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MEASUREMENT OF THE PERCEPTUAL ROTATION

OF VISUAL STIMULI

by

Floyd W. Stettler

A dissertation submitted in partial fulfillment
of the requirements for the degree

of

DOCTOR OF EDUCATION

in

Psychology

Approved:

UTAH STATE UNIVERSITY
Logan, Utah

1970

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PREFACE

All behavior has a history. The present emerges from the past, and current contingencies shape the future. Not only is favorable learning apperceptively cumulative, but maladaptive experience as well.

The hierarchical nature of learning and experience would suggest an early intervention to interrupt the compounding of patterns which predispose toward failure and defeat. As ineffectual adaptive patterns are applied over periods of time, they become increasingly ingrained as characteristic ways of dealing with life.

Since delay intensifies the problem, the child's initial exposure to the educational system becomes most crucial. Problems already present must be alleviated, handicaps must be relieved, an effectual base for future learning must be provided. The accomplishment of this profound task requires sensitive instruments, sophisticated and empathic diagnosticians, and precise remedial techniques. The needs are apparent, and the search is posed.

Grateful acknowledgement is offered to those faculty members who fostered my renewed interest in education. Phyllis Publicover particularly stirred my interest in research on the learning adjustments of special children. Arden Frandsen, a distinguished psychologist and writer, has extended direction and confidence. The members of my thesis committee, whom I recognize as outstanding scholars, have served my needs with acceptance and kindness. Their friendship and directive criticism has made my academic experience more impressive and meaningful.

The efficient collection of dissertation data was made possible by Arthur Jackson, principal at Edith Bowen Laboratory School, who offered

facilities and the cooperation of school personnel. The director of Children's World Nursery, Lucy Anne Morrelli, generously devoted much time and effort in shepherding four and five year olds through trial runs and testing sequences.

Floyd W. Stettler
Floyd W. Stettler

TABLE OF CONTENTS

	Page
INTRODUCTION	1
The Problem	2
Recognizing and Judging Rotation	3
Psychometric Assessment of Rotation	5
The PRA Task	11
CORRELATES OF PERCEPTUAL ROTATION	14
Age and Rotation	15
The Factor of Intelligence	16
Diagnostic Categories and Rotation	18
Rotation and Design	20
Spatial Coordinates and Rotation	21
The Factor of Cerebral Dominance	22
School Achievement and Rotation	24
INSTRUMENTS AND METHODS	26
Hypotheses	26
The Perceptual Rotation Apparatus	28
Variations of the Visual Stimulus	31
Selection of the Sample	33
Temporal Stability of Measurements	36
Relationship to Intelligence	36
Comparison With Another Instrument	37
ANALYSIS OF DATA	39
Statistical Assumptions	39
Effects of Stimulus Design	41
Developmental Characteristics	46
Reliability of Measurements	54
Validational Comparisons	62
Discussion of Other Findings	67
REPLICATIVE MEASUREMENTS	74
Changes in Methodology	74
Hypothesis	78
The Sample	80
Findings	80
Discussion	82

TABLE OF CONTENTS (Continued)

	Page
SUMMARY AND CONCLUSIONS	84
Instruments and Tested Samples	84
Hypotheses and Findings	85
Replicative Study	88
Conclusions	88
BIBLIOGRAPHY	89
VITA	98

LIST OF TABLES

Table	Page
1. Distribution characteristics of average rotational error for ages five and eleven on Disk 2	40
2. Correlations of performance on individual items with overall test scores for ages four, seven, and eleven	42
3. Mean and standard deviation of average rotational error for ages four through eleven on each of three disks	43
4. Reliability of total scores based upon seven day re-testing	54
5. The occurrence of reversals and mirror images	55
6. Average interitem correlations for ages four, seven and eleven	58
7. Product-moment correlation matrix for average error at each compass setting and for each disk at age seven	59
8. Intercorrelations for the seven year old group on Metropolitan Achievement, MPD, Quick Test, and PRA	63
9. Comparison of seven year old children from present sample and normative group on the Minnesota Percepto-Diagnostic Test	64
10. Mean and standard deviation of rotation error at each disk setting	69
11. Mean and standard deviation of rotation error for each disk on test-retest with two methods of scoring at ages four and five	81
12. Reliability coefficients for each disk at ages four and five for two methods of scoring	82

LIST OF FIGURES

Figure	Page
1. Design cards of the Minnesota Percepto-Diagnostic Test	9
2. Examples of rotation which occurred with PRA disks	12
3. Variant planes and angles of the Perceptual Rotation Apparatus	30
4. Actual size of design used on Disk 1	32
5. The straight line presented on Disk 2	34
6. Bender pattern No. 3 as used on Disk 3	34
7. Age trends in mean rotation error for each disk	47
8. Age trends in the standard deviation of average rotation error for each disk	48
9. Design No. 2 adjusted to register reversals	77
10. The cube outline used as Design No. 3	77
11. Actual size and arrangement of criterial and field elements as utilized on one disk of Design No. 4	79

ABSTRACT

Measurement of the Perceptual

Rotation of Visual Stimuli

by

Floyd W. Stettler, Doctor of Education

Utah State University, 1970

Major Professor: Arden Frandsen
Department: Education

Apparatus for study of the phenomenon of rotation consisted of two rotating turntables constructed to receive disks for presenting varied visual stimuli. Turntables were graduated into 360 degrees for measurement of angular discrepancy in the task of visually matching rotational positions. Subjects from ages four through eleven attempted to match six compass positions for each of three designs--a boxlike house, a straight line, and Bender-Gestalt Figure No. 3.

Errors of rotation were classed as either transpositional or non-transpositional. Transpositional error, involving reversal or mirroring of the directional aspect of the designs, largely disappeared by age six. Non-transpositional error declined rapidly between ages four and six, leveled off, then showed another significant decline at age nine. The three designs were readily conceptualized as to direction, showing no differences for inducing rotation. The error scores were minimally related to IQ and achievement. No correlation was found with rotation as measured by the Minnesota Percepto-Diagnostic Test.

Groups at ages four, six, and eight were retested after one week, disclosing low reliabilities for non-transpositional error, though mean

rotation error and standard deviation for the groups remained stable. Sixty-seven percent of four year olds showed instances of transposition, and as this source of error was scored as limited to fifty degrees and included in the composite score, the reliability for age four was raised from .52 to .96.

A second study of children at ages four and five was conducted to verify the possibility of obtaining high reliability by combining both types of error. Utilizing some variations in methodology and designs, test-retest correlations over a two-week interval yielded a reliability of .82 for age four and .93 for age five.

It was concluded that the method was applicable in assessing rotational error occurring on a perceptual-intuitive level, and that personal characteristics associated with perceptual-intuitive operations could be reliably measured at ages four and five.

(97 pages)

INTRODUCTION

Man is enveloped by a sea of stimuli. Waves of energy sweep over him, lapping at nerve endings, actuating receptor mechanisms. Out of this endless impingement of data the mind must select and classify, absorbing what is personally meaningful, relating it to past accretions, preparing the organism to adapt to the changing environment.

In a distinctively human endeavor the mind of man turns inward to explore its own mysterious operations. The mental processes have been probed and studied from many points of view, but access to the subtleties of the mind is not easily obtained. Much remains to be explored and understood.

A major approach to understanding cognitive operations recognizes the mind as a mediator between incoming stimuli and emergent behavior. Through definition of input and evaluation of output, the mediational activity may be inferred. By limiting sensory excitation to a single modality, as that of the visual receptor system, a more precise control of input variables is obtained. Similar precision in measurement of effector or response modes further refines the inferential data.

A number of instruments developed for assessing individual variations in visual perception have registered the phenomenon of rotation. The occurrence of this phenomenon has tended to be associated with the limited perceptual skills characteristic of formative years and with severe psychological abnormalities in later years. Considerable research interest has consequently been directed toward the question of whether measurements of rotation are applicable in the diagnosis of developmental abnormalities.

The Problem

Dependable behavioral tools for assessing the functioning of the central nervous system of children are urgently needed for the following reasons:

1. To facilitate research which enlarges the theoretical base for understanding mental operations.
2. To aid in the early recognition of neurological pathology.
3. To make possible the accurate differential diagnosis of organic brain damage, mental or maturational retardation, and emotional disturbance.
4. To assess readiness for primary education.
5. To predict specific learning disabilities and assist in defining remedial exercises.

In response to such crucial needs this dissertation describes an effort to extend knowledge of the phenomenon of perceptual rotation. The approach involved the design and application of an apparatus for measuring the occurrence of rotational phenomena induced under particular experimental conditions. The instrument utilized will hereinafter be designated the Perceptual Rotation Apparatus or the PRA.

A recognized method of testing hypotheses about perceptual phenomena requires the application of differing experimental operations which converge upon a single occurrence or characteristic. Such a "converging operation" (Garner, Hake, and Eriksen, 1956) facilitates the selection or elimination of alternative explanatory hypotheses. Hence, an approach to improved definition and understanding of the phenomenon of rotation lies in the comparison of results obtained from instruments utilizing differing variables.

Accordingly, the PRA was designed to test for the occurrence of rotations as posed by the following experimental variables: (1) the simultaneous presentation of two visual stimuli, (2) the limitation of motor involvement to a simple matching of the degree of rotation of the two stimuli, (3) the use of rotating disks offering a precise measurement of the degree of discrepancy in rotational matching, and (4) the use of visual stimuli readily recognized as directionally oriented.

These experimental conditions were unique in certain features from all previous approaches to the measurement of rotation. Any occurrence of rotations under the defined conditions, when compared with all prior experimental findings, might contribute to theoretical formulations about rotation and extend the diagnostic utility of this psychological phenomenon. A modicum of accomplishment in this direction would fulfill the objectives of this dissertation.

Recognizing and Judging Rotation

Recognition of rotation

As an object is rotated, turned on an axis paralleling the line of sight, are we able to perceive it as the same object? Does its identity remain stable with only its orientation seen as changing? At what ages and with what types of objects?

In a pioneering study Dearborn (1899) showed serially to adult subjects a large number of inkblots, some of which were repetitions. The figures were presented in each of four discrete compass orientations: 0°, 90°, 180°, and 270°. Subjects were able to recognize the previously seen blots most easily when presented in their initial or the 0° position. Nonsense shapes were also used by Arnoult (1954) in demonstrating that errors in identifying figures tended to increase as a function of

increases in the angular disparity of the standard and compared forms.

The experienced familiarity of a form tends to reduce the errors of identification occasioned by rotation. Gibson and Robinson (1935) used pen and ink drawings of the contours of continents, countries, and states, presenting these familiar figures in four compass positions. They concluded that learning tends to determine the orientation in which a shape looks normal and is readily recognized.

Learning and developmental patterns were measured by Rice (1930), using subjects between ages two and nine. He found that with familiar plane figures rotation strongly affected recognition prior to the age period of five to six. Hunton (1955), testing the age range from one year and ten months up to 14, demonstrated that reactions to animal pictures was not independent of spatial orientation, but above age eight the inversion of a picture brought little change in responses.

In the tachistoscopic presentation of realistic figures, Ghent (1960) found that recognition by children between three and seven was markedly dependent upon familiarity of orientation. Subsequently, Ghent and Bernstein (1961) proposed that recognition was impaired by orientation changes which interfered with a child's typical patterns of scanning a figure.

Recognition that an object remains essentially the same in any position of rotation is thus dependent upon the age of the subject and the simplicity or experienced familiarity of the figure. Recognition will also occur most readily in those orientations pragmatically natural to the particular object.

Judging the degree of rotation

Assuming that a simple object is recognizable in any orientation, how much of a rotation must occur before the shift in orientation is

detected? Studies providing information about the thresholds of discrimination as a function of age and compass position have been quite limited.

An early study by Radner and Gibson (1935) introduced a precedent for the PRA technique by asking subjects to orient a figure on a concentrically pivoted disk according to the rotation of a tachistoscopically presented standard. The degree of error was measured and averaged to demonstrate common tendencies to exaggerate anticipated rotation. Experimental conditions were not such as to provide information on expected levels of discrimination for the PRA.

In a 1947 study, Wursten measured the degree of error in duplicating lines, finding greatest accuracy near the vertical or horizontal coordinates. As subjects were asked to match 11 needles to a standard, an increasing error was again noted for the oblique positions. The average error in judging angular displacement of oblique lines varied from 18.3° in five year old children to 2.3° for adults.

The amount of error in judging degrees of rotation, as in Wursten's (1947) study, could be conceived as consisting of two components: (1) threshold error due to limitations in discriminative ability, and (2) errors of performance beyond the threshold of discrimination. These components of the error of estimation would tend to fluctuate according to numerous physiological and psychological factors. The occurrence of unusual departures from an expected range of ability constitutes the phenomenon of rotation under consideration in this dissertation. Psychometric applications of this phenomenon have been based upon the hypothesis that atypical errors of rotation have diagnostic implications.

Psychometric Assessment of Rotation

Clinical and research instruments have induced rotations under various

conditions of input and output. Typically a standard stimulus is presented, either tachistoscopically or as a printed design. The subject's duplication of the standard figure may require the assembly of concrete materials, a paper and pencil reproduction, or the selection of a matching design from multiple choices. Under any of the conditions of input and output an image of the standard stimulus must be cognitively retained or processed as an intervening variable. The extent of dependence upon this intrinsic image is affected by timed limitations in the presentation of the standard stimulus, by the familiarity and complexity of the design, and by the difficulty level or nature of the reproductive task.

Lack of specificity in scoring rotations

The Bender Visual Motor Gestalt Test (Bender, 1938) is the most widely used psychometric device which particularly scores and interprets rotations. As a series of nine designs are copied by the subject, both the direction and degree of rotation of reproduced figures may be considered in the interpretation of the overall test record. However, hypotheses about the meaning of rotational direction have been tentative and inconsistent (Hutt and Briskin, 1960; Jernigan, 1967), and the problem of assigning values and meaning to various degrees of rotation remains unsettled.

Thirty degrees was considered to be a scorable rotation by Hanvik and Anderson (1950), although others (Koppitz, 1964; Freed, 1964) have proposed 45° as indicative of significance. Clawson (1959) proposed that direction and amounts of rotation under 15° may have diagnostic value, though in a later context (Clawson, 1962) she defines rotation in terms of a discrepancy between standard and reproduction of at least 15°. Hutt and Briskin (1960) indicate that the meaning of rotation may vary

with its degree, and propose three categories in making interpretations: mild, 5° to 15°; moderate, 15° to 80°; and severe, 80° to 180°.

Hoppitz (1964) notes that a given deviation on the Bender Test may be considered by some investigators to be a sign of brain injury, by others a sign of emotional problems, and again by some a sign of emotional immaturity. The lack of reliable or specific meaning of such deviations as rotation constitutes a major weakness of the test (Herbert, 1964).

Scoring only the grosser rotations

One approach to resolution of questions around the values and meanings to be assigned to the degrees and directions of rotation is to utilize only those limited aspects of rotation which can be reliably associated with a specified clinical category. The Graham-Kendall Memory for Designs Test takes this approach, primarily utilizing grosser rotations of 90° to 180° and not scoring the small degrees of discrepancy. A relationship between the production of the more extreme degrees of error and the existence of organic brain damage has been hypothesized and demonstrated (Graham and Kendall, 1960).

Current application of this test requires that the subject reproduce each of a series of 15 designs after examining each card in turn for five seconds. The method carries motor requirements similar to those of the Bender Test, requiring in addition a longer period of memory inasmuch as the standard is removed before reproduction is attempted. Through accuracy of detail is not scored, memory is involved in the period of retention which facilitates the occurrence of rotations. The memory and motor requirements contribute to the inapplicability of the test for children under 8.5 years.

Summing small degrees of rotation

A contrasting approach to refinement of the diagnostic applications of rotational phenomena was taken by the authors of the Minnesota Percepto-Diagnostic Test (Fuller and Laird, 1963). Instead of neglecting small degrees of rotation, the minor discrepancies are added and the severe degrees are limited in the scoring.

Fuller and Laird (1963) selected the two Bender designs most conducive to rotation, Figures A and No. 3, and arranged to present each of the two basic designs in a series of three positions involving 90° shifts of both figure and background card, as shown in Figure 1, page 9. The subject's reproductions are then scored with a protractor measurement of error. All correct orientations are assigned one point and all rotations over 25 are limited to 25 points in the summation of errors.

Memory and accuracy requirements are limited by the continuous presentation of the standard and by scoring only the overall orientation of the copied figure. This allows application of measurements down to age five (Fuller, Sharp, and Hawkins, 1967), suggesting the feasibility of utilizing rotational phenomena in the early prediction or diagnosis of learning disabilities. However, validity and reliability figures are offered only for the initial standardization group from ages 8 to 15 (Fuller and Laird, 1963).

