulsen, H. (1972) Kognitiv struktur. København: Akademisk Forlag.

Rasch, G. (1955) Om populationer, standarder og profiler. 6. Nord. Militærpsykologkonference. København, 1954, p. 47-75.

Rasch, G. Probabilistic models for some intelligence and attainment tests. Copenhagen: The Danish Institute for Educational Research, 1960.

Rosman, R. R. (1960) The tilting-chair tilting-rod task: a methodological note. Percept. mot. Skills, 10, 9-10.

Sandström, C. I. Orientation in the present space. Stockholm: Almquist & Wiksell, 1951.

Sandström, C. I. (1954) A note on the Aubert Phenomenon. J. exp. Psychol., 48, 209-210.

Shaffer, J. W. (1962) A specific cognitive deficit observed in gonadal aplasia (Turner's syndrome). J. clin. Psychol., 18, 403-406.

Schneider, C. W. & Bartley, S. H. (1962) A study of the effects of mechanically induced tension of the neck muscles on the perception of verticality. J. Psychol., 54, 245-248.

Schöne, H. (1964) On the role of gravity in human spatial orientation. Aerospace Medicine, 35, 764-772.

Skinner, B. F. (1956) A case history in scientific method. Amer. Psychol., 11, 221-233.

Taylor, M. M. (1963) Visual discrimination and orientation. J. Opt. Soc. Amer., 53, 763-765.

Teuber, H. L. & Mishkin, M. (1954) Judgement of visual and postural vertical after brain injury. J. Psychol., 38, 161-175.

Tjio, J. H., Puck, T. T. & Robinson, A. (1959) The somatic chromosomal constitution of some human subjects with genetic defects. Proc. nat. Acad. Sci. (Wash.), 45, 1008-1011.

Turner, H. H. (1938) A syndrome of infantilism, congenial webbed neck and cubitus valgus. Endocrinology, 23, 566-574.

Wade, N. J. (1968) The effect of body posture on visual orientation. Ph.D. thesis submitted to Monash University, Australia.

Vandenberg, S. G. (1962) The hereditary abilities study: Hereditary components in a psychological test battery. Amer. J. hum. Genet., 14, 220-237.

Weiner, M. (1955) Effects of training in space orientation on perception of the upright. J. exp. Psychol., 49, 367-373.

Werner, H., Wapner, S. & Chandler, K. A. (1951) Experiments on sensory-tonic field theory of perception: II. Effect of supported and unsupported tilt of the body on the visual perception of verticality. J. exp. Psychol., 42, 346-350.

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

SUBJECT INDEX

Vernon, P. E. (1971) Analysis of cognitive ability. Brit. Med. Bull., 27, 222-226.

Wertheimer, M. (1912) Experimentelle Studien über das Sehen von Bewegung. Z. Psychol. Physiol. Sinnesorg., 61, 161-265.

Witkin, H. A. (1965) Psychological differentiation and forms of pathology. J. abnorm. Psychol., 70, 317-336.

Witkin, H. A. (1967) A cognitive style approach to cross-cultural research. Int. J. Psychol., 2, 233-250.

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.

Witkin, H. A., Lewis, H. B., Hertzman, M., Machover, K., Meissner, P. B. & Wapner, S. Personality through perception. New York: Harper, 1954.

Witkin, H. A., Dyk, R. B., Faterson, H. F., Goodenough, D. R. & Karp, S. A. Psychological differentiation. New York: Wiley, 1962.

Witkin, H. A. et al. (1974) Social conformity and psychological differentiation. Int. J. Psychol., 9, 11-29.

Witkin, H. A. et al. Field-dependent and field-independent cognitive styles and their educational implications. Princeton, New Jersey: Educational Testing Service, 1975.

Witkin, H. A. & Berry, J. W. (1975) Psychological differentiation in cross-cultural perspective. J. Cross-Cultural Psychol., 6, 4-87.

Zubin, J. (Ed.) Experimental Abnormal Psychology. New York: Columbia University Store, 1955.

