A STUDY OF RELATIONSHIPS BETWEEN SELECTED TESTS OF SPATIAL ORIENTATION ABILITY

A thesis submitted in partial satisfaction of the requirements for the degree of Master of Arts in

Physical Education

by

Michael F. Allmandinger

July, 1970
The thesis of Michael F. Allmandinger is approved:

---

Committee Chairman

San Fernando Valley State College

July, 1970
# TABLE OF CONTENTS

<table>
<thead>
<tr>
<th>LIST OF TABLES</th>
<th>v</th>
</tr>
</thead>
<tbody>
<tr>
<td>ABSTRACT</td>
<td>vi</td>
</tr>
</tbody>
</table>

## Chapter

I. INTRODUCTION .......................... 1
   The Problem .......................... 2
   Statement of the Problem .......... 3
   Statement of the Purpose ......... 3
   Scope and Limitations .............. 3
   Assumptions .......................... 4
   Hypothesis ........................... 4
   Definitions of Terms ............... 4
   Importance of the Study .......... 5
   Preview of the Remainder of the Study ............... 5

II. REVIEW OF RELATED LITERATURE ...... 6
   Spatial Orientation ............... 6
   Spatial Disorientation ............ 8
   Spatial Orientation in the Weightless Condition .... 10
   Spatial Orientation on Earth .... 10
   The Effect of Training on Spatial Orientation .... 11
   The Nature of Spatial Ability .... 13
   Summary ............................ 15
<table>
<thead>
<tr>
<th>Chapter</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>III. METHODS AND PROCEDURES</td>
<td>16</td>
</tr>
<tr>
<td>Selection and Orientation of Subjects</td>
<td>16</td>
</tr>
<tr>
<td>Standardized Tests</td>
<td>17</td>
</tr>
<tr>
<td>The Guilford-Zimmerman Aptitude Survey - Part V</td>
<td>17</td>
</tr>
<tr>
<td>The Guilford-Zimmerman Aptitude Survey - Part VI</td>
<td>18</td>
</tr>
<tr>
<td>Experimental Tests</td>
<td>19</td>
</tr>
<tr>
<td>The Cube Test of Spatial Ability</td>
<td>19</td>
</tr>
<tr>
<td>The Tumbling-Target Test</td>
<td>20</td>
</tr>
<tr>
<td>The Design of the Study</td>
<td>21</td>
</tr>
<tr>
<td>Instrumentation for the Tumbling-Target Test</td>
<td>22</td>
</tr>
<tr>
<td>Statistical Design</td>
<td>22</td>
</tr>
<tr>
<td>Summary</td>
<td>23</td>
</tr>
<tr>
<td>IV. ANALYSIS AND DISCUSSION OF DATA</td>
<td>24</td>
</tr>
<tr>
<td>Analysis of the Data</td>
<td>26</td>
</tr>
<tr>
<td>Discussion of the Data</td>
<td>26</td>
</tr>
<tr>
<td>V. SUMMARY, CONCLUSIONS AND RECOMMENDATIONS</td>
<td>30</td>
</tr>
<tr>
<td>Summary</td>
<td>30</td>
</tr>
<tr>
<td>Conclusions</td>
<td>31</td>
</tr>
<tr>
<td>Recommendations</td>
<td>32</td>
</tr>
<tr>
<td>BIBLIOGRAPHY</td>
<td>34</td>
</tr>
<tr>
<td>APPENDIX A</td>
<td>38</td>
</tr>
<tr>
<td>APPENDIX B</td>
<td>46</td>
</tr>
<tr>
<td>APPENDIX C</td>
<td>48</td>
</tr>
</tbody>
</table>
## LIST OF TABLES

<table>
<thead>
<tr>
<th>Table</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Correlation Matrix</td>
<td>25</td>
</tr>
</tbody>
</table>
ABSTRACT

A STUDY OF RELATIONSHIPS BETWEEN SELECTED TESTS
OF SPATIAL ORIENTATION ABILITY

by

Michael F. Allmandinger

Master of Arts in Physical Education

July, 1970

The purpose of this study was to investigate the relationships between selected tests of spatial orientation ability. Two tests which have been used as predictors of spatial ability plus two newly devised tests designed to predict that ability were given to 202 junior high school boys ages eleven through fifteen. Three of these tests were of the paper-and-pencil type while one was a physical performance test.