Simplifying the motor task

Visual-motor drawing tests such as the Bender, the Graham-Kendall, or the Minnesota Test, may leave considerable doubt as to whether the measured deviations have their basis in perceptual skill, in motor functioning, or in the coordination or linkage of visuo-motor functions. The copying task also tends to limit application under age eight inasmuch as

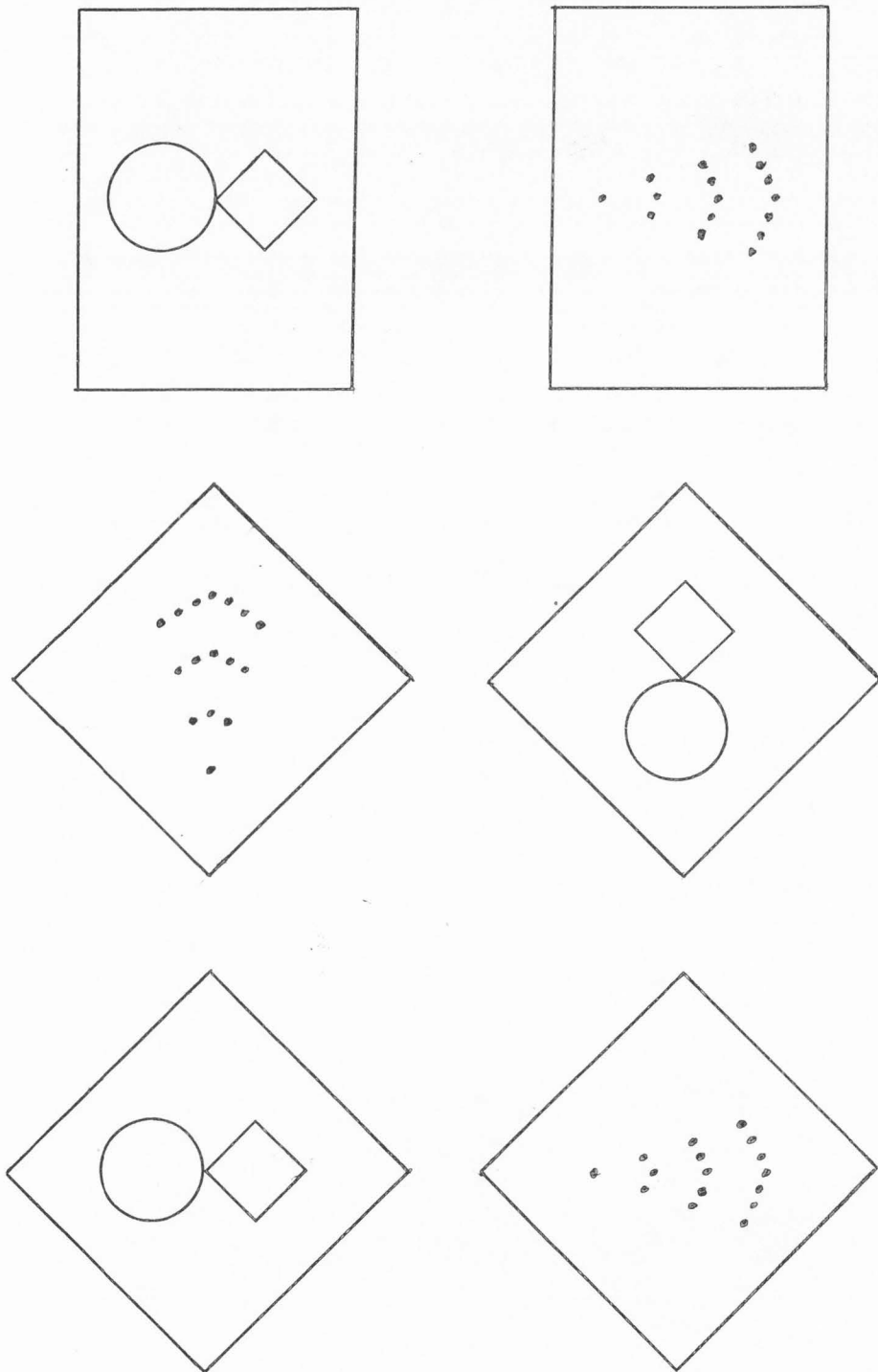


Figure 1. Design cards of the Minnesota Percepto-Diagnostic Test.

developmental factors at younger ages increasingly contaminate the psychodiagnostic aspects of the reproduction (Fuller and Laird, 1963; Koppitz, 1964).

Several instruments which assess rotations have reduced the motor requirements by allowing the subject to simply point out from among multiple choices the image perceived as identical to the standard. An example of this technique is provided by Wechsler and Hagin (1964) in their adaptation of a standard stimulus roughly resembling a lamb chop, requiring a multiple choice discrimination of the correct match from a card showing the same figure in six possible orientations. In addition to the reduction in the motor factor, incorrect responses on the Lamb Chop Test were limited by the fixed choices to the more severe rotations. Errors in the discrimination of rotations under these circumstances were significantly associated with reading skills in first and third grades.

Bannatyne (1969) has been actively researching the psychodiagnostic utility of multiple choice, non-motor assessment of errors in visual perception. The Bannatyne Visual-Spatial Memory Test makes use of a series of fifteen stimulus designs, allowing a 4 second presentation of each. After the exposure of each stimulus a blank page of the test booklet is turned, uncovering a series of eight designs from which the subject selects the one considered most like the standard. Along with an exact duplicate, variants of the stimulus design include a simplified version, a mirror image, a 90° rotation, a fragmentation, an out of proportion version, a complication, and a symmetrical version.

The Bannatyne Test, as it is being compared with the Graham-Kendall and other tests in a type of converging operation, is providing information relative to the qualitative differences in the types or degrees of rotation. Tentative hypotheses which relate to the present study on

rotation propose (1) that mirror image drawing as registered by the Graham-Kendall Test should not be classed as a rotation because other rotated drawings are negatively correlated with mirror drawing (Bannatyne, 1969), (2) that mirror-imaging in a non-motor test is a right hemisphere activity (Bannatyne and Wichiarajote, 1969a, 1969b), and (3) that mirror imaging in a visuo-spatial test may be a better indicator of developmental status than is mirroring which occurs in a copying or drawing test (Bannatyne, 1969).

The PRA Task

The present apparatus was designed to limit the motor component as with the Bannatyne Test, though utilizing a summation of small degrees of rotation as does the Minnesota Test. Memory requirements were virtually eliminated by allowing an untimed presentation of the standard stimulus as with the Bender and Minnesota measurements. At the same time memory for configurational details was entirely eliminated since the compared stimuli were identical and only the relative orientations of the matched figures was emphasized.

The PRA matching task allowed a possible range of rotational error between 0° and 180° . Although there is growing evidence that smaller degrees of rotation qualitatively differ from some of the grosser types of rotation (Arbital, 1968; Bannatyne, 1969), all of the orientation errors which occurred in the PRA exercise were tentatively referred to under the general designation of "rotation."

Figure 2 illustrates some examples of rotational error which occurred in the use of the PRA disks. A reversal occurred as elements of the figure were transposed across an assumed central axis of the figure. Such a reversing of elements might occur when the figure was in a

horizontal, vertical or oblique orientation.

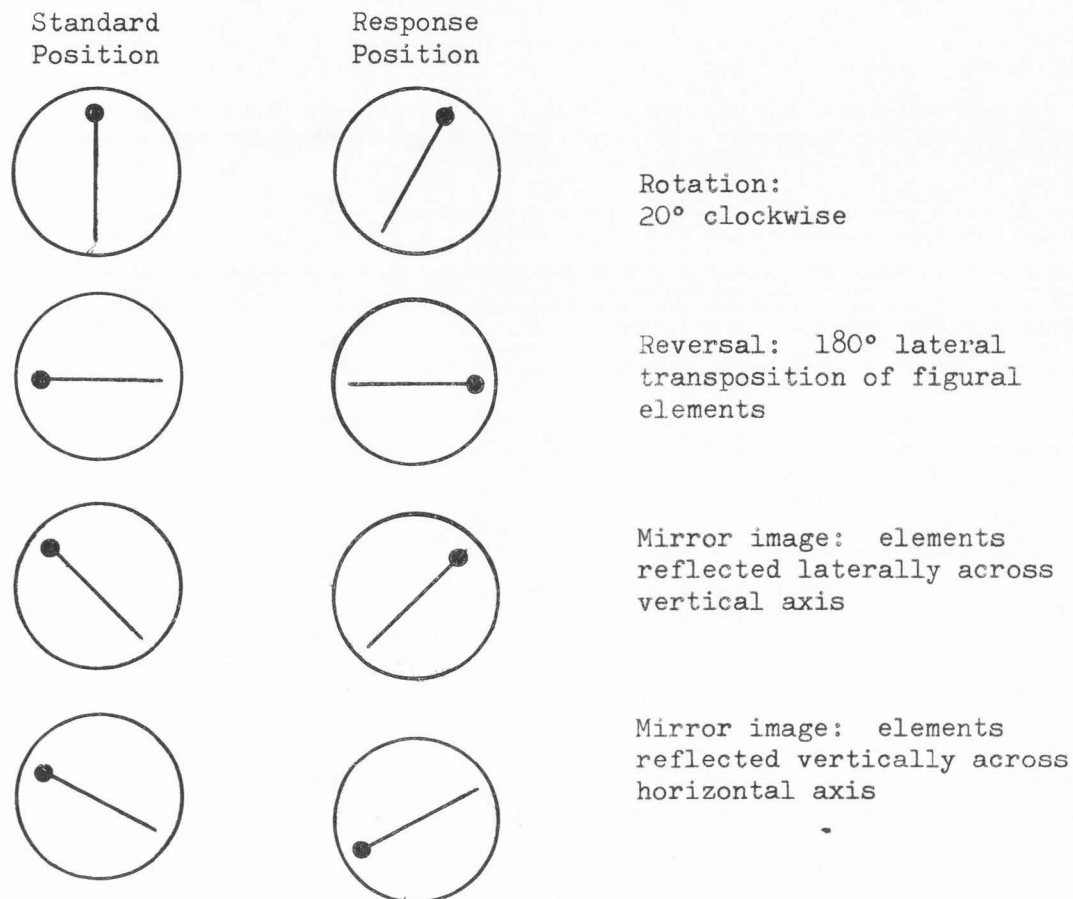


Figure 2. Examples of rotation which occurred with PRA disks.

A mirror image occurred when the directional lines of the figure were reflected across either the vertical or horizontal axis of the rotating disks. Since composition of the figure was fixed, the elements could not be symmetrically transposed, but only the directional aspect of a design could be reflected laterally or vertically into an adjacent quadrant.

The rotation errors occurring with the PRA were arbitrarily classed as either transpositional or non-transpositional. An error of

transposition involved both the reversal of an image into an opposite quadrant and mirroring into adjacent quadrants. All other errors were of the non-transposition type. This category included errors so fine as to be regarded as threshold errors of discrimination.

CORRELATES OF PERCEPTUAL ROTATION

Developmental research in visual perception quite readily yields data on changes occurring with increasing age, disclosing when a particular phenomenon may occur. However, the typical developmental-descriptive study does not indicate the theoretical problems and hypothetical mechanisms relating to why development occurs as it does (Rivoire and Kidd, 1966). In consequence, researches may be multiplied, but without the anticipated progress in basic theory. This criticism particularly applies with observations of perceptual rotation, a regularly occurring event with recognized correlates, but without an adequate theoretical base.

Years of research have not provided a composite theory or disclosed the underlying reasons for perceptual rotation (Shapiro and Beech, 1965), and even more challenging, the causes back of differential rotation by diagnostic categories is unknown. Bender (1938) postulated that primitive sensorimotor patterns depend upon principles of constant motion, and that this movement tends to be as a whirling vortex of radiating lines. Fuller and Laird (1963) reviewed some of the Gestalt Laws relating to the basic designs used on the MPD test, concluding that there is a continuum ranging from cohesiveness and stability to ambiguity and instability in perception. It was later proposed by Fuller (1965) that if perception is unstable or disturbed, the personality may also be disturbed and unstable. In effect, the association of rotation with pathology is being restated, and we are left without an understandable reason why reproduced designs are rotated in certain types of pathology.

An approach to this troublesome theoretical question lies in a review and synthesis of the numerous variables which are associated with perceptual rotation. Certain of these variables are subject to control or manipulation. Others are intrinsic and individualized, not accessible to experimental manipulation.

The present study is intended to add to knowledge of some of the following correlates of perceptual rotation and aid in the formulation of a theoretical basis for this phenomenon.

Age and Rotation

As previously noted, the matching of shapes in paired-comparison tasks is abetted by similarity of orientation. This dependence upon orientation in a recognition task largely disappears by about age eight (Hunton, 1955), much as does the tendency to verticalize copied lines (Fabian, 1945). Fabian's study disclosed that 51 percent of six year olds would rotate copied lines or figures, usually to a vertical orientation, as compared to 2 percent of eight year olds. Thus, dependence upon normal positioning in recognition tasks appears to be developmentally correlated with the preference for vertical orientation in tasks involving copied figures. Both maturation and training interact in this orientational development.

However, the ability to duplicate the exact spatial positioning of a standard, as in Wursten's (1947) experiments, appears to require a factor of discrimination or judgment which emerges more slowly. The measured decline of error in judging rotation extended into adulthood. Similarly, with precise registration of orientational judgments, Witkin (1959) noted improvement between 8 and 20 in the ability to orient a vertical rod relative to factors of gravity and field dependence.

In their initial presentation of the MPD, Fuller and Laird (1963) stated that rotations were a natural phenomenon disappearing by eight, hence rotations beyond eight were to be taken as indications of pathological processes. However, in a later establishment of age norms for a more extensive sampling of the general population (Fuller, Sharp, and Hawkins, 1967), it was concluded that there were significant differences between successive age groups from 5 to 14, at which time the measured perceptual factor matured.

Apparently, the precise measurement of rotational error presents a declining curve as a function of age. Any variations in rate of decline may be useful in disclosing the operation of intrinsic factors which underly the occurrence of rotation. These underlying processes must eventually be separated from extrinsic variables of training to allow clearer definition. The comparison of separate age curves derived from differing instruments may aid in describing the crucial mental processes.

The Factor of Intelligence

What is actually being measured when the ability to judge the rotation of a design is calibrated? How are the requisite skills related to those abilities subsumed under the construct of intelligence? According to Piaget (Flavell, 1963) intelligence and perception need to be sharply distinguished as types of adaptation. Piaget regarded perception as subordinate and inferior to the intellectual behaviors involving higher degrees of judgment, organization, or classification. Kretch and Calvin (1953) similarly note the subordinate nature of perception in proposing that perceptual responses proceed through hierarchical levels of organization, and that the ease of such a progression is related to measures of intelligence.

Support for the relatedness of intelligence and perception is afforded by Goins (1958), who reported positive correlations between non-verbal tests of visual perception and intelligence. Plenk and Jones (1967) noted that intelligence and Bender-Gestalt performance was correlated for three and four year old children. Rosenblith (1965) found a correlation of .35 between recognition of rotated triangles and intelligence, but warns that other factors predominate in perceptual skills. The correspondence between visual perception and intelligence is further indicated by factor analysis of the Frostig Developmental Test of Visual Perception. A combination of general intelligence and developmental changes in perception account for most of the variance of the test (Corah and Powell, 1963).

In developing the Minnesota Percepto-Diagnostic Test (MPD), Fuller and Laird (1963) noted a correlation of .40 between intelligence as measured by the Wechsler Intelligence Scale for Children (WISC) and the rotation scores of a normative group of children. In seeming contradiction they reported no correlation between intelligence level and the high degrees of rotation for the diagnostic categories. However, the diagnostic groups differed in average intelligence, suggesting that correlations would have been recognized had the entire range of subjects been treated as a unit.

From a later comparison of WISC and MPD scores with a group of 87 emotionally disturbed children, Fuller (1966) reported no correlation except with particular subtests of the WISC. Information, Arithmetic, and Picture Completion were found to be correlated inversely with MPD errors beyond the .01 level of significance. In the more extensive standardization of the MPD on 4000 normative children between 5 and 20 years, Fuller, Sharp, and Hawkins (1967) found the effects of intelligence

sufficient to require the application of a corrective factor to MPD scores used in psychodiagnostics. Quite significant is the fact that the higher the intelligence, the more control over errors in rotation or the more stable the perceptual system.

Graham and Kendall (1960) report that for the standardization group of children over 8.5 the Memory For Designs Test (MFD) correlated $-.39$ with intelligence. In a replicative study involving 50 third graders Bannatyne (1969) similarly found a $-.29$ correlation between the MFD and the Stanford-Binet. For the same group the Bannatyne Visuo-Spatial Memory Test (BVSMT) showed a correlation of $.30$ between intelligence and accuracy in selecting the correct design. Correlations with intelligence for the MFD and BVSMT are equivalent, the one test scoring error of rotation and the other accuracy of match.

Diagnostic Categories and Rotation

The fact that rotational tendencies in visual-motor tasks is associated with neurological and emotional pathology has been well established (Griffith and Taylor, 1960). This association of pathology and rotation clearly occurs with children (Hanvik, 1953; Byrd, 1956; Koppitz, 1958; Fuller, 1965) as well as with adults (Hutt and Briskin, 1960). The rotation of reproduced designs has been observed most frequently in the records of individuals who were psychotic, had intracranial pathology, or were mentally defective (Hutt and Briskin, 1960).