ABSOLUTE ERROR 42 44
ADDITION 64
ADDITIVITY 55 60 62 67
ADHERENCE 47
ADOLESCENCE 30
ADOPTED 29
AFFECTIVE 94
AFFERENCE 101 114 115
ALCOHOL 29
ALGEBRAIC MEAN 43
ALTERNATIVE 118 130 131 140 141 161
162
AMBIGUITY 131 65
AMPUTATION 25
ANALYSIS OF REGRESSION 65
ANALYSIS OF VARIANCE 53
ANGYAL A 96
ANIMAL 33
APPROACH FUNCTIONAL 17
APPROXIMATION 44
AREA GEOMETRICAL 64
AROUSAL 28 35 36
ARTEFACT OF TEST PROCEDURE 67
ASCH AND WITKIN 26 94
ASHBY W R 104 150
ASSUMPTION 45 62 67
AT HAND 117
ATTACHMENT PASSIVE 101
ATTNEAVE F 115
AUBERT H 25
AUBERTEFFECT 25 26
AUTHORITY 152
AVERAGING ARITHMETHIC 51
BASIS QUANTITATIVE 92
BICYCLE RIDER 150
BIOCULTURAL MODEL 153
BIOCYBERNETICS 102 144
BIOLOGICAL SYSTEM 146
BISCHOF AND SCHEERER 94 101 124 125 144 145
147
BISCHOF N 94 17 101 109 113 114
115 117 118 140 141 144
152
BLENDED TYPES 142
BLOCKING 131 141
BLOOMBERG M 31
BODY 25 27 28 33 34 47
97 98 99 109 115 120
121 123 132 147 149
BODY 153
BRAEMER W 152
BRAIN DAMAGE 25 29
BREAK DOWN 95
BRUNSWIK AND KARDOS 113
BRUNSWIK E 117
BUHLER K 113
BUILD-IN ERRORS 146

CASTRATED RATS 153
CAUSAL BRIDGE 105 109
CAUSAL RELATIONSHIP 163
CHANNELS 145
CHI 55 67 81
CHROMOSOME ABNORMALITIES 29 78 81
CHRONOLOGICAL AGE 20 150 152
CLASSIFICATION 92 154

CLEAR-CUT TYPES 142
CLINICAL 28 29 61
COGNITIONAL DEFICIT 15 76 77 83 84
COGNITIVE 76 75
COHEN AND TERAS 23 24
COMALLI P E 25
COMPARABLE CONDITIONS 44
COMPARATOR 149
COMPARATOR 152
COMPENSATION 112 113 114 115 120 121 122 125 130 147 147 149 161 162
COMPLETENESS 62 66
COMPLEXITY 14 19 24 30 44 45 46 61 93 101 118 157
COMPONENTS ADDITIVE 55
COMPOSE A MEAN 123 124
COMPROMISE 118 123 124 130 140 141 157 161
COMPROMISE 138
COMPULSIVE SYMPTOMS 29
CONCEPT HEURISTIC 16
CONFLICT 19 33 97 99 101 132 137
CONFUSION 123
CONSCIOUS 117
CONSISTENCY OF SCORES 44
CONSTANCY 28 94 101
CONSTANT DEVIATION 23 24 41 42 43 48 55 60 61 62 66 68 69 80 82 84 89 134 146
CONSTANT ERROR 42
CONSTRUCT VALIDITY 44 49 61
CONTEXT 47
CONTINUOUS DISTRIBUTION 141
CONTINUUM 48
CONVERGENT DETECTION 117
CORRECTION 113 117 118 123
CORRELATION 154 156 163
COUNTERBALANCE 52
COUNTERTORSION 126 146
CREATIVITY 28