The two standardized tests of spatial ability were the Guilford-Zimmerman Aptitude Survey - Part V and Part VI. Part V, titled Spatial Orientation, is weighted toward measuring spatial-relations factors. Part VI, titled Spatial Visualization, is weighted toward
measuring visualization factors. Both of these tests are paper-and-pencil tests.

The Cube Test of Spatial Ability used was devised by Vincent (29) and was designed to measure spatial orientation in an imaginary environment. This is also a paper-and-pencil test.

The Tumbling-Target Test was a performance test devised by the investigator. This test was designed to measure the subject's ability to remain spatially oriented during a disorienting type activity. This test required that the subject use his spatial orientation senses.

Each subject was given a score on each test and this data was programmed to produce a correlation matrix using the Pearson Product-Moment method of correlation. Each test was correlated with each other test.

The paper-and-pencil tests correlated with each other at the one percent level of confidence, but the tumbling test did not correlate significantly with any of the other tests.
CHAPTER I

INTRODUCTION

In gymnastics, as in all other sports, there seems to be a combination of factors which determine success. A successful gymnast must be strong, flexible, agile, and have a desire to succeed. But if that is all a gymnast has he will not be an outstanding gymnast. The gymnast needs yet another ability in order to be outstanding and that is the ability to know where his body is in relation to the things about him in space. Without this ability the gymnast would not be able to execute the complicated movements necessary to become outstanding.

In a study undertaken to devise tests for predicting potential gymnastic ability, Wettstone (30) stated that the kinesthetic sense, or the muscular sense, ranks high among traits needed to be a good gymnast. The kinesthetic sense is but one of the three senses used in human spatial orientation (22:229). The other senses relied upon, vision and the vestibular sense, also play major roles in the human's ability to orient himself in space.

Physical education as a field of study is surprisingly void of literature in the area of spatial orientation. Studies performed in the area of kinesthesia seem to try to isolate that sense from its natural complex functioning with the other spatial orientation senses. As reported in the literature (1,2,12,19), kinesthesia is but one
sense the human uses when spatially orienting himself. The study of spatial orientation then should not be limited to limb positions in relation to the body.

The field of psychology has created the most widely used tests of the spatial orientation ability. Guilford and Zimmerman have been pioneers in designing tests which measure spatial orientation factors. Their tests have all been paper-and-pencil type tests. They have been used by the U.S. Air Force as measures of spatial orientation ability (13).

There seems to be a need for further research in the area of human spatial orientation ability and its importance in physical education. With the opening up of space travel much important information concerning spatial orientation ability has been amassed. This information is of importance to any area of study in which the body can become disoriented. It has been hypothesized that spatial orientation abilities can be improved through participation in activities which require that ability (14:274, 15:160). Yet it has not been undertaken to devise physical performance tests which measure spatial orientation ability and which are relevant to physical education. Physical educators should be interested in human spatial orientation and methods to determine individual ability in this area.

THE PROBLEM

Statement of the Problem

A need exists for a test which will measure the ability an individual has to orient himself in space.
Statement of the Purpose

The purpose of this study is to investigate the relationships between selected tests of spatial orientation ability. These tests will be of a type that could be used by physical educators as an efficient method of determining this ability.

Scope and Limitations

This investigation was concerned with devising a battery of tests which would measure an individual's ability to orient himself in space. The tests used were geared toward specific spatial orientation involved in gymnastics.