The presence of gross rotations in the record of a child does not consistently indicate brain damage but may be taken as indicative of a serious disturbance in ego functioning (Clawson, 1962). Emotionally disturbed children make more minor rotations of 15° to 25° than do normal children (Clawson, 1962), although rotation in children must

also be recognized as an aspect of immaturity (Fabian, 1945; Koppitz, 1958).

On the basis of summed rotational errors the MPD test purports to diagnose the bases of reading disabilities in children, also providing cut-off scores for the differential diagnosis of normality, personality disturbance, and organicity (Fuller and Laird, 1963). However, critical reviews suggest that the most appropriate application of the MPD lies in the diagnosis of brain damage (Coan, 1965), and that measurements may not be sufficiently discriminative to allow assessment of minimal or moderate degrees of organicity (Leavitt, 1965). In exploring such usage Uyeno (1963) demonstrated that the MPD discriminated 77 percent of the organics and 88 percent of the psychotics in a sample consisting of 104 hospitalized patients.

Both the degree and the direction of rotation of copied figures is believed to have diagnostic implications. Hutt and Briskin (1960) hypothesize that mild rotation in a clockwise direction may be associated with depression whereas counterclockwise shifts suggest antagonistic qualities. Serious conflict with authority figures may be reflected in severe counterclockwise rotation. Similarly, the records of children on the Bender Gestalt Test suggest that children with flattened affect will rotate clockwise, whereas minor rotations in a counterclockwise direction denote heightened affect (Clawson, 1962).

There is some evidence that specific areas of the brain may be related to rotation. Fuller and Laird (1963) note that identifiable damage to occipital, parietal, or temporal areas is productive of rotations, whereas damage to frontal or associational areas does not seem to promote rotations. However, studies involving the MFD indicate that any attempt to localize specific functions in specific areas of the brain is a

precise experimental task beyond the application or purposes of measures of rotation (Graham and Kendall, 1960).

Rotation and Design

Certain designs or figures are more conducive to perceptual rotation than are others. In developing the MFD Graham and Kendall (1960) noted that certain designs were more susceptible of rotation and thus more discriminative of brain damage. Shapiro (1953) made a careful study of the rotation of block designs, demonstrating that diagonal lines of symmetry, diamond figures, and diamond grounds were in the stated order relatively influential in evoking rotations.

Fuller and Chagnon (1962) proposed that stimulus objects which are not equivalent will contribute differently to rotation, and cue utilization will differ for each diagnostic group. For example, they hypothesized that increased emotional disturbance will narrow the field of awareness, reducing the ability to use field cues to stabilize rotational tendencies. The MPD later emerged out of the theory that certain designs are more apt to elicit rotations, and that reactions to the cues provided by certain designs will be relative to variables of constitution or experience (Fuller and Laird, 1963).

Apparently there is an interaction of design, field cues, and intrinsic factors in the production of rotations. The use of interchangeable disks with the PRA provides a manipulable variable for exploring the effects of design. Whatever the aspect of the stimulus configuration being varied, individuals may be expected to respond in terms of their own uniqueness. General tendencies are statistically interpretable, and individual deviance of sufficient degree may convey clinical meanings.

Spatial Coordinates and Rotation

There is a close relationship between the development of three dimensional spatial orientation and the ability to judge the rotation of objects. Piaget, Inhelder, and Szeminska (1960) affirm that spatial perception and facility with the components of spatial orientation develop in age-related stages. From sensorimotor associations of action and spatial position the child moves toward an egocentric awareness of spatial relations, eventually making use of natural horizontal and vertical references, and thence learning to apply Euclidean coordinates to points of view beyond himself.

A child first operates with more facility in the vertical direction than the horizontal (Gesell, Ilg, and Getman, 1967). The integration of various visual and gravitational clues produces the phenomenal sense of uprightness (Gibson and Mowrer, 1938), the egocentric basis for judgment of rotation. Consequently, vertical discriminations are most easily mastered (Rudel and Teuber, 1963; Wohlwill and Weiner, 1964), and primary grade children continue to rotate reproduced lines to the preferred vertical orientation (Fabian, 1945).

The gradual development of skill in copying geometric forms provides some indication of the gradient of difficulty in dealing with angular rotation. As the ability to give direction to linear strokes emerges, the child moves through a progression of skills in duplicating the cross, square, rectangle, the triangle, and finally the most difficult form, the diamond (Ilg and Ames, 1964). Oblique lines, reflecting experience with linear perspective, are the most difficult to master, and diamond shaped figures and grounds tend to produce more rotation in tests of orientation than do vertical or horizontally oriented patterns

(Goldstein and Sheerer, 1941).

Developmental process thus indicates that in the judgment of line direction the child moves through a sequence of first recognizing verticality, then horizontality, and finally is able to discriminate various oblique orientations. The degree of error in judging perceptual rotation should tend to harmonize with this sequence, the most accurate judgments occurring in vertical position, and the greatest rotational errors appearing around certain oblique positions.

The Factor of Cerebral Dominance

Horizontal reversals of form tend to be the most persistent of all errors in orienting visual images (Rosenblith, 1965). Though reversals are differentiated from other errors of rotation, there appears to be some interaction of reversal and mirrorization with other types of rotation (Kelley, 1935). Though the bases of these phenomena have not been defined, the occurrence of horizontal reversals has generally been associated with limitations in cerebral dominance, and the occasions of mirrorization about the vertical axis may have a similar basis.

The emergence of cerebral dominance appears to mediate an internal sense of sidedness which facilitates lateral judgments. There are no objective directions in space, and the right-left gradient purportedly becomes the basis for conceptualizing the coordinates of space (Roach and Kephart, 1966). The mediation of the central nervous system, as posed between stimulus and response, is most clearly seen in the making of right-left directional choices (Hebb, 1949).

It has been noted by Delacato (1963) that the lateral progression of the mind begins about age three and is completed at about six and one-half. Similarly, Ilg and Ames (1964) observed that the concept of

right and left begins to intrigue the child of three and four, eventuating in a more accurate positional sense after age seven. These estimates correspond to experimental observations that three year olds do not respond to a task of recognizing reversals (Wohlwill and Weiner, 1964), and children of three and four cannot distinguish mirrored oblique lines, (Rudel and Teuber, 1963), though the ability rapidly improves over the next few years.

There is some evidence that right-left directional orientation matures more slowly and may be differentiated from the tendency to mirror or reverse visual images. Boone and Prescott (1968) demonstrated a gradual decline in right-left discrimination errors between ages five and ten. Although the child of five knows his own right and left, not until 10 or 11 is the conception of right-left comprehended as an abstraction dissociated from any specific concrete referents (Elkind, 1961). Not until age 14 does the Stanford-Binet Intelligence Scale (Terman and Merrill, 1960) anticipate a moderately accurate application or right-left discrimination as a non-egocentric directional concept.

In considering the question of cerebral dominance and directional sense it becomes necessary to distinguish between the following areas of lateral concern: (a) the sensorimotor development of manual and ocular preference, (b) an awareness of personal right-left orientation, (c) the stabilization of reversals and mirrorizations of visual images about the vertical axis, and (d) the ability to envision directional orientation in extra-personal space. Though maturation of these aspects of laterality appear to occur in the designated sequence, their interactions and casual associations with cerebral dominance have not be clarified (Coleman and Deutsch, 1964). Inability to differentiate these related applications of laterality has led to considerable confusion in research findings.

School Achievement and Rotation

Much research is being directed toward the diagnosis and treatment of those perceptual-motor characteristics which limit the child in making an adequate school adjustment. Of particular concern are those children having a favorable intellectual endowment, but who are discovered to have special learning disabilities after they have experienced two or three years of failure in the regular school program. To distinguish true dyslexic children from those who may simply have a slower rate of maturation remains a prominent focus of research (Eisenberg, 1962). Educators now envision the use of preschool diagnostic clinics to assess the presence of perceptual handicaps (Denhoff and Novack, 1967), allowing the application of immediate corrective exercises (Jansky, de Hirsch, and Langford, 1966), forestalling a succession of failures and classroom problems.

Disability in using the symbols of language occurs in every socioeconomic group, in children of normal vision and adequate intelligence. Studies of elementary school children have disclosed that as many as 13 percent may be significantly impaired by dyslexia or word blindness (Faigel, 1965). Associated diagnostic symptoms are the inability to integrate parts of a word into a whole pattern, laterality and directional confusion, difficulty in shifting from experience with three dimensional objects to representation on a flat surface, and the tendency to rotate and reverse numbers and certain alphabet and word forms.

Directional function acquires a critical significance in the individual's ability to recognize and use academic symbols (Hermann, 1959), whereas its significance is minimal in the perception of ordinary objects. Some symbols change in identity as their spatial orientation

shifts, whereas real objects retain their identity. Hermann (1959) sees directional uncertainty as responsible for reversals, rotations, and disfigurement of the form of symbols. Visual-perceptual difficulties are indicated by inability to recognize and reproduce words (Peter, 1965), and the ability to copy lines and shapes correctly in regard to direction is directly related to school achievement (Koppitz, 1958, 1964).

Isolating partial correlates

Intelligence and maturational level appear to mediate the relationship between perceptual-motor skills and reading ability (Benton, 1962). With children of nine and older, Coleman and Deutsch (1964) found no significant difference between normal and retarded readers on tests of lateral dominance or on right-left discrimination tests. Nevertheless, studies of younger children are more apt to show a relationship between certain perceptual-motor and reading skills (Smith and Keogh, 1962; Wechsler and Hagin, 1964; Muehl and Fry, 1966; Chang and Chang, 1967; Singer and Brunk, 1967). Ability to recognize the direction of line, the orientation of letters and words, the shapes of symbols, and the overall configuration of words are perceptual skills basic to beginning reading. Other cognitive skills become involved in advanced reading.

When intelligence is controlled, even beginning readers are not differentiated by factors of hand dominance and right-left orientation (Balow, 1963). However, with lower intelligence levels these factors become associated with reading retardation (Koos, 1964). This accords with measurements from ages 5 to 16 provided by Fuller, Sharp, and Hawkins (1967) showing that higher intelligence tends to stabilize the tendency toward rotation.

INSTRUMENTS AND METHODS

Hypotheses

The Perceptual Rotation Apparatus (PRA) was designed to provide experimental circumstances in which the rotation of visual stimuli might occur. Measured errors of rotation would necessarily be a function of both the perceptual system and the methodology. Knowledge relative to the perceptual mediation of rotational phenomena would therefore be provided by comparisons of PRA results with those obtained by differing instruments.

Research hypotheses were formulated to facilitate comparisons. A review of related theory and research findings suggested a plausible direction and intent for each hypothesis.

Hypothesis No. 1

The judgment or perception of rotation will be affected by the nature of the visual stimuli used with the PRA.

Designs are reported to vary in their ability to induce rotations. However, diagnostic applications would require that rotational phenomena occur as a facet of individual behavior, a characteristic tendency of the perceptual system occurring irrespective of the nature of the design. The use of dissimilar or contrasting designs would test for such consistency of behavior.

Selection of designs to reflect varying degrees of familiarity would also aid in evaluating the effects of experience on the susceptibility of a design to rotation. Nevertheless, to retain the matching

task within the sphere of perceptual operations, designs must be selected which can be immediately and globally perceived as directionally oriented.

Hypothesis No. 2

Rotational error as measured by the PRA has developmental characteristics related to age.

Recognition of rotated objects and judgment of the degree of rotational error have been shown in various researches to be related to age. The rotational phenomena such as mirroring, reversals, and moderate shifts of orientation tend to occur in contradiction of expected levels of accuracy. The PRA should disclose expected accuracy in judging orientation over ages characterized by perceptual-intuitive as well as higher levels of cognitive mediation. Resolution of questions relating to the significance of minor degrees of rotation might thus be aided.

Hypothesis No. 3

The PRA measurements of the rotation of visual stimuli are reliable.

The reliability of measurements provides an indicator of whether a stable personality trait is being measured. The present psychodiagnostic usages of rotational error suggest that rotations occur more frequently or to a greater degree for particular individuals. However, the lack of diagnostic specificity suggests that changes in visual stimuli, modes of scoring, or other instrumental variables are needed to improve reliability. Whether the characteristics of the PRA would contribute to diagnostic specificity would be determined by the degree of stability in its assessment of rotational phenomena.

Hypothesis No. 4

PRA judgments of the rotation of visual stimuli are related to

intelligence as measured by a standardized device, the Quick Test (QT).

Non-motor, visuo-spatial assessments of perceptual ability have consistently shown some dependence on factors associated with intelligence. Any correlation between the PRA measurements and intelligence would therefore depend upon the reliability of the PRA method. Non-reliability would be verified by the absence of correlation with a reliable index of intelligence.

Hypothesis No. 5

The measurement provided by the PRA is related to the rotational factor assessed by a standardized diagnostic instrument, the Minnesota Percepto-Diagnostic Test (MPD).

Since both instruments utilize techniques for eliciting rotations, some degree of correlation would be expected, depending of necessity on the reliability of the instruments. Significant correlation would offer validation evidence that the two devices shared a process essential for the occurrence of rotations. If only the MPD reliably registered rotations, the difference would again lie in variables of technique. The absence of reliability in an ostensible test for rotation, confirmed by negligible correlation with a reliable instrument, would allow clearer definition of the factors essential for the occurrence of rotational phenomena.

The Perceptual Rotation Apparatus

Study of perceptual rotation was facilitated by devising a simple instrument which would provide measurements of rotational error lending to numerical presentation and tending toward normal distribution. The apparatus for quantifying rotational judgments consisted of a round

table 30 inches in diameter, on which two 8 inch turntables were diametrically mounted, each having a circumference scale graduated in degrees. The subject's turntable was mounted horizontally, and the examiner's vertically. The face of each turntable was constructed to receive the series of selected designs. The examiner's disk constituted the perceptual standard which the subject attempted to match in position of rotation.

The round table reduced extraneous environmental cues which might support or bias the subject's orientational skill. The table surface was painted in a somewhat mottled effect to reduce the possible use, conscious or subliminal, of real or imagined lines on the table surface. The primary visual focus of the subject tended to be upon the two disks and the orientational cues which remained inherent in the visualized line between the disks and in the horizontal table surface. The table surface was leveled and oriented in the same room position for each testing session to assure uniformity of any extraneous cues, even though such cues may be assumed to be peripheral and out of focus. Also, all measurements were taken by the same examiner throughout the study.

Positioning of the examiner's turntable vertically in relation to the turntable of the subject involved the same interplane shifting of stimuli seen in typical classrooms between chalkboard and desk. This planar shift and the separation of the two turntables was intended to reduce the directness of simultaneous visual focus upon both disks, favoring the possible occurrence of rotations. The separation of disks did not appreciably affect the immediacy of the temporal connection between stimulus and response, considered by Bartley (1958) to be a distinguishing feature of perception.

The horizontal-vertical positioning of the two turntables and the

relative visual angles are illustrated in Figure 3. Chair and table heights were adjusted for each age group to keep the eye of the observer approximately 15 to 18 inches above the table. The subject was seated

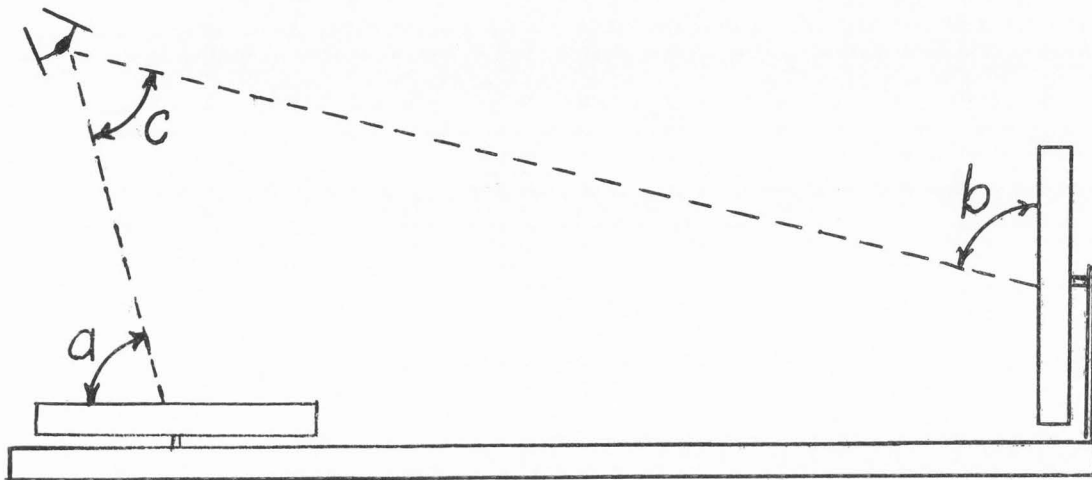


Figure 3. Variant planes and angles of the Perceptual Rotation Apparatus.

directly in line with the horizontal turntable, but he was free to move his body position in various directions, making it impossible to maintain uniformity of visual angles. It was assumed that variations in the angles of incidence, a and b, and the angle separating the visual percepts, angle c, would not affect results.

A unique feature of the PRA was the graduated scale on the circumference of each turntable. Most previous experiments on rotational error required protractor measurements or limited the subject to only a few discrete choices, scoring responses as correct or incorrect. The PRA provided a direct reading of the degree of discrepancy between the examiner's standard and the subject's matching disk. The numerical degree of error in the judgment of rotation constituted the treatable data.