CRITERIA EXPERIMENTAL 34
CROSSCULTURAL 30 61
CRUDE AVERAGE ERROR 42
CUBITUS VALGUS 76
CUE FUNCTION 35 36
CULTURAL 29 153
CULVER ET AL 13 33 34
CURRAN AND LANE 37
CUT-OFF POINT 138
CUTOFF LINE 157
CYBERNETIC 17 19 20 93 102 104
144 150 151 154 164
DAVIES AND LAYTHAM 47
DAWSON J L M 153
DEFENCE 28
DEFINITION QUANTITATIVE 34 35
DEPRIVATION 28
DEVELOPMENT 83 18 20 23 26 27
28 29 30 38 51 76
141 149 150 164
DEVIATION 43 44 48 49 52 53
67 68 69 79 80 81
49
DIFFERENCES INDIVIDUAL 16 18
DIFFERENTIATION 16 23 29 30 152
DIMENSION 16 28
DIRECTION OF DEVIATION 79
DISCRIMINATION 28
DISORIENTATION 95 96 117 151
DISTAL 17 105 106 109 112 114
115 117 145 146 147
DISTRIBUTION NORMAL 53 54
DISTURBANCE 100 101 109 112 113 114
115
DOMINANT 130 140 161 162
DORSAL SIDE 123
DYNAMIC 132 144 101
E-EFFECT 25
EDUCATION 29
EDWARDS A L 53 54
EFFECTIVENESS 29
EKG 131
EMBEDDEDNESS 47 99 157
EMBEDDINGNESS 100
EMG 131
EMOTIONAL 28
ENDOCRINOLOGICAL 153
ENVIRONMENTAL 151
EQUIDISTANT SCALE 37
EQUILIBRIUM STATE 116
EQUIVALENCE 144
EQUIVALENT 117 117 123 138 141
EQUIVOCAL 140
ERROR 49
ESSENTIAL VARIABLE 150 151
ESTIMATED LIMIT 141

ETIOLOGICAL 164
EXHAUSTIVE 164
EXPERIMENTAL 115
EXPLANATORY POWER 132
F TEST 53 54
FACE VALUE 28
FAILURE OF CALCULATION 112
FEEDBACK 125 147
FEEDFORWARD 125
FIELD AS A WHOLE 97
FIELD DEPENDENCE 13 16 17 18 19 23
27 28 29 30 31 33
34 35 37 41 46 46
48 52 56 60 61 63
66 67 68 75 79 81
84 92 93 96 97 98
99 100 101 120 150 155
156 157 161 164
FIELD DEPENDENCE 153
FIELD STRUCTURE 97
FILTER MECHANISM 115 121 149
FINAL SUGGESTION 125 126
FINE AND DANFORTH 45 46 61 163
FISH 123 152
FISHER M H 131
FISHER R A 65
FLIPFLOP 131 140 161 162
FLOW 145 147
FLOWDIAGRAM 17
FLUCTUATION RANDOM 15
FORD JONES POLANI ALMEIDA AND BRIGGS 76
FORMULA ONE 43
FORMULA TWO 43
FRACCARO KAIJSER AND LINDSTED 76
FRAME DEPENDENCE 47 48 62 65 66 67
68 69 75 80 82 84
89 92 95
FREE INPUT 145 146 154
FREEDOM FROM DISTRACTIBILITY 76
FUNCTION CONSISTENT 46
FUNCTIONAL 19 93 101 104 113 118
137 144 161 162 164
GENE EFFECT 151
GENERALIZATION 154 162
GENETIC 153 154 164
GENUINE GENERAL 163
GESTALT 97 98
GIBSON AND MOWRER 27
GIBSON AND RADNER 24 47
GIBSON J J 13 27 33 35 94 115
116 120 122 123 152
GIROTTI AND BERETTA 47
GRAVITY 100
GROBERG DUSTMAN AND BECK 47
GROUPCENTERED 154
GROWTH RETARDATION 75 78 83

GRUEN A
GSR 45 46 48 53 61
HAES UDO DE 131
HAES UDO DE AND SCHOENE H 126 131
HISTORY 131
HOLST AND MITTELSTAEDT 23
HOLST E V 113 144
HORMONAL 123 124 144 152
HOWARD AND TEMPLETON 154
HYPOTHETICAL CONCEPTUALIZATION 13 23 25 41
HYPOTHETICAL MECHANISMS 124
IDEOGRAPHIC TEST PROFILE 17
ILLUMINATION 163
ILLUSION 65
ILLUSION OF ORIENTATION 28
IMAGINED 96 100
INACCURACY HYPOTHESIS 117
INCOMPATIBLE TENDENCIES 27
INCOMPLETENESS 130
INCONGRUENCE 65
INCONGRUENCE 100 123 138
INCONGRUOUS 124 130 131 132 132 141
144
INDIVIDUAL DIFFERENCES 118
14 24 25 27 28 33
34 36 51 52 61 69
77 93 104 113 122 126
INDIVIDUAL TEST PROFILE 152 153 154
INDIVIDUALCENTERED 162
INDUCTIVE APPROACH 155 162
INFERABLE VARIABLE 154
INFORMATION 145 147
13 98 122 100 101 106
109 114 121 123 130 144
INFORMATION PROCESSING 147
19 19 93 102 104 113
INFORMATION THEORY 118 120 137 144
INNER FIELD 116 144
INSTABILITY PERCEPTUAL 101
INSTRUCTION 75
INTEGRATION 28
INTELLECTUAL 29 30
INTELLECTUAL 28
INTERACTION 76
55 13 33 113 152 153
INTERFERENCE 161 162
INTERPRETATION ONEDIMENSIONAL 109 114
JENSEN U J 93
JOINT RECEPTOR 163
KARDOS L 109
KARYOTYPE 113
KEY PERSON 76 78 81 82 83
KLEINT H 152
KLINEFELTERS SYNDROME 24 117 131 162
KOFFKA K 151
KOHLER I 116 122
KURTZ R M 115
LABILITY 45
LEARNING 130 131 140 161 162
153 154