The limitations of this study were: 1) The subjects in this study were junior high school boys enrolled in the investigator's physical education classes at Placerita Junior High School in Newhall, California; 2) The number of tests which were administered were limited by the time allotted to the author by the administration of Placerita Junior High School; 3) A limited amount of class time which could be devoted to the testing situation; 4) The testing of subjects on different days.

Assumptions

To conduct this study it was necessary to make the following assumption. It was assumed that the Cube Test of Spatial Ability and The Tumbling-Target Test (see chapter 3) are valid tests of spatial orientation. This assumption is based on the concept of "face validity".
Hypothesis

This investigation was designed to test the following null hypothesis: it is predicted that there is no significant relationship between any of the tests given.

Definition of Terms

In order to facilitate common understanding, the following definitions were established for this study.

**Spatial Orientation**  Spatial orientation is a complex function of the mechanoreceptors of the skin and muscles, of vision, and of the otic labyrinth by which the individual is able to remain constantly aware of his position in space. (22:229) "It involves knowledge of the body and its position as well as the positions of other people and objects in relation to one's body in space." (21:64)

**Kinesthesis**  "Kinesthesis is best understood as a behavioral term. It includes the discrimination of the position of body parts, the discrimination of movement and amplitude of movement of body parts, both passively and actively produced. Visual and auditory information is assumed to be absent." (16:71) In this study Kinesthesis is considered to be only one aspect of the more broad concept of spatial orientation.

**Spatial Disorientation**  Spatial disorientation is a psychophysiological condition in which persons perceive sensations which are false or at variance with reality in terms of time, position, location, motion or acceleration (14:261).
Otic Labyrinth  The otic labyrinth is sometimes referred to as that part of the inner ear known as the semicircular canals. The vestibular apparatus is another common term used when referring to this area in terms of its function in spatial orientation. This organ detects acceleration or deceleration of the head around any of the three axes.

Importance of the Study

It is known that various activities in physical education require a greater ability to orient oneself in space than do others. Gymnastics is one physical activity which requires that the participant know where his body is and what relation it has to the ground or piece of apparatus on which he is working. A spatial orientation test geared toward gymnastic movements may prove to be a help to physical educators in predicting potential gymnastic ability.

Preview of the Remainder of the Study

Chapter II will contain a review of the literature concerning spatial orientation and its relationship to physical activity. In Chapter III the methods, techniques and procedures used in the investigation will be described. The data and the findings will be presented and discussed in Chapter IV. The summary of the study, major findings, the conclusions and recommendations for further study will be included in Chapter V.
CHAPTER II

REVIEW OF RELATED LITERATURE

The purpose of this study was to investigate the relationships between selected tests of spatial orientation ability. The study was concerned with the review of the literature in the field of physical education relating to spatial ability and gymnastic ability, in the field of psychology concerning spatial perception and orientation, and in the aerospace medicine field concerned with actual spatial disorientation and the reasons for such a state.

The review of the related literature attempts to organize the information from the above three fields into a comprehensive look at human spatial orientation as the author intends to study it.

Spatial Orientation

In order to understand the complicated area of spatial orientation one must first define the term. The California State Department of Education stated that:

Spatial orientation involves the ability to select a reference point to stabilize functions and to organize objects into correct perspective. It involves knowledge of the body and its position, as well as the positions of other people and objects in relation to one's body in space. A person's knowledge of body image, laterality, and directionality provides the reference points to which he can relate, and through this knowledge he perceives his environment. (21:64)
Aerospace medicine has been greatly concerned with spatial orientation since the advent of manned space flight. Slager (23:299) wrote: "Spatial orientation is a complex function of the mechanoreceptors of the skin and muscles, of vision, and of the otic labyrinth." Thus Slager says that spatial orientation is maintained by a combination of kinesthesia, vision and the vestibular sense. This is supported by many other authors (1,2,12,19).