Variations of the Visual Stimulus

In order to test the hypothesis that variants of the visual stimulus would affect judgments of rotation, a series of three designs was used: (1) a familiar object, (2) a single line, and (3) an unfamiliar figure. Each design was presented in the same sequence of six compass positions: 0° , 90° , 55° , 140° , 20° , and 120° . The points on the sequence were selected to provide an inconsistent direction of disk motion, to equalize use of quadrants, and to vary the displacement from horizontal or vertical reference points.

Designs were drawn in black ink on interchangeable disks of white poster paper. The design used for introducing the procedure, presented in operational size in Figure 4 on page 32, was a box-like frontal view of a house with an antenna as a pointer. Four year old children were readily able to comprehend the "game" through the use of this culturally familiar image. The idea of "tilting the house" was an established concept, and this disk provided a learning experience transferrable to the less concrete designs.

The following presentation was followed to introduce the procedure to the four year old children:

Each of us has a wheel to turn. Look, you can turn your wheel like this. (Demonstrate) Now you do it. (Child was encouraged to touch hands to each side of the turntable as an optimal mode for turning the disk.) Good. Now I am going to turn my wheel and then you turn your wheel to make your picture look just like mine. First, I'll make my house stand straight up like a house should stand. Now you turn yours to look just the same. Do it very carefully, so I can see if you do as well as other boys and girls. Very good. Now I'll turn my house on its side, and you make yours the same. Let go of the wheel when you have it exactly in the right place. Fine. Now I'm going to hide my house and turn it, then you see if you can find the right place.

Thereafter the examiner's disk was shielded for each movement to

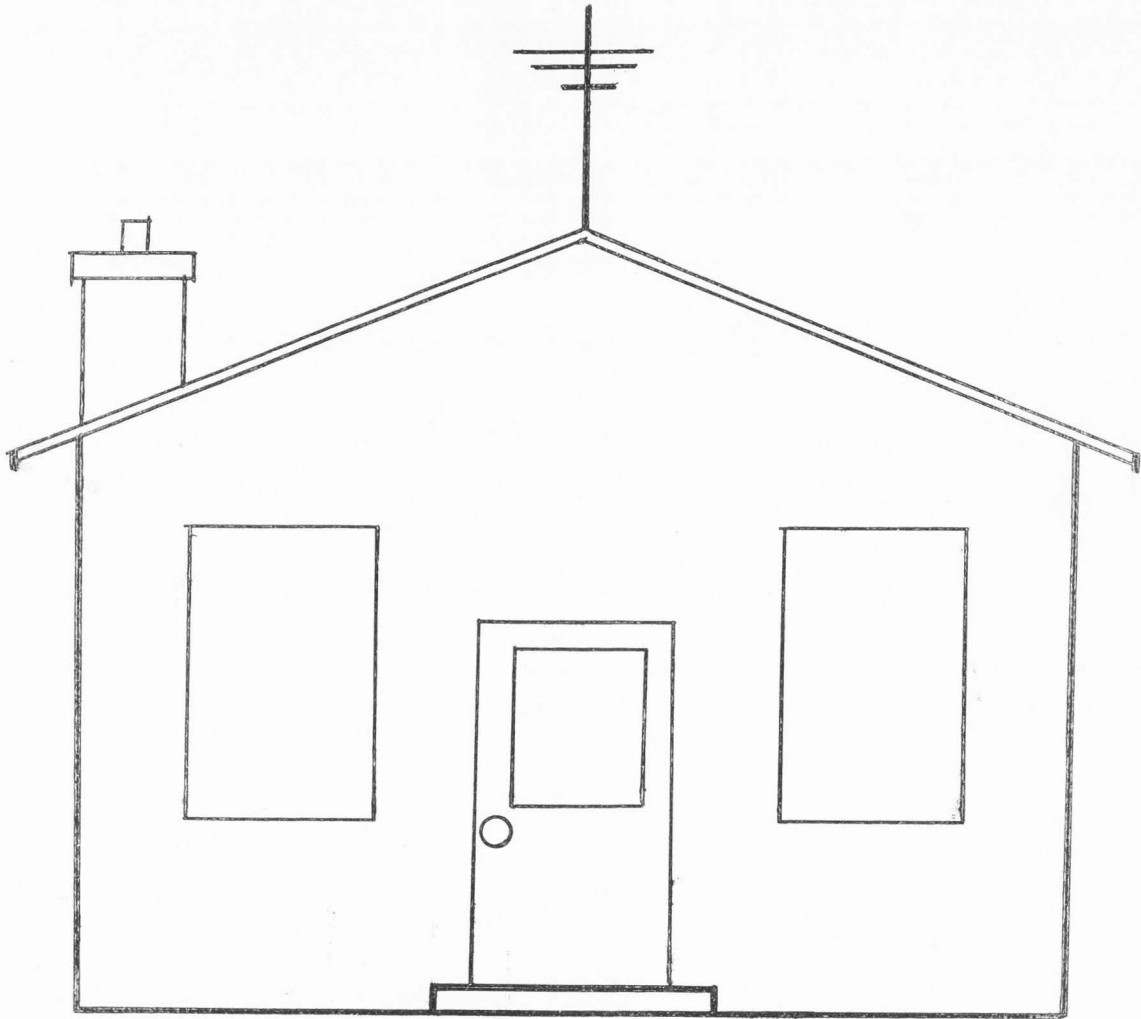


Figure 4: Actual size of design used on Disk 1.

favor the appearance of reversals and mirror images. However, hiding the direction and extent of movement appeared to have no effect upon the ability to judge rotational position. The young child's comprehension of the operation was abetted by allowing him to sit in and watch the manner in which the preceding subject responded. The instructions were increasingly limited for older subjects who quickly understood the operation of the PRA and responded to the simple directive of turning their disk to the same position as the standard. The idea of making the setting exactly the same was emphasized for all ages.

Regular encouragement was offered as needed. There was no apparent diminution in motivation for most subjects. The task appeared to be of interest, and the change of disks after six settings tended to renew the challenge. Some children referred to the operation as "fun," and a number asked about other designs or pictures to extend the trials.

Designs for Disk 2 and Disk 3 are presented in Figures 5 and 6 on page 34. The second disk was presented as "a straight line," and offered subjects a more precise though less concrete pattern for orienting their disk. The third disk was presented as a "dot pattern," a duplication of Design No. 3 of the Bender-Gestalt Test. This design was also used by the Minnesota Percepto-Diagnostic Test and offers a logical base for intertest comparisons. Presentation of the series of three disks required about six to ten minutes.

Selection of the Sample

Prior studies indicate that the judgment of angular rotation requires perceptual or cognitive abilities which improve with age. Such improvement is expressed in the hypothesis that the measurement provided by the PRA reflects a developmental characteristic related to age.



Figure 5: The straight line presented on Disk 2.

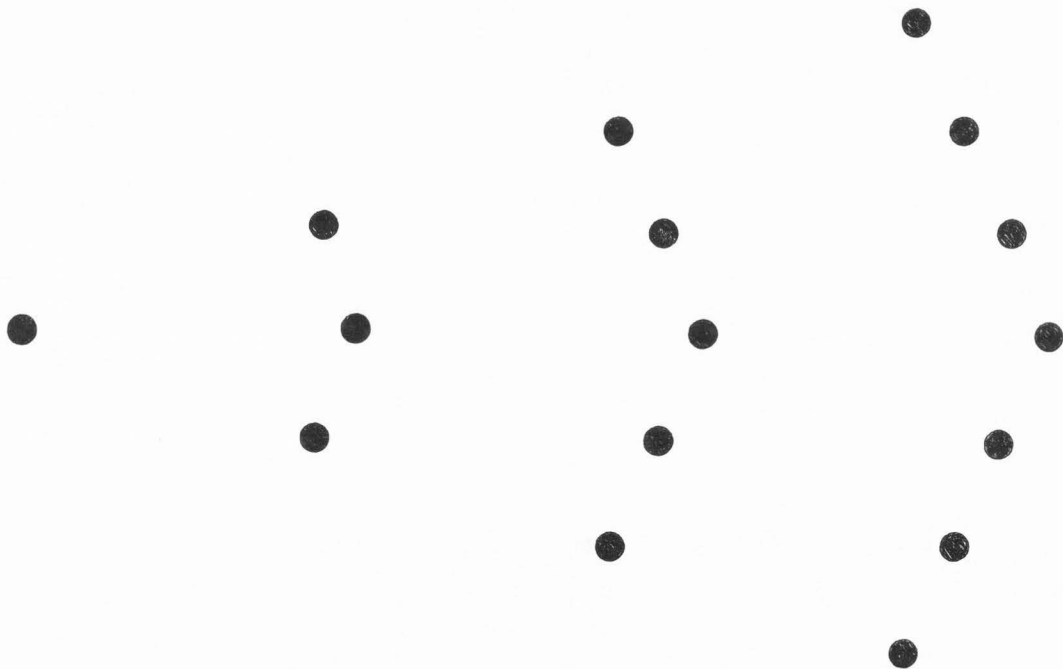


Figure 6: Bender pattern No. 3 as used on Disk 3.

A sample of subjects stratified in terms of age, offering some consistency in terms of other influential variables, was required to test this hypothesis. There was no intent to select a sample which would assure generalizability of results. The comparisons offered by any replicative studies would have to take into account the distinctive features of the samples studied.

Children of ages five through eleven were provided by the Edith Bowen Elementary School in Logan, Utah, and four year olds were obtained from the Children's World, a kindergarten and nursery school at Ogden, Utah. The two schools are somewhat alike in drawing most of their pupils from Caucasian families reflecting an average or middle socioeconomic status, though with some diversity to broaden the range of the sample characteristics.

It is probable that a number of variables interact to produce the measured judgment of rotation. To demonstrate a developmental pattern related to age, the factors which might confound the perceptual or cognitive factors associated with age must be kept relatively constant in their effect over the age range; otherwise a graphical or tabular delineation of the age trend would be distorted. The inclusion of all children within the chosen schools offered some reassurance of obtaining equivalent groups at each age level. However, some distortion may have been introduced by differences in the character of children from the nursery program as compared with the elementary school children.

Such factors as sex, cultural background, intelligence, motivation, and other unknown influences were assumed to be relatively equivalent by using each child from the designated schools. Only two four year old children from the nursery at Children's World were considered ineligible because of mental retardation, and one cerebral palsied child from

Edith Bowen was excluded. Individual differences in the influential factors were considered to be negligible in their effect by the inclusion of 22 to 27 children at each age level in providing a group average.

Temporal Stability of Measurements

The third hypothesis, proposing that the PRA measurements of the rotation of visual stimuli are reliable, was assayed by use of the test-retest method over a period of seven days. The four, six, and eight year old groups were included in this assessment of reliability. It was anticipated from the observed responses of four year olds that the most unreliable PRA readings occurred at this age. It was also expected that some change in the reliability of readings might be demonstrated by later ages. Any variation in reliability at different ages would of itself provide useful developmental data.

Relationship to Intelligence

The fourth hypothesis, asserting that PRA judgments of rotational position of visual stimuli is related to intelligence, was tested by the administration of a standardized intelligence test to the group of seven year old children who also received the PRA and MPD tests. An intelligence test was needed which could be quickly and easily administered on an individual basis, allowing all three measures to be administered on the same occasion to favor a uniformity of testing circumstances. The Quick Test (QT) appeared to meet the desired qualifications. The three measures were administered in the sequence of QT, MPD, and PRA, taking less than 30 minutes for the entire sequence. It was assumed that no contaminant learning would occur during the series, and the sequence was not randomized.

The Quick Test requires approximately 10 minutes for administration and has excellent qualities for building or maintaining rapport. Studies reported by the authors (Ammons and Ammons, 1962) indicate reliability coefficients from .73 to .89 with kindergarten children, and validation correlations with the revised Standard-Binet and the Wechsler Tests of .77 to .96. The QT utilizes the visual-perceptual mode of stimulus input and also requires no motor or verbal response. A word is presented to the subject who then points to one of four pictures as best illustrating the word. In consequence, the QT is similar to the PRA and MPD in utilizing visual perception. It provides a standardized measure of perceptual verbal intelligence, yet taps an ability which does not appear directly related to orientational skills.

The Metropolitan Achievement Tests are administered annually to all pupils at Edith Bowen School in grades one to six. These tests were last administered in March of 1968, and scores were available for all returning students. These scores were correlated with the PRA measurements made in September of 1968, a time in the school year when nearly all pupils at a given grade level may also be categorized as being at a particular year of age.

Correlation values would be limited by the six month gap between administration of the two measures and the fact that scores were not available for the new students, approximately 25 percent of each group. Nevertheless, it was considered that the computed relationships might provide additional theoretical information about PRA measurements, particularly as related to intelligence and school achievement.

Comparison With Another Instrument

The fifth hypothesis alludes to the probability that the readings

of rotational error provided by the PRA are related to the rotational factor as assessed by a standardized diagnostic instrument. Such a comparison, making use of any indicated correlation, would aid in the interpretation of PRA scores.

The Minnesota Percepto-Diagnostic Test (MPD) was selected for administration to the group of seven year olds. By age seven the responses to both the PRA and MPD are relatively stable, and motor limitations would not seriously contaminate MPD responses. Age seven is also still within the age range at which perceptual accuracy is associated with beginning academic skills (Wechsler and Hagin, 1964; Chang and Chang, 1967), and possible applications of the PRA technique would involve measurements at this and earlier ages.

The MPD was an appropriate comparative instrument in using visual designs and in offering a rotational score in the same units as the PRA. Revised norms for using the MPD with normal and limited IQ populations have been developed (Fuller, Sharp, and Hawkins, 1967). The improved normative sample now consists of 4000 students, ages 5 through 20, selected from several states. Raw scores are now convertible to standard scores, adjusted for both IQ and age variation, improving the usefulness of the test for diagnostic and clinical applications.

ANALYSIS OF DATA

Statistical Assumptions

The scalar graduation of the PRA disks into 360 degrees provided standard units for measuring those attributes of perceptual rotation being studied. The intervals between readings on the two rotating disks were thus quantifiable and comparable, having a defined relationship to any rational zero point on the circumference scale. In addition, the absolute magnitudes of measured discrepancies in matching disks could be computed in terms of other standardized scales according to the radii of the points in question.

It was assumed that a sufficient number of disks settings expressive of the psychological phenomenon in question should approximate the normal curve. However, since the elected method of scoring was to add and average the error or discrepancy in the settings of the two disks, the frequency distributions were necessarily skewed. Typical examples of the characteristics of the error curves are depicted in Table 1. Mean, median, and mode for the summative settings of Disk 2 by the five and eleven year old groups indicated that distributions were not symmetrical, but were positively skewed toward the higher degrees of error. This was merely a condition of the elected method of scoring in which the degree of error was limited by zero on one side, but was unlimited in the other direction. With the older group the decreased dispersion of scores reduced the extent of the range largely on high-error side of the curve, although the skewness was retained and the mean was still displaced from

Table 1. Distribution characteristics of average rotational error for ages five and eleven on Disk 2.

Age	N	Mean	Median	Mode	Standard Deviation	Range
5	44	8.4	8.0	5.5 & 8.5	3.5	2.7 to 19.7
11	25	4.0	3.7	3.7	1.8	1.8 to 9.8

the median toward the extreme scores. The bimodal curve for age five was an indication of further departure from normalcy due to the limited number of measurements for an age level marked by a broad range of error.

The scoring of errors for depicted group averages and age curves did not include the major errors of rotation known as mirror images and reversals in which figural elements were perceived as if transposed into adjacent or opposite quadrants. Such transpositions occurred only at the earliest ages, and their inclusion would have provided an inconsistent basis for age comparisons. Non-transpositional or minor errors of rotation were imposed upon transposed images in a typical manner and could be scored separately and consistently.

Testing of hypotheses

Though the research hypotheses were directional, being stated as positive assertions, all statistical tests were based upon the null hypothesis, postulating equivalence of means and homogeneity of variance, and utilizing two-tailed tests of probability.

Because of the limited degrees of freedom in samples, ranging as small as 22, inferences relative to discrepancies between mean values were derived from distributions of the t statistic. Because the two-

sided t test is robust and not apt to be affected by moderate nonnormality (Ferguson, 1966), it was assumed that sample size was sufficient and departures from normality were not so gross as to seriously affect estimations of probability. Standard probability values of .05 and .01 were taken as denotative of significant differences, with differentials at these levels occurring due to chance factors only five times or once per one-hundred repetitions respectively.

Since the variance of a distribution is not a function of skewness, the variances of age groups could be usefully compared by means of an F ratio. Sample sizes were sufficiently large to allow probabilistic inferences. However, in each instance of its use the probability value provided by typical tables of F (Ferguson, 1966) was doubled to compensate for the restrictive procedure of always placing the larger of the two variances in the numerator.

Effects of Stimulus Design

Hypothesis No. 1

The judgment or perception of rotation will be affected by the nature of the visual stimuli used with the PRA.