LESTER G 45 46 47
LEVEL OF DESCRIPTION 138
LEVEL OF SIGNIFICANCE 80 136
LIGHT INTENSITY 14 18 19 36 37 58 68 89 92
LINEAR MAPPING 147
LOCALISATORISCHEN UNRUHE 130
LOCALIZATION 94
LOGICALLY EXHAUSTIVE 132
LOKALISATIONSTENDENZ 130
MAGNUS R 33
MANIODEPRESSIVE 29
MANN C W 14
MATURATION 152
MATURATION 154
MEASUREMENTS REPEATED 54
MEDICAMENT 29
METHOD 19 45
METHOD NEW 14 18 19 49 51 52 53 55 58 60 63 66 69 75 77 79 80 82 83 84 89 92 121 155 161
METHOD TRADITIONAL 14 15 19 35 36 37 38 41 44 51 52 58 60 63 66 68 69 75 77 79 81 83 84 153 154 155 157
METHOD TRADITIONAL 89
METZGER W 115 116 162
MITTELSTAEDT 144
MODEL STATISTICAL 53
MORANT AND ARONOFF 24
MOTHER-CHILD 29
MULLER G E 25 130 162
MULTIDIMENSIONAL 84 92 93 100 153 161
MULTIVECTORIAL 145 147
MUSCLE 109
MY 55 62 63 63 66 67 68 80 82 89 134
NATURAL BREAKS 155
NATURAL CUT-OFF POINT 155 156
NAYLOR H 24 47
NEAL E 24 94 94
NEGATIVE BACKWARD COUPLING 146
NEURAL DISCHARGE 17
NEUROPSYCHOLOGICAL 20
NEUTRALIZE 114
NIELSEN NYBORG AND DAHL 15 76 78 89 150
NONSIBLING CONTROL GROUP 78 81 82
NONSPECIFIC INFORMATION 69
NONVERBAL TEST 77
NONVERIDICAL 96 105
NORMAL DISTRIBUTION 44
NY 55

NYBORG AND ISAKSEN 54 55 58 63 79
NYBORG AND NIELSEN 102 150 151
NYBORG H 23 24 25 27 35 36 48 51 52 54 58 61 63 64 68 79 80 96 152 155 156
OBSERVABLE VARIABLE 145
OBSESSIVE SYMPTOMS 29
OCONNELL ET AL 24 47
OESTROGEN 153
ONEDIMENSIONAL 157
ONTOGENETIC 101 102 146
OPTIC 95 96 97 100 106 109 112 114 115 117 118 120 122 123 124 125 126 130 132 134 137 141 144 152 154 156 157 161
OPTICAL SUGGESTION 149
OPTICAL VECTOR 125
ORGANISMIC CONDITION 123
ORIENTATION 17 19 20 26 92 94 95 96 100 140 141 144 152 153 162 163
ORIENTING 93 95 100 101 102 104 105 109 112 113 114 115 117 120 124 137 140 144 149 150 151 152 153 164
OUT-THERE STANDARD 97
OUTER FIELD 101
OVERCOME A CONTEXT 27 28
OVERCOMPENSATION 138 140
OVERDETERMINATION 132 141
PARADOXICAL PERCEPTION 141
PARANOIA 29
PEDAGOGICAL 61
PERCEPTUAL ORGANIZATION 76
PERCEPTUAL SYSTEM 101
PERFORMANCE IQ 76 77
PERMISSIBLE DEVIATIN 151
PERSONAL COMMITMENT 95
PERSONALITY 16 28 46 53 61 156
PERSONSPECIFIC 18 20 24 53 69 99 134 154 164
PHENOMENAL 17 109
PHENOMENOLOGICAL EVENTS 45
PHI 55 15 16 20 60 62 63 65 66 67 68 69 79 82 89 92 122 130 132 134 136 137 140 141 149 150 156 161 162 164
PHI UNWEIGHED 82
PHI WEIGHED 80
PHYLOGENETIC 146
POINT OF SUBJECTIVE VERTICALITY 42
POLANI HUNTER AND LENNOX 76