It is generally understood that sight plays an important part in any normal individual's adaptation to his environment. Sight is relied upon more than any other sense when moving about on the ground. It has been shown that man is incapable of maintaining aerial equilibrium and orientation without the aid of vision (2:226). Armstrong (2) pointed out that the lack of a visual point of reference when the human body is rotated brings about false messages sent to the brain by the vestibular apparatus. Sight seems to be an absolute necessity when flying and a near necessity when on the ground in order to maintain one's orientation to space.

The vestibular apparatus or the otic labyrinth is that portion of the inner ear which serves as a gyro for the human being. The vestibular apparatus actually has two functions in relation to spatial orientation. The first is concerned with sensing of the position of the head in space and the second is concerned with the sensing of any change in rate of motion (14:269). The vestibular apparatus is sensitive to motion in all three dimensions.

Kinesthesia is the third sense involved in spatial orientation. Kinesthesia has been called the muscular sense or the sense of
muscular effort (31:227). Rasch and Burke (22:108) described kinesthesia as: "... the perception or consciousness of muscular movement and the position of one's body parts in space." Kinesthesia depends upon proprioceptors in the muscles, tendons, and joints of the body to send information to the central nervous system concerning the position and movement of the limbs (22:108).

Thus spatial orientation is an integrated functioning of three complex sense receptor mechanisms in the body. All three sense areas play a part in total body orientation in space. When all are functioning correctly the human knows the position of his body in relation to his environment.

**Spatial Disorientation**

"Disorientation implies false perceptions, incorrectly sensed cues, and inappropriate responses to stimuli." (14) Slager (23:229) reported that spatial disorientation occurs when two of the three senses used are lost. In the weightless condition the vestibular sense is partially lost, and the kinesthetic sense is greatly affected, thus disorientation occurs. Hardy reported that "... unusual body and head movements which are not normally encountered in locomotion may provide misinformation, illusions and disturbing effects." (14:271)

Johnson and Taylor (17:24) classify spatial disorientation in two categories. The first category is called static disorientation. This includes disorientation in location, being lost, and in attitude, being unable to distinguish the vertical. The second
category is called dynamic spatial disorientation. The important factor in dynamic spatial disorientation is motion. There are two types of motion disorientation; linear or movement along a line, and angular or movement which includes rotation. Johnson and Taylor (17:29) stated that the most effective means of producing dynamic spatial disorientation is by "... exposing the head to angular acceleration that stimulates more than one of the semicircular canals simultaneously."

Spatial disorientation is a common occurrence in flying (12). The most common cause of disorientation in flying is the loss of visual orientation cues. It is during this time that it becomes common for a pilot to fail to maintain the proper attitude of his aircraft due to false stimuli from the vestibular sense. It has also been reported by Souder (25:4313) that: "The elimination of light source resulted in an overall disorientation of performance." Mann, Berthelot-Berry and Davterive (19:538) stated that: "The intact organism will use any and all cues which are appropriate to the situation..." to avoid spatial disorientation. They go on to say that in daylight the visual cues will predominate, but that in reduced visibility situations the proprioceptive cues will become most important. It was reported by Fairbanks (9:20-1) that springboard divers depend heavily upon vision to spatially orient themselves. Armstrong (2:227) wrote that spatial disorientation will come about whenever the human being is rotated and no visual point of reference is supplied. Jackson as cited by Worchel (31:4-10) stated that vision is more important than is the vestibular apparatus in maintaining
orientation and equilibrium. These studies all seem to indicate that vision is the most important factor in avoiding spatial disorientation.

**Spatial Orientation in the Weightless Condition**

The weightless condition experienced in outer space has presented somewhat of a problem to astronauts in their spatial orientation. When the gravitational pull on the vestibular apparatus is removed, spatial orientation is severely affected. The fluid in the inner ear which stimulates receptors under normal gravity conditions no longer works in the weightless state. The astronaut has no awareness of his body's position in relation to the capsule by means of the vestibular apparatus (15:82).