Findings on the equivalence of designs

Designs were not sampled from a family or universe of design types, but were selected for specific reasons. Disk 1, the familiar figure, was to assure that younger children grasped the principle of a slanting or rotated object. Disk 2, the straight line, represented both the simplest and most clear indicator of direction. Disk 3, the Bender design, had been found in prior research to be particularly susceptible of rotation (Fabian, 1945; Fuller and Laird, 1963).

The similarity of task and the apparent directional content of the designs would suggest that the errors in each compass position might be additive to facilitate comparison of designs. Correlation studies supported this assumption. Table 2 provides a matrix of the correlation between individual items and overall rotational error for three of the age groups. Correlations are all positive and of sufficient size to justify

Table 2. Correlations of performance on individual items with overall test scores for ages four, seven, and eleven.

Individual Items	Correlation with Overall Rotational Error on PRA		
	Age 4	Age 7	Age 11
Disk 1			
0°	.52	.27	.50
90°	.50	.12	.52
55°	.29	.50	.37
140°	.68	.20	.27
20°	.15	.59	.09
120°	.50	.16	.64
Average Error	.73	.76	.75
Disk 2			
0°	.23	.09	.05
90°	.06	.13	.13
55°	.66	.12	.33
140°	.34	.59	.68
20°	.34	.53	.44
120°	.64	.39	.47
Average Error	.80	.78	.82
Disk 3			
0°	.08	.15	.39
90°	.37	.38	.14
55°	.04	.23	.23
140°	.40	.42	.24
20°	.57	.57	.26
120°	.63	.18	.28
Average Error	.82	.79	.62

the addition of errors to obtain composite scores and averages. The

additive nature of scores is further affirmed by the fact that averaging the error on each design stabilizes and substantially improves correlations with overall scores.

Accordingly, Table 3 presents a comparison of average error and dispersion for each disk or design. The means and standard deviations

Table 3. Mean and standard deviation of average rotational error for ages four through eleven on each of three disks.

Age	N	Disk 1		Disk 2		Disk 3		Overall	
		\bar{X}	s	\bar{X}	s	\bar{X}	s	\bar{X}	s
4	27	13.1	6.8	11.1	5.2	12.3	5.3	12.2	4.5
5	44	9.0	3.8	8.4	3.5	8.7	3.9	8.7	2.7
6	26	6.1	2.1	5.9	2.6	6.9	3.2	6.3	2.0
7	24	6.6	2.4	5.3	2.1	7.1	2.4	6.4	1.8
8	24	5.5	1.8	6.1	2.3	6.7	2.3	6.1	1.3
9	23	6.0	1.8	5.7	1.2	5.3	1.8	5.7	1.1
10	22	4.3	1.7	3.8	2.2	5.0	2.3	4.4	1.5
11	25	4.3	1.7	4.0	1.8	4.5	1.5	4.3	1.3

generally show only small variations for each age level. Error scores on Disk 1, the introductory disk, are not consistently higher than scores for the other two disks. Even at age four the degree of difference is quite probable in terms of the standard deviation at that age.

There were no significant F ratios in intra-age comparisons of variance on the three designs. Intra-age comparison of means required a small correction in values of t needed for specific probability levels because of non-homogeneity of variance (Ferguson, 1966). However, this small increase in the requisite t value was more than offset by larger t ratios due to correlation of measurements. That portion of the variance

resulting from experimental error is reduced by positive correlations existing between measures repeated for the same age group (Winer, 1962).

Only two instances of significant differences in response to design were registered. At age seven the mean error on Disk 2 differed from the mean for Disk 3 at a probability level of less than .01. At age eight the means for Disk 1 and Disk 3 differed at a probability value of less than .05. Since there are a total of 24 intra-age disk comparisons in Table 3, one or two instances of significant difference should occur by chance alone. The general consistency of performance on all other intra-age comparisons indicated the appropriateness of risking a Type II error and accepting the null hypothesis of no difference between means at each age level for the particular designs under study.

Mirror images and reversals occurred in considerable number at ages four and five. Such gross rotations of the subject's disk, transposing the visualized image into adjacent or opposite quadrants, were considered as differentiated from the small degrees of error typically registered by the PRA. Of the total number of transpositions manifest by the four year old group, 31 percent occurred on Disk 1, 40 percent on Disk 2, and 29 percent on Disk 3. For age five, 56 percent occurred on Disk 1, 26 percent on Disk 2, and 18 percent on Disk 3. The erratic patterning of the interaction of transposition with stimulus design did not favor the application of statistical tests of difference.

Discussion of the effect of design

In considering the influence of design it must be noted that both the nature of the selected designs and the nature of the PRA exercise allowed a perceptual response. Perception is defined as occurring globally (Hermann, 1959), immediately and unanalytically (Strauss and Lehtinen,

1947); whereas cognitive activity outside the perceptual sphere may require analytical categorization of data, the storage of encoded information, and the imposition of conceptual transformations upon the encoded information (Lee, Kagan, and Rabson, 1963).

The PRA task could be regarded as a perceptual operation because the compared stimuli were unanalytically perceived as identical, could be globally intuited as directional, and were presented simultaneously, requiring very limited retention of the images in memory. Some subjects utilized overt verbal behavior as a means of retaining an integrated configuration. Disk 3, the unfamiliar image, was sometimes conceptualized as a "Christmas tree" or an "ice cream cone." This occurred more frequently between four and six, facilitating a global or undifferentiated perception of the pattern of dots as directionally oriented.

The use of speech as an orientational aid accords with Nickiforova's (1963) finding that accurate reproduction of visual images is aided by verbalization. The verbal-loop hypothesis of Glanzer and Clark (1964) proposes that in performing a perceptual task the subject translates the input information into words which are subsequently applied to determine the output in recognition or reproductive tasks.

It would appear that rotation is a facet of behavior which occurs on a perceptual level irrespective of the nature of the design. The use of three designs of varying familiarity confirmed that rotational error as measured by the PRA is not specific to any particular type of configuration.

Possible applications of PRA technique

Manipulation of design characteristics would allow testing of the ability to conceptualize particular patterns, a classificatory skill

which improves with age (Siegel, 1953). The ability to match the rotation of disks appears to be generally developed by age four and could be utilized as a non-verbal indicator of whether a design has been perceived in such a way as to implement rotational matching.

Explorations of field dependence (Witkin, 1965) would be abetted by PRA disks which required separation of criterial elements from various levels of ground complexity before an orientational response could be made. The PRA would also provide an alternative to Goldstein's (1967) method of using a verbalized indication of direction to signal recognition of an obscured pattern, and would allow applications down to age four.

Impairments in abstractive skills might be detected by using disk elements which must be integrated on dimensions of shape, size or spacing before rotation could be matched. This approach would supplement the studies of Beck (1966, 1967) concerning the properties of stimuli which facilitate grouping.

Developmental Characteristics

Hypothesis No. 2

Perceptual rotation as uniquely measured by the PRA has developmental characteristics related to age.

Findings on age trends

The presentation of descriptive statistics in Table 3, page 43, discloses considerable variation with age. The trends are more clearly visualized in the graphical delineation of means and standard deviations as shown in Figure 7, page 47, and Figure 8, page 48.

The mean rotation error showed a rapid decline between ages four and

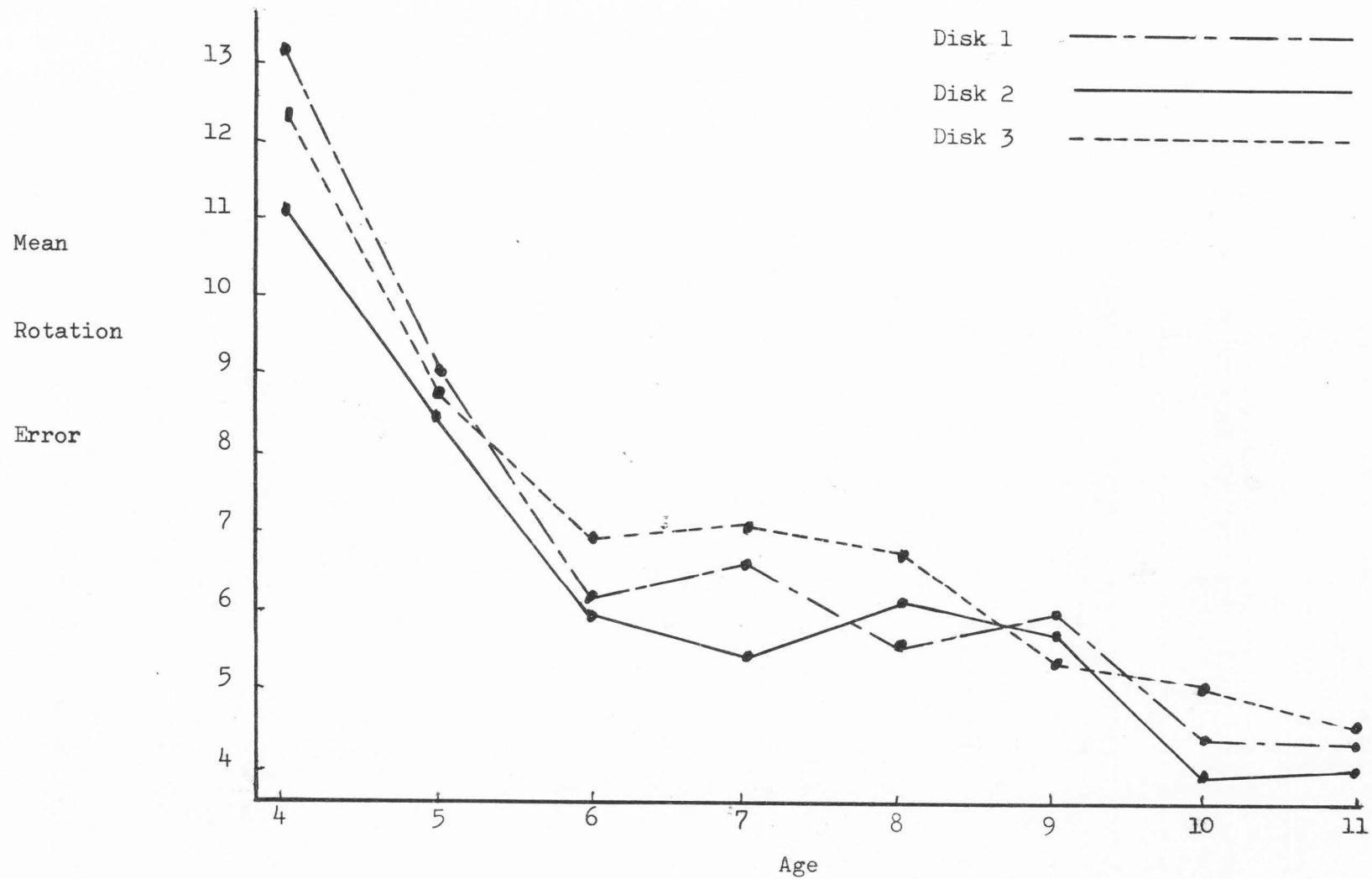


Figure 7: Age trends in mean rotation error for each disk.

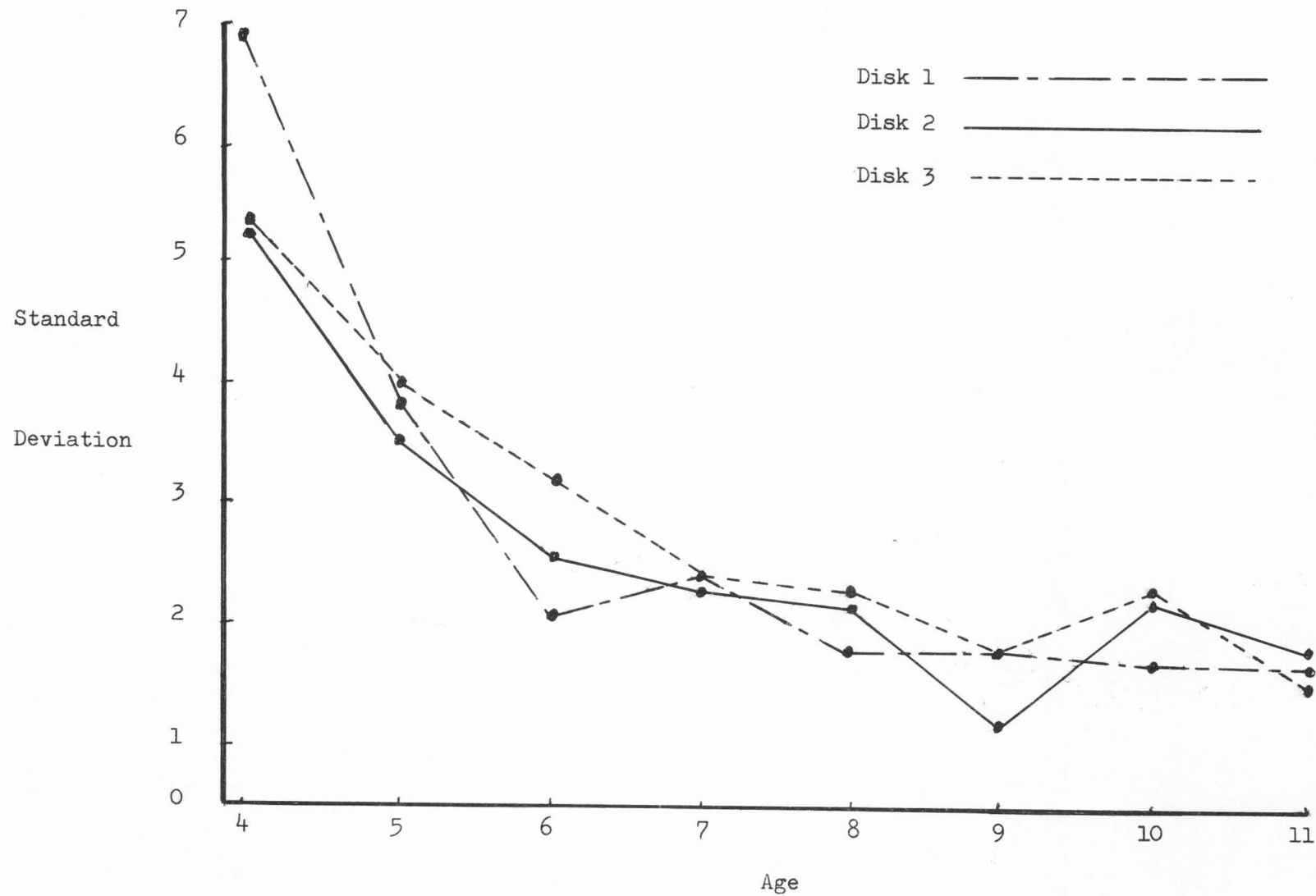


Figure 8: Age trends in the standard deviation of average rotation error for each disk.

six for all three disks. The substantial reductions in error between four and five, and from five to six, were significant at a probability level of less than .01. By age six approximately two-thirds of the group were able to estimate rotational position within an average of 6.3 degrees, plus or minus two degrees of deviation.

The mean rotation error, particularly as seen from the overall average shown in Table 3, tends to level out between ages six and nine, indicating that there was little improvement in accuracy from one year to another during this period. However, the composite group variance continued to decline during this period.

A second zone of change is indicated between ages nine and ten where the overall rotation error (see Table 3, page 43) again took a substantial drop, the decline having a probability level of less than .01. The drop remained confirmed at age 11 and thereafter error declined gradually by another degree according to trial measurements on adult subjects. This second period of rapid change occurring around nine and ten included a major decline in mean error on Disk 3 from age eight to nine. A year later the average error on Disks 1 and 2 drops sharply, showing differences between successive means from ages nine to ten significant at the .01 level.

The standard deviation of average rotational error, as graphed in Figure 4, showed the sharpest declines for all disks between ages four and five. A high rate of decline continued for Disk 1 between five and six. The F ratios for these variance changes were significant at the .01 level. The pronounced decrease in variance for Disk 2 settings from eight to nine, as well as the rise between nine and ten, were similarly significant at a probability level of less than .01.

Discussion of age trends

The degree of error occurring on the PRA task, reflecting limitations in discrimination as well as orientational errors in operational judgment, raises questions about the interpretation of small degrees of error in such devices as the Bender-Gestalt or the MPD. The average degree of operational error at early ages confirms Clawson's (1962) recommendation that orientational errors under 15° in the Bender-Gestalt records of children are not interpretable as meaningful rotations. The MPD differs from the Bender-Gestalt in relying upon a summation of small degrees of error in the drawing of six figures, setting a total of 20° as the borderline of normal perception. The average PRA error for six settings suggests that the MPD cutoff point for normality may be too low. However, the MPD drawings are presented at compass orientations in which the highest PRA accuracy was recorded.

Considerable difficulty is encountered in comparing instruments. Apparently the quantitative dimensions of rotational tendencies are not comparable except as methodologies are precisely duplicated. For example, Wursten (1947) found that in a matching task involving the angular displacement of oblique lines, the average error in judgment ranges from 18.3 degrees in five year olds to 2.3 degrees in adults. In the present study the highest average error for five year olds was 12 degrees at the 55 degree setting. Variations in methodology apparently make quantitative comparisons inappropriate.