POPULATION DEPENDENT	154	164				
POPULATION DEPENDENT	20					
POSTURAL	27	27				
POULSEN H	163					
PREFERED PRINCIPLES	141					
PREPUBERTY	150					
PREVALENCE	76					
PRIMARY AMENORRHOEA	83	75	78			
PROTECTED	152					
PROXIMAL	17	106	112	115	146	147
PSYCHOMETRIC METHOD	154					
PSYCHOPATIC	29					
PSYCHOPHYSIC METRIC	35					
PURE VESTIBULAR VERTICAL	124	125	149			
PURPOSE	146					
RANDOM VARIATION	137					
RANGE	44					
RASCH G	162					
REAFFERENCE	113					
REALITY CONTACT	94					
RECONSTRUCTION	113	115	116	117	122	
REDUNDANCY	115	116	117	121		
TRAINING	28					
REDUNDANCY	123	154				
REGRESSION LINE	65	66				
REGULARITY	117	153				
REGULATION	150					
RELATIVELY RELEVANT FACTOR	162	163				
RELIABILITY	114	124				
RESPONSE COMBINATIONS	132					
RESPONSE CONSISTENCY	15	20	43	48	51	52
	53	54	60	61	75	79
	80	82	84	89	92	121
	122	131	140	141	155	156
	161					
RESPONSE PATTERN	52	53	56			
RESPONSE SET	42					
RESPONSE-FAN	136	137				
RETINAL	105	106	109	112	114	115
	116	122	124	145	146	
RETUNE	121	122				
REVERSED SIGN	114					

REVERSIBLE FIGURES 131
RFT 13 14 15 16 17 18 19 20 23 24 25 26 30 31 33 34 36 37 38 41 45 46 47 48 49 51 53 54 58 60 61 62 63 66 67 68 69 75 76 77 78 79 80 81 82 84 92 93 95 96 97 98 99 100 101 102 104 105 109 112 113 116 117 118 120 121 122 123 124 126 130 131 132 134 137 140 141 144 146 149 151 152 153 154 155 157 161 162 164
RHO 55 62 63 65 66 67 68 80 82 89 134
ROD 23 24 25 26 27 34 47 48 52 60 61 62 64 64 65 66 68 69 78 79 80 80 82 84 89 105 106 134 136 146
ROSMAN R 24
RUBBER CUSHION 64
SANDSTROEM C I 25 94 95
WITKIN ET AL 93
SANDSTROEM C I 151
SCALAR 145
SCHIZOPHRENIC 29
SCHNEIDER AND BARTLY 24
SCHOENE H 26 114 120
SCORES AVERAGED 46
SELF 29
SENSITIVITY 13 34 99
SEPARATION 29 47
SET 28
SEX CHARACTERISTICS 76 83
SEX CHROMOSOME 15 16 75 76 89 92
SEX DIFFERENCES 29 151
SEX DIFFERENCES 152
SEX HORMONE 153
SHAFFER J W A 76
SIGMA 20 60 80 82 121 122 132 136 138 140 141 149 150 156 161 162 164
SIGMA ONE 54 55
SIGMA TWO 54 55
SIMPLE AVERAGING 157
SIMPLIFICATION UNJUSTIFIED 45
SIMULTANEITY 118 131 132 141 162
SISTER CONTROL GROUP 78 81 82 83 150
SKIN SENSE 109
SKINNER B F 154
SOCIAL 28
SOCIAL FIELD DEPENDENCE 152
SOCIALIZATION 30 31