The loss of the gravitational pull will also affect the kinesthetic sense. The body musculature no longer works under the constant pull of gravity. Under these conditions the only stimuli coming from the muscles are those of the muscles stretching and contracting. While the loss of gravity has no effect on eyesight, the only way the astronauts can obtain information on the attitude of the capsule is by looking out of the window and at the instrument panel (15:82).

**Spatial Orientation on the Earth**

On the earth, the factor of gravity always plays a part. The vestibular apparatus uses the pull of gravity to aid in perceiving the direction of the vertical. "On earth, the vertical and the direction of weight usually coincide." (23:229). The kinesthetic sense is also aided by the gravitational force as an always present
source of position information (16:72). The eyes play their part on earth as in outer space.

The Effect of Training on Spatial Orientation

Numerous studies have shown that some type of training, practice or knowledge of results aids the subject in his spatial orientation (5,6,7,8,14,15,18). Bramer (5:363) reported that kinesthetic factors were developed in experienced pilots and the pilots were able to use kinesthetic awareness to fly better than pilots with less experience. Cratty (6) stated that practice of kinesthetically monitored movements brought about improved performance on tasks requiring use of the kinesthetic mechanism. According to Jokl (18) flight training enables a pilot to become acquainted with his sensations and that these sensations become less marked with experience, thus the pilots are less easily confused. He continued:

... the test pilot becomes immunized to rapid change in motion. Dizziness and vertigo disappear, and he is able to interpret his sensations so that he shows little reaction to rotation or other rapid changes in position. The whirling dancer, for instance, is able to stop suddenly without falling, whereas the novice will fall. (18:147)

Dodge (8:2) has shown that humans can adapt to rotation. He notes that dancers and other people who get repeated stimulation of the vestibular apparatus adapt to this stimulation. Dockeray and Isaacs (7:125) found that pilots with experience, sailors, and balance acrobats were more sensitive to change in tilt than those with less experience in flying or balancing.
The research carried out in weightless conditions, both in the earth's atmosphere and in outer space, has indicated that practice or training aids in maintaining spatial orientation. Astronauts Cooper and Carpenter reported, according to Henry (15), that a light work load should be assigned on the first earth orbit so that the astronaut has the opportunity to practice motor movements and become familiar with his new situation. Hardy (14) reported that extensive prior training and knowledge of results allowed the astronauts to orient their arms, legs and fingers while in weightless flight. He stated that the kinesthetic sense could be trained (14:274).

Wettstone (29) found that kinesthetic ability ranks high as a prerequisite for a good gymnast. Fairbanks (9) stated that the ability to pick out visual cues while rotating is of very great importance to springboard divers. Neither author made reference to the importance of the vestibular apparatus to the gymnast or diver in his attempt to remain spatially oriented. Jokl (18) stated that participation in gymnastics in general and tumbling specifically, "... renders people less sensitive to rotation in space." He does not say, however, that this participation enhances the kinesthetic sense or the sense of vision. He does say: "Their internal ears have become conditioned to experience rotation, and their brains interpret more correctly the new kind of sensory messages from the internal ears." (18:160)

The above studies seem to substantiate the assumption that practice or training in activities that require the subject to be spatially oriented do in fact improve the spatial orientation ability of the subject. The question arises, however, are subjects actually
improving their general spatial ability, or are they just improving their ability to do that particular task? This seems to be an unanswered question in the literature on spatial ability and spatial orientation.

The Nature of Spatial Ability

The early 1950's marked the beginning of a concentrated effort on the part of researchers to attempt to identify human ability factors which were distinctly connected with spatial orientation ability. The field of psychology made the first attempts in this area. Some felt that humans obtain ideas of shapes and arrangement by feel and kinesthesis. Others felt that the sense of sight was the key (11:388).