However, graphical comparisons of age trends provide useful information. Present results tend to confirm prior findings of Gibson et al. (1962) that the ability to detect rotations and transformations of letter-like forms matures rapidly between ages four and seven. Similarly, Fabian (1945) noted that though over 50 percent of five year olds rotate Bender-

Gestalt design No. 3, the same figure as on Disk 3, only six percent rotate by age eight. Standardization figures for the Frostig Developmental Test of Visual Perception (Maslow, Frostig, Lefever, and Whittlesey, 1964) confirms that the maturation of perceptual-motor functioning usually occurs prior to age eight.

The PRA task was comparatively quite simple, and the major improvements in accuracy occurred by age six. The leveling of accuracy between six and nine was accompanied by a continuing decline in group variance, suggesting that slower developing individuals continue to improve, moving toward the typical group performance and reducing the range of error. The significant declines in error around nine and ten appeared accompanied by an increasing variance, suggesting that the trend at this point was most marked in a few precocious individuals and that the range of performance was again broadened until slower individuals accomplished the same transition.

It is noteworthy that the major change in error rate with perceptual tasks occurs at the age period at which Piaget (Flavell, 1963) outlines a transition from the perceptual domination of pre-operational thought to the stage of concrete operations. An extensive review of various theoretical formulations and research findings, describing a broad range of perceptual and cognitive skills, led White (1965) to postulate the age period between five and seven as a transition zone for movement from associational skills to a cognitive level of operations. Present findings also suggest a second shift in accuracy of judgment occurring between nine and ten years, although this transition is not as pronounced. The evidence is insufficient for attributing this second increase in accuracy to intellectual maturation associated with movement from concrete to formal levels of operations (Flavell, 1963).

Rotational errors occurring with the PRA task appear to be phenomena reflecting perceptual-intuitive operations. The design and its rotational orientation is received as input without analysis and there is an immediate "jumping to a conclusion" type of response. Perceptual-intuitive operations appear to be involved in both the moderate degrees of rotation and the major transpositional errors.

Movement toward the level of concrete operations brings a reduction in all aspects of rotation registered by the PRA. Higher levels of cognitive operation are seen to emerge as orienting axes or spatial coordinates are conceptualized as imposed upon the rotating disks, enabling a more careful estimation of the degrees of angularity.

Observations of subject behavior

The increasing accuracy of judgments of rotation is attributable, not only to higher levels of cognitive skill, but also to changes in variables of anxiety and motivation. Kagan (1966) describes a stable dimension of behavior bounded by the semantic differential of reflection-impulsivity. This dimension describes the degree of delay, the weighing of alternatives, and the caring about correctness in performing a task requiring a definite judgment. The antecedents or components of reflective versus impulsive behavior were presented by Kagan (1966) as including constitutional predispositions, attentiveness or involvement in the task, and anxiety over task performance. It was noteworthy in the current methodology that the observed behavior of subjects showed that anxiety over task performance was functionally related to age and declining variance, with the period of greatest anxiety occurring around age nine, apparently associated with a further refinement in accuracy of rotational judgment. It would appear that the reflectivity-impulsivity

dimension has a declining range and is mediated by higher level cognitive operations.

Pre-school children took one quick look at the examiner's disk, then set their own disk rapidly and with minimal vacillation, rarely taking a second look at the standard. In the primary grades increasing numbers of children glanced back at the standard to make one or more verifications of position. By age nine the behavior of many children disclosed a more careful weighing of disk position, sometimes accompanied by a deliberate slanting of the head or changing of body position. The apparent behavioral accompaniments of intuitive perceptual recognition and the later cognitive judgments appeared also to involve the introduction of increasing concern over accuracy. Certain compulsive children in whom this preoccupation was exaggerated would juggle disk position extensively. Though there was no apparent threat to their well-being, the position of their disk became a matter of unusual affect. The possibilities of error were no longer readily accepted.

In contrast, perceptual matching involved a more rapid association or identification of position, carrying an assumption of rightness. Even grossly inaccurate responses were regarded as appropriate or acceptable, and a second glance was superfluous. There was no precise age of demarcation, even in terms of group averages. The shifting levels of operation appeared quite individualized. Indeed, certain eleven year olds continued to make intuitive assumptions, and an occasional child of four might reposition his disk after visual verification.

In addition to the reflection-impulsivity dimension a second factor enunciated by Kagan (1966), the matter of motivation and involvement, appears also to be a strong determinant of the declining error curve. It is probable that much of the error manifest by children from four to six

did not reflect a deficiency in the ability to perceive, centrally process, and motorically duplicate rotational position, but consisted of error occurring from the intuitive assumption of rightness. The task may not have adequately involved children of the perceptual-intuitive level in offering a true measure of perceptual accuracy. Further, tasks involving a limited number of choices are less apt to expose the same attitudes as the PRA task which offers a latitude of choice and no immediate reinforcement of correctness. Nevertheless, the PRA technique and results do suggest that a concern over rightness or accuracy is an accompaniment of the movement from perceptual to higher cognitive levels of functioning.

Reliability of Measurements

Hypothesis No. 3

The PRA measurements of the rotation of visual stimuli are reliable.

Findings on reliability

Groups at ages four, six, and eight were retested under identical physical circumstances after an interval of one week, providing the data of Table 4. Contrary to initial expectations, the four year old group

Table 4. Reliability of total scores based upon seven day retesting.

Age	N	<u>Initial Test</u>		<u>Second Test</u>		r
		<u>X</u>	s	<u>X</u>	s	
4	27	12.2	4.5	12.1	3.6	.52
6	26	6.3	2.0	6.9	1.7	.11
8	25	6.1	1.7	6.4	1.7	.37

showed more individual consistency, the product-moment correlation for this group being significant at the .01 level. The correlation for age six was negligible, and for age eight the coefficient of .37 had a probability value of greater than .05.

None of the means or variances changed significantly over a period of one week, verifying the assumption that the attribute being measured would not be influenced by recent learning. A particular level of performance appears to be maintained by each age group as a whole, but studies of individual performance showed somewhat erratic behavior. Some individuals remained near the same level of accuracy, whereas others showed gross changes in accuracy between the two testing sessions.

As already noted in previous discussion, the errors of rotation registered by the PRA were arbitrarily divided into two categories: (1) non-transpositional or minor degrees of error, and (2) transpositional errors involving shifts of the directional aspect of the design into opposite or adjacent quadrants. Errors of transposition occurred largely at the youngest ages, as shown in Table 5, and were not included in the tabular

Table 5. The occurrence of reversals and mirror images.

Age	N	N showing Trans-positions	% showing Trans-positions	Number of reversals	Number of mirrors
4	27	18	67	20	52
5	44	15	33	7	33
6	26	4	15	4	11
7	24	3	12	2	4
8	24	1	4	0	2

or graphical presentation of developmental characteristics. The actual

count of reversals and mirror images is presented in Table 5, page 55, to illustrate the relative extent of the two types of transposition. The incidence of transpositional error was relatively small considering that each subject made 18 disk settings. In general the tendency to mirror or reverse an image occurred coincidentally with particular subjects.

The fact that the coefficient of reliability based on non-transpositional error was most favorable at age four suggested the possibility of including errors of transposition in computing reliability for this age level. Since 67 percent showed transpositions, the effects upon reliability might be quite substantial. Justification for adding the two components was provided by the finding that non-transpositional error correlated .57 with the number of instances of transposition.

The MPD method of scoring was tentatively applied to the test-retest groups at age four. Each transposition was scored as 25 points and non-transposition error was also limited to 25 degrees maximum scoreable error. Using this approach to scoring raised reliability for age four from the previous .52 to .74.

The MPD scoring system did not allow a full range of non-transpositional error. Most four year olds had at least one instance out of the 18 settings of error over 25 degrees, though only five children showed instances of an error over 50 degrees. These operational errors over 25 degrees were found to correlate .65 with the number of instances of transposition, indicating the value of including a broader range of non-transpositional error in assessing reliability.

It was decided to score all transpositions as if limited to 50 degrees, while scoring non-transpositional error at its full value within the limit of 50 degrees. The obtained reliability coefficient of .96 suggested that this method was optimal and only slight improvement might

accrue from scoring transpositions at a still higher value.

As expected, the discrimination and rotational factors accounting for high reliability at age four were found to have some relationship with age. In computing correlations the age variable was restricted to the particular month, zero to eleven, in the interim between ages four and five. This age factor correlated $-.29$ with the number of instances of transposition, $-.21$ with the degree of non-transpositional error, and $-.38$ with composite error as was scored to achieve the reliability coefficient of $.96$.

Findings on internal consistency

Reliability on repeat testing is predictable on the basis of internal consistency or the intercorrelations of test items (Nunnally, 1967). The items of the PRA test consisted of a series of disk settings which were essentially similar. Some variation was introduced by different compass positions and some design dissimilarity. Presumably, if stable perceptual skills were being measured, an individual showing high accuracy at a particular disk setting would tend to manifest equivalent ability for other positions or disks.

However, matrices of interitem correlation disclose considerable variability in performance, depicting the operation of chance factors or uncontrolled sources of variance. Table 6 provides a summation of data from interitem correlation of non-transpositional error for ages four, seven, and eleven. The error at each compass setting was correlated with the error at each of the other 17 settings. The average value is presented in the table. The low and erratic correlations suggest that the homogeneous content of the items tends to be transcended by the operation of chance factors. The discrimination required to

consistently make disk settings at a particular level of accuracy is probably beyond the capabilities of the perceptual system at any age

Table 6. Average interitem correlations for ages four, seven and eleven.

Individual Items	Average Correlation With All Items		
	Age 4	Age 7	Age 11
Disk 1			
0°	.20	.07	.19
90°	.19	.02	.17
55°	.04	.05	.06
140°	.21	.01	.01
20°	-.04	.08	.01
120°	.10	-.06	.13
Disk 2			
0°	.11	.02	.01
90°	.03	.05	.09
55°	.20	-.07	.07
140°	.09	.16	.20
20°	.07	.15	.08
120°	.22	.09	.08
Disk 3			
0°	.02	.02	.14
90°	.14	.13	.04
55°	-.03	-.03	.05
140°	.09	.06	.00
20°	.17	.12	.00
120°	.20	-.01	.03
Overall Average	.11	.05	.08

level. With the PRA technique the accuracy of a particular setting must always be partially mediated by chance factors which tend to be averaged out in the group mean.

Combining a series of readings for any individual reduces the effect of non-systematic chance components, also allowing increasing correlations as more systematic components are summed. The matrix for age seven in Table 7 illustrates this principle. The correlations between

angular settings are lowest and frequently negative. Each subject's average score on an angle is based on three readings, whereas each average disk score is based on a series of six compass settings. Correlations of disk to angle are consequently higher and generally positive.

Table 7. Product-moment correlation matrix for average error at each compass setting and for each disk at age seven.

	Disk 2	Disk 3	0°	90°	55°	140°	20°	120°	Total
Disk 1	.41	.34	-.03	.22	.44	.54	.53	.27	.76
Disk 2		.46	.32	.39	.10	.34	.78	.39	.78
Disk 3			.34	.20	.34	.62	.44	.36	.79
0°				.26	-.21	.43	.17	-.19	.26
90°					-.17	.26	.13	-.06	.34
55°						.04	-.02	-.03	.37
140°							.32	.05	.65
20°								.38	.74
120°									.44

Discussion

Acceptance of the research hypothesis relative to reliability of measurements was regarded as conditional, dependent upon age level and the scoring of particular types of error. The null hypothesis clearly obtained at all ages for those sources of variance which were designated non-transpositional error. Even at age four the coefficient of .52 was far below the value of .80 which Numally (1967) would regard as appropriate for any instrument used in basic research.

In an examination of the rotation of block designs, John (1964) also noted inconsistencies in performance, suggesting that differences

in approach to the task or in motivational variables might account for the erratic nature of rotational errors. Similarly, the PRA technique appears beset by uncontrollable fluctuations in motivational factors, as well as other intrinsic and environmental factors, all of which militate against reliability of individual performance.

Although the range and level of individual fluctuations appear to be circumscribed by factors which demonstrate a developmental trend, the inadequate reliability of individual performance would make it difficult to validly identify the attributes denoted by the age trends. Only at age four was there an indication that sources of variance might be consistently identified with individualized traits of personality. At age five the range of non-transpositional error was still extensive and correlated with the occurrence of transpositions, suggesting that fairly high reliabilities might also obtain for age five as both categories of error were scored. By age six the PRA registered few transpositions and such a small range of non-transpositional error that chance factors transcended any consistency of measurements.

Assuming that the high reliability of composite error at age four was not a chance characteristic of the particular sample, the task offered by the PRA might have some application in measuring developmental level in preschool years. Differential rates of development are apparent in the low correlations with age. Reliable individual differences appear to be mediated by factors of perceptual development as well as by factors of impulsivity and motivation. Whether these factors as registered by the PRA would be useful in assessing readiness for school or in predicting learning disabilities would have to be determined by replicative and longitudinal studies.

Should replication establish that the PRA is an effective research

instrument at preschool levels it would be of value to make some alterations in the PRA task to extend its reliable use into the primary grades where learning disabilities make their appearance. Improved reliability of measurement might be approached by (1) increasing the number of test items, (2) adjusting the difficulty or discriminative level of items to broaden the range of performance, and (3) extending testing to include a more diversified sample of subjects.

The PRA exercise involved only three observations for each compass position and six observations for each design. The higher and more consistent correlations between designs or disks, as depicted in Table 7 on page 59, indicates that an increase in test items would favorably affect reliabilities.

The discrimination of line direction matures to a fair degree of accuracy in most children by age four. Matching of the disk settings may have seemed a trivial task to some, providing no real challenge, lending to random responding or the observed careless attitude which probably reduced correlations on non-transpositional error. Using a design particularly contributive to transpositions, while controlling turntable starting positions, would exploit the component of gross rotations. Also, the use of a design which would be less easily perceived as directionally oriented might increase difficulty level for age six and older. The use of a design requiring analytical and abstractive skills would tap broader variations in the higher levels of cognitive functioning. Certain compass positions may also be found from interitem analyses, as illustrated in Table 6 on page 58, to contribute to a greater range of discriminative variation.

Low reliabilities at age six were also attributable to the restricted range of deviance of the sample. Probably very few cases of minimal

cerebral dysfunction or special learning deficits existed in the sample from Edith Bowen School, and the PRA exercise was not capable of reliable discrimination within a limited range of development or training. It is quite possible that the nursery school sample of four year olds reflected a broader range of abilities than did pupils of the elementary school. The inclusion of individuals representative of deviant categories in the sample would extend the range of scores and verify possibilities for using the PRA technique to discriminate certain developmental anomalies.

Validational Comparisons

Hypothesis No. 4

PRA judgments of the rotation of visual stimuli are related to intelligence as measured by a standardized device, the Quick Test (QT).

Hypothesis No. 5

The measurement provided by the PRA is related to the rotational factor assessed by a standardized diagnostic instrument, the Minnesota Percepto-Diagnostic Test (MPD).

Findings on intertest correlations

Table 8 shows the product-moment correlations of PRA performance with scores on three other instruments. For the sample of seven year olds, correlations of .40 and .52 are required for significance at the .05 and .01 levels respectively. The correlation of .59 between the Metropolitan and the Quick Test, an expected relationship between IQ and achievement, is the only statistically significant coefficient in the matrix.

The PRA and MPD provide scores of rotational error or perceptual-

motor inaccuracy, consequently correlating negatively with intelligence and achievement. The PRA relationships for both Disk 3 and the total of

Table 8. Intercorrelations for the seven year old group on Metropolitan Achievement, MPD, Quick Test, and PRA.

	Metro	QT	PRA	
			Disk 3	Total for Disks 1, 2, and 3
MPD	-.13	-.28	-.03	.15
Metropolitan		.59	-.28	-.20
Quick Test			-.25	-.21

all three disks are presented to provide a better basis for comparison with the MPD which utilizes the same Bender-Gestalt pattern of Disk 3 for three of its six cards. Nevertheless, it is remarkable that there was no correlation in rotational tendencies for the two instruments for Disk 3.

Squaring the Pearson coefficients indicated that the overlap variance between PRA total and MPD was only 2.25 percent. Application of the technique of partial correlation disclosed that 59 percent of this small relationship between PRA and MPD is produced by the common variable of intelligence. Removing the effect of intelligence left an overlap variance of less than 1 percent. Similarly, the common variable of intelligence accounts for most of the observed correlation of the Metropolitan with the PRA and MPD.

The group average on the Quick Test was 113.6 with a standard deviation of 18.1. Table 9 indicates that the mean for seven year olds on the MPD was 50.1 with a standard deviation of 15.7. The MPD standard-

ization group for age seven, having a comparable IQ of 112, showed a mean

Table 9. Comparison of seven year old children from present sample and normative group on the Minnesota Percepto-Diagnostic Test.

	\bar{X}	s	IQ	Correlation with IQ
MPD: Present Sample	50.1	15.7	113.6	-.28
MPD: Normative Group	50.5	19.6	112.0	-.17

of 50.5 and standard deviation of 19.6. Hence the MPD mean of the present sample agrees very closely with that of the standardization group, though the variance for the larger group is considerably higher.