SOMATORECEPTOR 120
SOMESTHETIC 97 100 106
SPACE 94
SPATIAL EXPERIENCE 154
SPECIALISATION 29
SPECIFICITY 34
STANDARD ERROR 41 44
STANDARD SCORE 42
STARTING POSITION 55 47 48 52 60 61
62 64 66 68 69 80
82 84 89 134 146
STATIC TILT 144
STATOLITH 114 120 126 130
STATURE SHORT 76
STIMULATION TACTILE 13 14 18 25 33 34
35 36 92
STIMULATION UNILATERAL 24
STRESS 29 131
STRUCTURE GEOMETRICAL 14 60 62 63 64 67
68 89 92
STYLE 28 30 31
SUBJECTIVE FRAME OF REFERENCE 147
SUBJECTIVE VERTICAL 42
SUBSYSTEMS 29
SURGICAL REMOVAL 123
SURVIVAL 94 150 151
SYSTEM COMPLEX 104
SYSTEMANALYTIC 17 161
SYSTEMATICAL 138 140
T TEST 53
TAYLOR M M 25
TELEONOME SYSTEM 146
TEUBER AND MISHKIN 25
TEXTURE DENSITY 116
THERAPY 29
TILTING STAND 36
TIME 94
TJIO PUCH AND ROBINSON 76
TOTAL RFT INDEX 42
TOTAL UNIVERSUM 93 162
TRACKING DOWN 114
TRAINING 28 31
TURN THE OBJECT REPRESENTATION 114 120
TURNER GIRLS 16 76 77 81 82 83
84 92 121 122 150 153
TURNER H H 76
TURNERS SYNDROME 75 76 77 78 83 151
TURNERS SYNDROME 15
TWINS 29
TYPICAL CONTEXT 115 122
ULCERS 29
UNCERTAINTY 162
UNCOMPLICATED COMPROMISE 131 141
VESTIBULAR 140
UNDERCOMPENSATION 138 140
UNEASINESS 95 130 131 140

UNEQUIVOCAL 141
UNIQUE PERFORMANCE 161
UNSECURITY 130
UNSIGNED DEVIATION 23 41 42 45 47
UNWAHRNEHMBAR VORHANDEN 116 117
UPRIGHT DEFINITION OF 64
VALIDITY 15 18 19 45 60 96
VALIDITY CONSTRUCT 46
VARIABILITY 46 48 61 101 102 102 113
VARIABILITY INTRAINDIVIDUAL 46
VARIABLE CONTAMINATION 14 37
VARIABLE CONTAMINATION 48
VARIABLE ERROR 41 43
VARIATION CHANCE 56
VARIATIONS SYSTEMATIC 105
VECTOR 124
VECTORIAL ADDITION 115 121 125 126
VECTORIAL MODEL 124
VECTORIAL PARAMETER 132
VECTORIAL VARIABLES 145
VERIDICAL 105 109 124 140 161
VERTICAL 13 17 25 26 27 33 35 36 42 45 46 47 52 58 60 61 64 68 69 79 80 89 92 93 94 95 96 100 101 104 105 106 109 112 113 114 115 116 121 122 124 125 132 137 144 146 147 149 151 153 162 163 164
VERTICAL 120 150 152
VESTIBULAR 96 97 99 100 106 109 114 117 118 123 124 125 132 137 138 140 141 144 147 152 154 156 157
PHI 132
VESTIBULAR-SOMESTHETICAL 19
VISUAL 99 132 147
VISUAL AFFERENCE 147
VISUAL SUGGESTION 124 125
WADE N J 25
WARRANTOR 117
WEIGHT 101 124 134
WEIGHT RATIO 153 154

WEINER M 24
WERNER AND WAPNER 24 47
PROTECTED 152
WERTHEIMER M 13
WITHIN-STANDARD 97
WITKIN AND ASCH 26 35 42 48 61 77 79
WITKIN AND BARRY 29
WITKIN AND BERRY 30
WITKIN ET AL 13 23 28 29 31 42 44 47 49 69 77 93 97 98 99 120 149 150 152 154 163
WITKIN H A 31 33 61
XYY CHROMOSOMES 151
YES-NO PROCEDURE 132
ZUBIN J 154