In 1950 Thurston presented a paper in which he listed seven factors. Three of the factors were said to have to do with visual orientation in space . . . . . . S₃ (the third factor) was said to represent the ability to think about those spatial relations in which the body orientation of the observer is an essential part of the problem. (11:390-1)

Further investigations in this area brought out three factors called (1) space, (2) spatial orientation and (3) visualization (11:31).

Guilford and Zimmerman devised an aptitude survey of the paper-and-pencil type. Part V of this survey was designed to measure the person's "... ability to appreciate spatial relations of things with reference to the human body." (13:28) Part VI of the survey was designed to test the subject's ability to visualize movements of an
inanimate object. Two years after this aptitude test appeared, Guilford and Zimmerman carried out a study to find out the exact nature of the spatial-relations and visualization factors of their test.

Although the test of spatial orientation appears to be weighted in both spatial-relations and visualization factors, it does seem to represent best a measure of spatial relations or spatial orientation and to vindicate its inclusion with other test in the battery which were selected to bring out the spatial factor. (32:208)

Guilford and Zimmerman reported that the spatial-relations factor was found to be one of the two most important factors for learning how to fly an airplane (13:28). They also stated that this ability is important in occupations such as aircraft pilot and athlete (13:31).

The United States Air Force has adopted a test of aerial orientation which is similar in concept to the Guilford-Zimmerman Aptitude Survey - Part V. This test is also a test of spatial ability and is used as a screening device by the Air Force.

It seems that the field of psychology has concluded that spatial ability can be determined by a paper-and-pencil type test. The author could find no study in which a paper-and-pencil test was correlated to a gross body movement test of spatial ability. However, the paper-and-pencil tests do seem to have a positive relationship with success in flying (13:28-31).
Summary

Spatial orientation has been shown to be a complex function involving vision, the kinesthetic sense and the vestibular sense. Spatial disorientation can come about when the use of two of the senses are lost or when one of these sense areas sends false cues to the central nervous system. There have been many cases of disorientation by misinterpretation of cues reported in the aerospace medicine literature (12,15,18). People who are reportedly put into situations where they use their spatial orientation senses become better at spatially orientating themselves. There are paper-and-pencil tests which have proven valid in predicting spatial ability but these have not been statistically correlated to any gross motor tasks. Chapter III deals with the methods and procedures that were used by the investigator to study the relationships between selected test of spatial orientation ability.
CHAPTER III

METHODS AND PROCEDURES

This chapter deals with the methods and procedures which were used to conduct this study. The study attempted to investigate the relationships between selected tests of spatial orientation ability. The study was designed to determine what intercorrelations exist between two standardized tests (Guilford-Zimmerman Aptitude Survey, Parts V and VI), and two separate newly devised tests of spatial ability. The Guilford-Zimmerman Aptitude Survey and one experimental test are paper-and-pencil type tests. The remaining experimental test is a gross body movement type test. One significant aspect of this study was to determine the degree of relationship between a motor test of spatial ability and paper-and-pencil tests of spatial ability.

Selection and Orientation of Subjects

The subjects used in this study were 202 seventh, eighth and ninth grade boys in the investigator's physical education classes at Placerita Junior High School. Each student attending school on the day which one of the tests was given took that test. Only data obtained on students who were present for all four tests were used in this study.

Each subject received a full briefing prior to each test in which he participated. The instructions to each of the paper-and-
pencil tests were read to the group while they themselves read them. The specific instructions for each test appear in Appendix A and C of this thesis. The subjects received a demonstration of the motor test of spatial ability and were instructed as to the best methods to use in executing these movements. Each subject was schooled in the movements he was required to perform on the Tumbling-Target Test as part of his regular physical education class.