The $-.21$ correlation of Quick Test and PRA measurements was comparable to the correlation of $-.17$ obtained between IQ and MPD for the standardization group. The present sample showed a coefficient of $-.28$ between MPD and Quick Test. Each of these figures indicate that the overlap variance of intelligence and rotation is less than 10 percent.

Since the seven year old group under study comported reasonably close to standard performance for the MPD, and since MPD and PRA scores did not correlate, it was necessary to accept the null hypothesis that the two instruments do not reflect the same factors. The negligible correlation between PRA and QT similarly sustains the null hypothesis of no relationship with intelligence.

Discussion of validation comparisons

It was considered unlikely that the absence of anticipated relationship between MPD and PRA was due in part to methods of scoring. For the seven year old group transpositional error on the PRA was not included

in the scoring. Data from Table 5 on page 55 indicates that by age seven there were only six instances of errors of transposition. On the MPD the present sample of seven year olds showed no instances of mirroring or reversals. It would appear that omitting the scoring of transpositional errors on the PRA would be a negligible factor in accounting for the absence of correlative variance in PRA and MPD.

Since reliability is a necessary condition for validity, the negligible correlation between the PRA and other instruments must be taken as corroborative evidence that the PRA methodology did not reliably measure typical rotational phenomena, certainly not from age six and upwards.

The fact that the MPD and similar instruments, such as the Graham-Kendall Memory for Designs Test (MFD), reliably induce and measure rotational phenomena at later ages than did the PRA facilitates "convergence" upon the factors which are basic to the occurrence of these phenomena.

Devices to measure rotation may be classed in terms of whether the output behavior requires only a visually mediated choice of correspondence or involves a visual-motor reproduction of the input stimulus. The occurrence of rotations under either output condition rules out the motor connections as essential variables. This is affirmed by the work of McPherson and Pepin (1955) who demonstrated a 91 percent reliability in the occurrence of rotations under vastly differing modes of motor duplication, indicating that covert central processes mediated the rotations.

A factor common to all methods of inducing rotations is the subject's dependence upon a retained central image of the visual stimulus. As visual focus is shifted between the standard and the reproduced or selected output figure, the correspondence is mediated by means of a retained image or iconic representation (Bruner, 1964). If the covert image shifts due to constitutional defects, immaturity or emotional stresses, the

external choice of orientation may rotate in consonance with the shifting inner icon. Also, an uncertain inner image may shift as influenced by newer orientations suggested by multiple choices offered in a non-motor test.

An interval of dependence on the iconic representation occurs in all methodologies whether the standard figure is continuously displayed as on the PRA and MPD or is removed after a measured exposure as on the MFD or the Bannatyne Visuo-Spatial Memory Test (BVSMT). However, dependence on the central image, favoring the occurrence of rotations, may be increased by (1) decreasing the period of exposure to the standard, (2) adding to the complexity of the stimulus figure, and (3) by requiring motor duplication. Anyone of these procedures also adds to the relative difficulty of the task, affecting the age level at which the procedure is applicable (Fabian, 1945).

It must also be noted that the factor of motor duplication introduces qualitative changes in the task which affects central processing and the consequent meaning of the response. Since handedness is involved in a copying task, the factor of cerebral dominance is introduced as an intervening variable (Bannatyne, 1969). Requiring motor duplication of a configuration removes the operation from the sphere of global perception, requiring an analysis of figural components and the cognitive guidance of the motor synthesis of elements. The period of concentration on the cognitively directed duplication of figural elements not only poses an interval of dependence on the iconic representation, but if the task is of sufficient difficulty, regressive processes are actuated. With sufficient stress from task requirements the subject tends to regress toward earlier stages in the ontogenetic emergence of spatial and copying orientation. Designs are regressively rotated toward verticality

in relation to field lines or the terrestrial horizon.

Fabian's (1945) study of the tendency toward verticalization illustrates the rotation of the copied figure to a preferred and simpler orientation for copying. Over half of the five and six year olds rotated the Bender No. 3 design, 80 percent of these being a rotation to the vertical. Yet on the simpler nonmotor task of the PRA exercise, 90 degree rotations to the vertical did not occur at any age level.

From a review of the operation of rotational devices it would appear that the PRA technique might be applicable in assessing developmental status at preschool levels. Difficulty level is minimal, allowing application at age four. Designs can be selected which allow a clear view of perceptual development without introducing regressive tendencies or requiring the use of higher levels of cognitive functioning. The unlimited choice of disk positions in the subject's response also permits a free expression of the reflectivity-impulsivity dimension of personality, a factor which has been related to motivation and school success (Zucker and Stricker, 1968).

Discussion of Other Findings

Sexual differences

No hypothesis was made concerning the relative performance of males and females. Nevertheless, certain of the findings may aid in formulating theoretical constructs concerning the operation of the PRA, and may also aid in the design of further research.

It was found that boys as a group performed more accurately than girls at every developmental level except age eight, although none of the differences were statistically significant. The greatest difference in mean scores occurred at age eleven, where the t ratio reflected a

probability level of .06. Results would accord with Oetzel's (1962) review of studies of spatial ability, providing indications that boys tend to score higher than girls.

Sex differences were apparent at age four in the production of transpositions as 88 percent of boys but only 45 percent of girls demonstrated instances of reversals or mirror images. The probability for such a difference in proportion is less than .01. The relative percentages showed little divergence at ages five and six, and by ages seven and eight only exceptional cases showed traces of this factor.

Spatial orientation

The developmental trends in the estimation of various rotational positions might be of value in elucidating studies dealing with orientation to spatial lines. Table 10, page 69, provides the measures of error for each age level. The angles are ordered from left to right in the table according to relative degree of error and variance.

The relative difficulty for each setting is much the same at each age level. Only a few settings are unusually displaced from the typical trend, such as the 20 degree position for age seven and the 55 degree position for age four. These discrepancies are attributable to chance factors, and no hypothesis is offered for them.

The progression in the difficulty level for particular angles follows the known development of spatial orientation. The initial orientation to the vertical is an aspect of man's biological nature and his adaptation to a gravitationally oriented sphere. Man stands vertically and extends his gaze horizontally, and the typically shorter vertical lines of his environment become the reference markers from which the more extensive horizontal lines recede.

Table 10. Mean and standard deviation of rotation error at each disk setting.

Age	0°		90°		20°		120°		55°		140°	
	\bar{X}	s	\bar{X}	s	\bar{X}	s	\bar{X}	s	\bar{X}	s	\bar{X}	s
4	4.3	2.5	9.6	8.5	13.7	7.6	15.9	10.3	12.8	7.7	16.8	8.3
5	4.1	3.0	6.1	3.4	10.0	5.2	9.6	5.1	11.9	6.0	9.9	5.1
6	2.7	1.9	4.9	2.6	5.6	2.6	7.8	3.6	8.0	4.1	6.9	2.8
7	1.8	1.1	3.4	2.1	8.3	5.3	8.0	3.1	8.7	4.7	7.7	3.7
8	2.0	1.4	3.3	1.9	5.9	2.4	7.4	3.3	8.9	3.2	8.8	4.2
9	2.0	1.3	3.4	2.2	6.5	2.0	5.5	2.3	6.9	2.7	9.6	5.1
10	.9	.9	2.2	.2	5.2	2.3	5.0	2.2	6.6	4.8	5.9	3.2
11	1.0	.9	2.2	1.3	4.5	2.4	5.6	3.3	6.6	2.5	5.9	3.2

Vertical segments of line at any depth or displacement are always perceived as vertical, and are most readily ingrained. Horizontality presents more difficulty, since horizontal lines in our three-dimensional surround are usually seen as oblique except as they approach the median plane. As a horizontal line extends to either side of the observer, it presents a mirrored obliquity, lending to the tendency to mirror oblique lines. The essence of depth perception through linear perspective lies in the perceptual recognition that angularly displaced lines are still horizontal. The degree of obliquity becomes associated with both depth and direction, a complex developmental process reflected in the progressive accuracy in judging the rotation of an oblique line.

Rotational movement toward a simpler orientation in copying tasks might be expected to favor the vertical axis. The precedence in learning of verticality is well established (Taylor, 1961; Gesell, Ilg, and Getman, 1967). Up-down reversals occur less frequently than left-right (Wohlwill and Weiner, 1964), and vertical errors in orientational tasks tend to disappear earliest (Rosenblith, 1965). The greatest accuracy of reproduction occurs along the vertical axis (Berry, 1968a).

The oblique lines are developmentally the last and most difficult to stabilize. The greatest errors of positioning and reproduction continue to occur with the diagonal orientations (Beery, 1968a). Diagonal components are consequently more apt to produce designs which are conducive to rotation and transposition. The diamond shapes are typical examples in offering no cardinal locus for copying. In attempting to reproduce the diamond children not only struggle with oblique lines, but are further motivated to place the longer axis in a vertical position to reduce the three-dimensional awareness elicited by the horizontal form (Ilg and Ames, 1964).

The PRA technique appears to be quite adaptable to studies of spatial orientation. Variable field lines could be placed around the rotating disk to facilitate studies needed for clarifying the role of spatial frameworks (Wohlwill, 1960). Perhaps an arrangement of placing both rotating disks against a vertical background might be more appropriate for certain studies. A variable line could be placed across the face of each disk to test the ability to orient a design from a relative point of view. The PRA method would allow measurement of error without limiting response possibilities to a few cardinal positions.

Direction of rotation

The question of direction of rotation error was considered in terms of both group and individual patterns. For each age group frequency distributions of position estimates for the oblique angles showed a consistent group tendency to exaggerate the angle between the setting and the major axis. For example, 120 degree settings tended to be displaced further than 30 degrees away from the 90-270 degree axis, and the 140 degree settings tended toward more than 40 degrees displacement from the 0-180 degree axis. On the other hand, when the separation of the true setting from the vertical was only 20 degrees, this setting was adjudged closer to the vertical.

Data appears to accord with studies by Jastrow (1893) and Piaget, Wursten, and Johannot (1949) as their experiments are reviewed and interpreted by Beery (1968b). In the study by Piaget and by Beery, results might best be described as a tendency on the part of subjects to move their reproduced line further from either the horizontal or the vertical axis, quite like the tendency with the PRA. With the simple task required by these studies there appeared to be an attempt to counter the

tendency to merge displacements of 20 degrees and smaller with the major axes.

Individual patterns on the PRA indicated that errors of discrimination or rotation might occur in either a clockwise or counterclockwise direction because of chance factors. Although verticalization of an image would involve a particular direction of movement, this type of rotation did not occur with the PRA. The transpositional type of error, involving a shift of image into adjacent or opposite quadrants, occurred in a definable lateral or vertical movement. However, these shifts were not consistent in type or direction for any one child. At this juncture it would appear that the direction of rotation with the PRA task has no significance in the diagnostic assessment of children.

Specie differences

Considerable experimentation has explored the differences between various species in discrimination of line direction. All of the species tested thus far--the cat, pigeon, octopus, goldfish, and young child--are able to discriminate horizontal from vertical. However, only the pigeon (Ziegler and Schmerler, 1965) and the cat (Sutherland, 1963) are able to differentiate between oblique lines presented successively as mirror images. Sutherland (1963) has hypothesized that the ability of a species to discriminate between rectangular lines in different orientations depends on the relative number of cells in the visual system having receptive fields in each orientation. This idea relates to the discovery by Hubel and Wiesel (1962) that the cat had specific receptor cells in the visual system which particularly detected oblique lines.

Findings by Rudel and Teuber (1963) that three and four year old children could not discriminate mirror obliques suggested that the

discriminative cells had not matured sufficiently at these ages. However, Over and Over (1967) proposed that the poor discrimination of mirror images in young children was not due to deficiencies in the input coding processes, but was related to categorization capacities. They found that children could readily detect differences in line orientation, although procedures which required that a particular orientation be held in memory involved the recognition of similarity, a categorizing activity.

The responses of children on the PRA tend to verify that at least by age four humans have appropriate receptor cells for detecting all angular positions. Further, the difficulty with mirror images does not appear to be a matter of deficiency in categorizing slanting lines. The problem appears to lie in the lateral organization of the brain which allows one oblique line to be classified or perceived as identical to the mirrored counterpart. The cat and pigeon, similarly having cells for detecting slant, do not have the problem of coordinating a laterally organized cortex with the mirrored aspects of linear perspective.

The PRA exercise demonstrated that the occurrence of transposed images is quite distinct from the ability to perceive angularity. To the preschool child the rotation or mirroring of an image in no way affected its character or categorical features. Only with maturation and appropriate training does the positioning of mirrored elements take on meaning (Cronin, 1967). Position or direction may then be transferred from model to replicated form through the medium of a stabilized iconic representation.

REPLICATIVE MEASUREMENTS

The initial study, utilizing subjects between ages four and eleven, suggested that the PRA technique might find reliable application prior to age six. A method of scoring which combined all rotational error within a limit of 50 degrees appeared to provide a measure of stable personality traits at age four. However, the obtained results may only have reflected a chance occurrence with the particular sample. Further, reliability was not assessed for age five, and any potential of the PRA method for preschool screening would depend upon the reliable measurement of developmental characteristics at this age as well as at four.

In considering a repetition of the initial study it was recognized that imperfections in initial controls had made duplication impossible. Highest reliability had required the scoring of mirror images and reversals, and the production of these transpositions for some subjects was likely affected by the starting positions of their turntable. Since these starting positions had not been controlled, precise replication was not feasible. It was therefore decided to introduce various changes which might favor duplicative studies and obtain further information about designs and rotational phenomena.

Changes in Methodology

Rationale for disk positioning

For each measurement the subject's turntable was placed at a specified position prior to exposure of the examiner's disk. Each subject would then have the same initial percept of discrepancy between the two

disks, and also have the same cues for direction of rotation and possibilities for stopping rotation at a reversed or mirrored position. Trial manipulations of the first disk insured that each child grasped the principle of matching the orientation. The examiner's disk was then hidden and each turntable placed at the prescribed position. Revealing the examiner's disk was accompanied by a verbal invitation for the subject to attempt a precise match. Social reinforcers from the examiner were used to insure or maintain high motivation.

The following sequence of turntable positions was utilized:

Examiner	0	270	60	220	330	120
Subject	90	0	180	90	180	0

Vertical and horizontal positions were retained, although the horizontal orientation was shifted toward 270 degrees instead of 90 as in the initial experiment. The succeeding four settings required one position in each quadrant. Interitem correlations of initial settings, though somewhat indefinite, suggested that the utilized displacements of 30 and 40 degrees from major axes favored stability of measurements.

Subject starting positions were at cardinal points and were selected to balance the effect of inviting a clockwise (CW) or counterclockwise (CCW) rotation on the occurrence of transpositional error. The first three settings invited CCW rotation as the nearest approach to a perfect match, whereas the succeeding three settings posed a CW rotation.

Rationale for designs

Design appeared to interact with technique in the production of rotational error. Hence there could be no reservoir of tested designs to sample or apply in any application of the rotating disks. Although it would be useful to test a variety of configurations, such a procedure

would be appropriate only after the instrument or method was demonstrated to have some value. For present purposes the selection of designs was based on rational and theoretical considerations.

Question had been raised about the simplicity and unchallenging nature of the PRA task. Reliability would be favored for ages five and older by increasing the number of measurements and extending the range of difficulty of the items. Accordingly, a fourth design was added, raising the number of individual readings to 24 per child. Designs were also altered or substituted to affect task difficulty.

The boxlike house shown on page 32 was retained as the initial disk. The familiarity of this image facilitated introduction of the child to the technique of matching various orientations. Although this design was quite familiar, it exceeded Bender No. 3 design in posing or inducing transpositions.

The straight line was quite susceptible of mirrorization, although offering no way of registering reversals. A three-eighths inch circle was placed on the line as shown in Figure 9 on page 77. Without experimental evidence there was no basis for optimally offsetting the circle. The offset was deemed sufficient to assess the developmental tendency to reverse figures rather than the capacity to discriminate the degree of offset. Whether the reversal marker would affect the occurrence of mirrorizations in such a simple design could not be anticipated.

The Bender No. 3 design had not involved a higher level of task requirement than the more familiar figures, and had been readily perceived as an integrated indicator of direction. It was decided to replace this figure with a design in which the factor of dimensional confusion might impair global perception. This design, shown in Figure 10 on page 77 was a Necker type cube in which the given directional indicator was



Figure 9. Design No. 2 adjusted to register reversals.

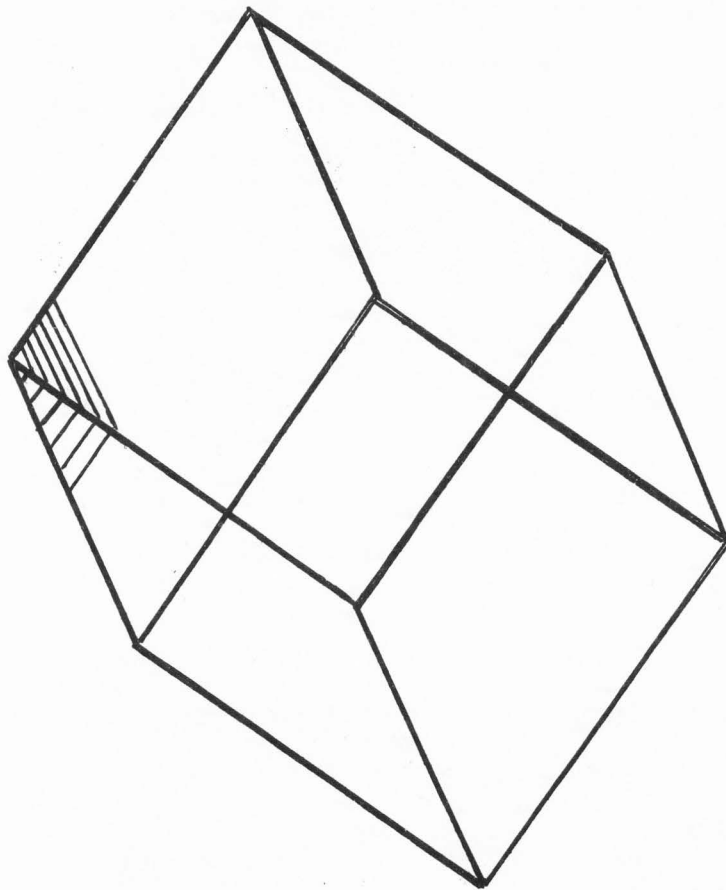


Figure 10. The cube outline used as Design No. 3

placed so that the lines of the cube would be oblique at all required settings. It was hypothetically considered that some subjects would not be able to stabilize their perception of the figure because of the vacillating three-dimensional properties. Difficulty in perceiving three-dimensional objects as flat two-dimensional representations has been associated with impaired readiness for school (Frostig, Lefever, and Whittlesay, 1961) and with brain damage (Hunt, 1959).

The fourth design, shown in Figure 11 on page 79, featured a key row of five equally spaced three-eighth inch circles. The field elements of the examiner's and subject's disks, though containing equivalent elements, were differentially arranged so that matching could be accomplished only by means of the criterion row of circles. Two blackened quarter inch circles aligned with the orienting row offered an indication of direction. Precision in orienting the fourth disk would be aided by the Gestalt perception of the criterial row of circles in each of the required compass positions. Such perceptual categorization based upon congruity of size and spacing may be developmentally related to later skills in cognitive classification (Wohlwill, 1962). The fourth disk might also assess relative freedom from the distraction of the field elements. Though there are no pertinent studies of redundancy offering a basis for determining appropriate numbers of criterial and field elements, it is well established that distractibility is associated with disorders of learning (Clements, 1966).

Hypothesis

The null hypothesis which motivated the second study was that there would be no significant reliability of PRA measurements on four and five year old children.

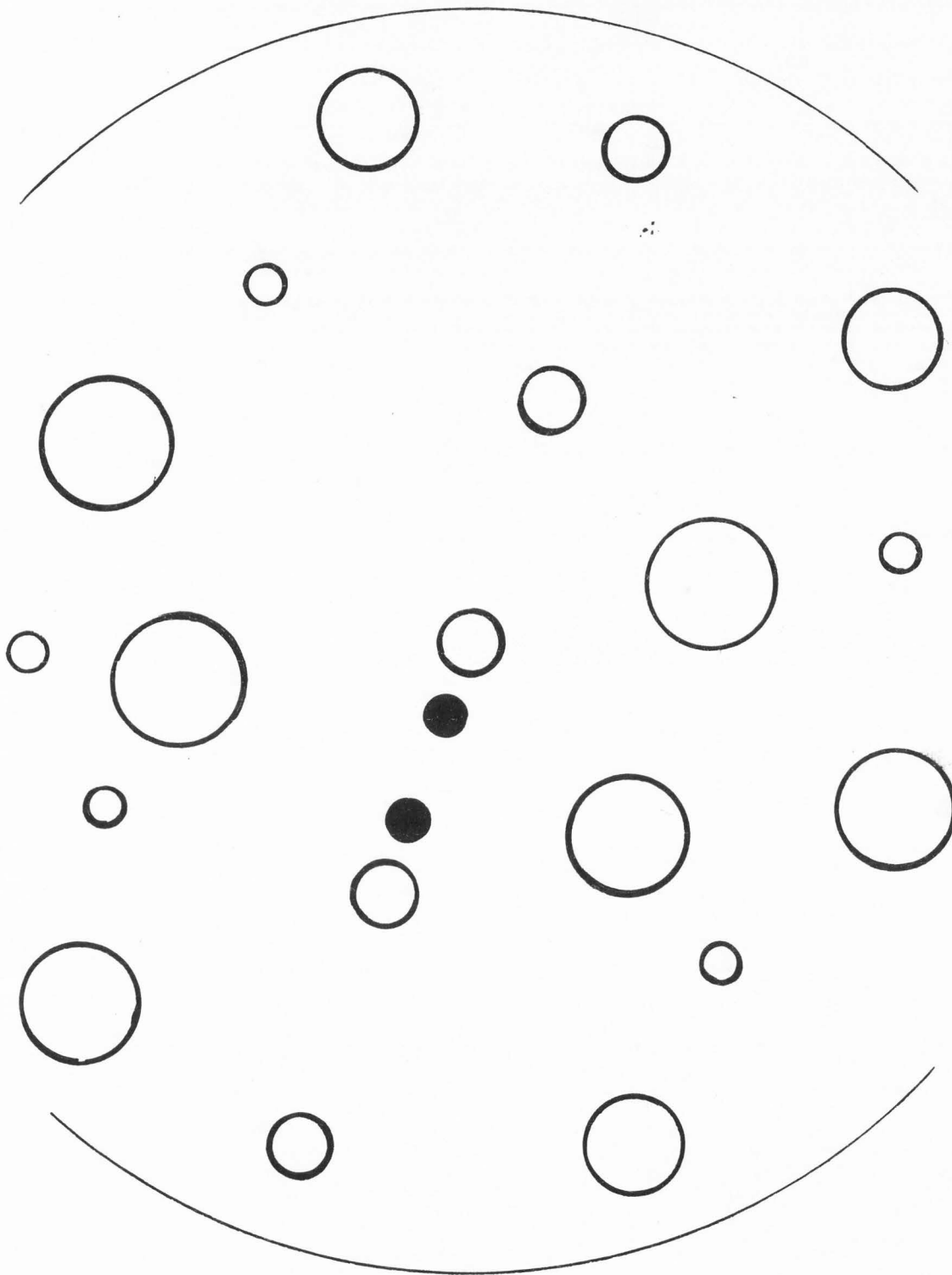


Figure 11. Actual size and arrangement of criterial and field elements as utilized on one disk of Design No. 4.

The test-retest method was used, with the interval extended to two weeks. Alternative modes of scoring particular sources of error would again be applied to ascertain the relative stability of these types of error.

The Sample

The sample was obtained from the Children's World Nursery and Kindergarten of Ogden, Utah. The four and five year old children registered at the nursery during the January, 1970, period of testing were used in the second study. Only one four year old, too retarded to grasp the necessary method, was excluded. There were twenty-six children in each age group with approximately equal numbers of males and females. Average age of the two groups was 54.3 months and 65.4 months.

Again, the sample was not representative, although the nursery in question draws children from a broad area and is not a neighborhood establishment.

Findings

Table 11 on page 81, showing means and standard deviations for the two methods of scoring, provided an indication of the relative performance of the two age groups. The figures on overall performance show decrements in all sources of error between the two testing sessions, although in each instance accompanied by an increment in deviation. This apparent factor of learning was most marked in the decrease in transpositions for age five.

The rate of occurrence of transposition for each of the four designs with the group at age four was 26, 29, 49, and 76, respectively.

The five year old group manifest only 13, 9, 16, and 64 transpositions for each of the disks.

Table 11. Mean and standard deviation of rotation error for each disk on test-retest with two methods of scoring at ages four and five.

	<u>Transpositions Not Scored</u>				<u>Transpositions Scores</u>			
	<u>Initial</u>		<u>Retest</u>		<u>Initial</u>		<u>Retest</u>	
	X	s	X	s	X	s	X	s
Disk 1								
Age 4	11.7	4.9	12.4	6.3	17.8	9.1	18.5	9.6
Age 5	11.8	3.8	10.4	5.7	15.2	8.8	12.3	9.5
Disk 2								
Age 4	11.9	4.7	12.5	5.7	17.9	10.2	17.4	9.6
Age 5	10.8	4.5	9.8	4.3	13.8	9.8	12.7	8.8
Disk 3								
Age 4	22.7	5.1	19.4	6.7	30.1	10.2	26.5	11.2
Age 5	18.5	6.1	18.2	6.0	21.4	8.9	21.0	9.0
Disk 4								
Age 4	15.5	6.4	15.1	6.4	32.0	11.0	29.8	11.1
Age 5	11.7	4.2	13.1	5.6	28.6	11.7	23.5	10.4
Overall								
Age 4	15.4	3.5	14.5	4.9	23.5	7.8	23.1	8.5
Age 5	13.2	3.3	12.8	4.3	19.8	7.5	17.4	7.9

Table 12 provides an indication of the relative contributions of each design to the overall reliability. Again as in the first study the scoring of transpositional error substantially improved the measured stability of individual performance. Scoring all sources of rotational error produced an overall reliability of .82 at age four and .93 at age five.

As all sources of error were combined in the scoring, the correlation of rotational error with months of age was $-.31$ for age four and $-.46$

with age five. Combining the two age groups produced an overall reliability of .89 over the two week interval and a correlation of $-.46$ with months of age.

Table 12. Reliability coefficients for each disk at ages four and five for two methods of scoring.

	Disk 1	Disk 2	Disk 3	Disk 4	Overall
Age 4 (N = 26)					
Transpositions Scored	.78	.55	.78	.71	.82
Transpositions Not Scored	.80	.47	.19	.36	.69
Age 5 (N = 26)					
Transpositions Scored	.85	.84	.53	.68	.93
Transpositions Not Scored	.59	.60	.20	.34	.77

Discussion

The findings on reliability are sufficiently impressive to reject the null hypothesis and to sustain further application of the PRA technique in basic research on perceptual characteristics. Whether the traits which can be assessed by the method bear any relationship to school learning in the primary grades would have to be determined by follow-up studies. Further work is also necessary in arriving at optimal combinations of designs, angular positions, number of settings, etc.

The second study, using designs more difficult to orient, left some doubt as to whether new factors were being assessed and whether reliability was diminished by reducing the ease of orientation. The data from Table 12 suggests that with disks three and four the higher level of difficulty tended to produce more inconsistency in rotational error which

derived from non-transpositional sources.

Observations of subject behavior also indicated that factors other than tendencies to mirror or reverse images were involved in certain of the extreme degrees of error. Occasionally a child could not detect the criterion row of circles on the fourth design or unsuccessfully struggled to match the discrepant field elements. Some subjects were obviously lost and inclined to accept any disk position. The standard method of scoring required that all shifts of image to opposite or adjacent quadrants be classified as gross errors of transposition. Though many of these errors were not true transpositions, they apparently contributed to the reliability of the scoring method.

No reliable data were obtained relative to the effects of direction of rotation on the occurrence of rotational error. Some subjects playfully turned their disk before attempting a match. Others studiously tried alternative locations for the difficult designs. Most subjects appeared able to rotate their disk with equal ease in either a CW or CCW direction in making a match, though frequently the direction of rotation traversed the longer route to the true match.

SUMMARY AND CONCLUSIONS

The perceptual rotation of visual stimuli has long been observed as a feature of special learning defects in the primary grades. The measurement of the direction and degree of this phenomenon is finding increasing application in psychological diagnostics. However, the basis of rotational tendency remains largely unknown, its manifestations with differing instruments has been difficult to correlate, and the establishment of lawful relationships between rotation and various developmental and behavioral anomalies has needed refinement. This dissertation describes the initial applications of a technique which might add to our knowledge of rotational phenomena.

Instruments and Tested Samples

The major instrument utilized has been designated the Perceptual Rotation Apparatus (PRA). It consisted of two concentric turntables mounted diametrically on a round table. The two turntables, the examiner's mounted vertically and the subject's horizontally, were fashioned to receive round disks bearing alternative designs. A circumference scale was graduated into 360 degrees to allow a direct reading of the discrepancies in the setting of the two disks as the subject was directed to match the exact rotational position of the examiner's disk.

Subjects were drawn from Children's World Nursery and Kindergarten of Ogden, Utah, and Edith Bowen Laboratory School at Logan, Utah. Sample sizes ranged from 22 to 44 over the age range of four to eleven. Each child was requested to match six compass positions for each of three

disk designs. The exercise was repeated one week later to provide reliability comparisons for ages four, six, and eight. The seven year olds were also administered the Quick Test and the Minnesota Percepto-Diagnostic Test. Results on these tests were also compared with performance on the Metropolitan Achievement Test.

A replicative study, made approximately 16 months after the initial study, involved a new sample of four and five year old children registered at Children's World Nursery and Kindergarten.

Hypotheses and Findings

Methodology was directed toward evaluation of the PRA as a research instrument as well as to provide data about perceptual rotation. A series of research hypotheses, directionally formulated, provided questions to be weighed statistically, using two-tailed tests of possible nullification of these hypotheses. The research directives and pertinent findings, as listed below, offered a basis for expansion of knowledge of rotational phenomena.

Hypothesis No. 1

The judgment or perception of rotation will be affected by the nature of the visual stimuli used with the PRA.

This hypothesis was not sustained by the measurements. The three designs employed were representative of familiar objects, lines, and unfamiliar figures, and were easily conceptualized by subjects of all age groups to offer a clear impression of orientation. Positive interitem correlations indicated that the performance on all three designs was additive, providing a more reliable series of measurements for deducing age trends.

A second study, utilizing complex designs in which the directional components could not be readily intuited on a perceptual basis, produced substantial differences in performance between designs.

Hypothesis No. 2

Rotational error as measured by the PRA has developmental characteristics related to age.

The errors registered by the PRA were classified as either transpositional or non-transpositional errors. Transpositional error involved the mirroring or the reversal of an image into adjacent or opposite quadrants. Non-transpositional error involved shifts of orientation within the same quadrant and included those errors sufficiently small as to be regarded as threshold errors of discrimination. Inasmuch as transpositional error largely disappeared by age six, only non-transpositional errors were used in describing age trends.

It was found that the mean rotation error declined rapidly between ages four and five and from five to six, with age differentials significant at the .01 level. Reduction in error was accompanied by coincident declines in variance for these same years, with ratios significant at the .05 level.

Between ages six and nine, mean rotational error leveled off, though variance continued to decline. A further significant drop in mean error at the .05 level occurred between nine and ten, accompanied by substantial though not statistically significant increase in deviation.

Unquantified subject behavior showed a marked change with age in the reflectivity-impulsivity dimension, as well as in the degree of motivation or the observed anxiety about accuracy. The progression from intuitive, unverified judgments toward a concern over correctness appeared

to be correlated with a declining deviation in performance for successive ages.

Hypothesis No. 3

The PRA measurements of the rotation of visual stimuli are reliable.

The assumption of reliability of performance over time was not sustained for ages four, six, and eight. However, major sources of error at age four were found to be additive as non-transpositional error was found to correlate .57 with the occurrence of transpositions. Combining both categories of error by scoring transpositions as limited to 50 degrees of error raised the test-retest reliability at age four from .52 to .96. Transpositions largely disappeared by age six and a combined scoring would not have affected reliabilities at ages six and eight.

Hypothesis No. 4

The PRA judgments of the rotation of visual stimuli are related to intelligence as measured by a standardized device, the Quick Test.

Experimental data disclosed a product-moment correlation between PRA and Quick Test of $-.21$. Since the shared variance of the two measures was less than 5 percent, the null hypothesis of no relationship was sustained. Similarly, correlation between PRA and Metropolitan Achievement Test was negligible.

Hypothesis No. 5

The measurement provided by the PRA is related to the rotational factor assessed by a standardized diagnostic instrument, the Minnesota Percepto-Diagnostic Test (MPD).

This hypothesis was nullified by the discovery of a negligible correlation of $.15$ between PRA total and MPD at age seven. Most of this

minimal correlation was attributable to the common variable of intelligence. The reliability of the finding of no relationship was supported by the fact that the current age sample was comparable in IQ and standard deviation with the MPD standardization group.

Replicative Study

A second study was conducted to verify whether the PRA technique could measure traits reliably at age four and to ascertain whether significant reliabilities might also extend through age five. The sample of four and five year olds from Children's World Nursery and Kindergarten were administered a series of four designs at each of six compass positions.

By scoring all sources of error, though setting an upper limit at 50 degrees, test-retest reliability over a period of two weeks was .82 for age four and .93 for age five. When the two age periods were combined the reliability was .89, although the correlation of test scores with months of age for the initial administration was only -.46.

Conclusions

Rotational error in matching the orientation of visual designs occurs on a perceptual-intuitive level of operations.

The perceptual-intuitive rotation of visual stimuli in the present matching task tended to occur irrespective of the nature of the designs, occurring more extensively or frequently in some individuals as determined by intrinsic factors in the perceptual system.

The presently used technique for assessing rotational error is capable of reliably measuring personal traits or characteristics at ages four and five.

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