**Standardized Tests**

**The Guilford-Zimmerman Aptitude Survey - Part V**

Part V of the Guilford-Zimmerman Aptitude Survey, hereinafter to be known as the boat test, is a paper-and-pencil type test which is designed to rank subjects on their respective spatial orientation ability. This test has been used as a tool to select subjects to execute tasks which require a great deal of spatial ability (13:32). This test has also been used by physical educators as a prediction of spatial ability (20). The spatial ability isolated in this test is one in which the individual must think about "... spatial relations in which the body orientation of the observer is an essential part of the problem." (11)

The test is comprised of test items which require that the subject be able to look at two pictures of the bow of a boat and be able to correctly designate the attitudinal change the boat has made between pictures. The horizon in the two pictures on each test item is different. The task is to decide which way the boat has moved in order for the horizon to take on the new look as represented in the
second picture.

The boat test was found to have a split-half reliability coefficient of .88 using the Spearman-Brown Formula (13). This test was shown to have a significant positive relationship with the tests of Thurston and others which were shown to test spatial-relations factors (33). The boat test has a .58 loading of the spatial-relations factor and is thus considered a valid test of spatial orientation (33).

The Guilford-Zimmerman Aptitude Survey - Part VI

This portion of the Guilford-Zimmerman Aptitude Survey, hereinafter to be known as the clock test, is a paper-and-pencil test of spatial visualization. This test has been used as a predictor of spatial ability (20).

In this test the subject is asked to imagine movements of a clock around three axes. A clock is shown in a starting position and the subject is given directions to visually move the clock. The movements can be in any one of the three axes or in a combination of all of the axes. The subject is to visualize the resultant position and choose the correct answer from a number of possible answers.

The clock test was found to have a split-half reliability coefficient of .91 using the Spearman-Brown Formula (13). This test was shown to have a significant positive relationship with the tests of Thurston and others which were shown to test the visualization factor of spatial ability (33). The clock test has a .52 loading of the visualization factor and is thus considered a valid test of spatial visualization (33).
Experimental Tests

The Cube Test of Spatial Ability

The Cube Test of Spatial Ability, hereinafter to be known as the Cube test, is a paper-and-pencil test devised by Vincent (29) which is designed to measure an individual’s spatial orientation ability. The test purportedly determines the subject's ability to mentally visualize his own body in various positions in space. The subject was required to think of himself enclosed in a cube with the numbers one to six placed on the sides of the cube so that he could read them from the inside (refer to Appendix A). A problem is presented in which the subject must visualize himself rotating about three axes of his body and be able to identify the position in which he would finish. The subject is given a starting position in reference to numbered sides of the cube and is then instructed to rotate a specific number of times about the axes of the body. The test then requires the subject to select the number which he visualizes will be on the wall in front of him when he has executed all movements on that particular test item. He is given six choices on each of twenty test items.

The cube test was shown to have a significant test-retest reliability. Using seventy subjects, a correlation coefficient of .71 was found between the first and the second attempts at taking this test. A period of six weeks separated the two testing dates. The validity of the box test has not been established. One sub-purpose of this study was to test for that validity.
The Tumbling-Target Test

The Tumbling-Target Test, hereinafter to be known as the tumbling test, is a test devised by the author to determine the individual's ability to keep spatially oriented while twisting and somersaulting about the body axes numerous times in a short period of time. The test consists of a number of elementary gymnastic tumbling movements followed by a target striking task. The twisting and somersaulting was designed to stimulate the vestibular apparatus as the subject moved about two axes of his body.

The tumbling test required the subjects to execute the following tumbling movements: (1) One forward roll; (2) Two log rolls (rotating about the length axis of the body); (3) One backward roll; (4) Two and three quarters twists to the left while in a standing position. Immediately following the final rotation of the final movement the subjects were required to touch, with either hand, a target mounted at shoulder height. The object was to touch the center of the target in order to get the maximum score. The subject was scored according to the deviation from the center of the target as well as the time it took him to do the various movements. (See Appendix B)

The test-retest reliability coefficient for the time and for the accuracy scores of the tumbling test were shown to be statistically significant. Trial two and trial three of each component were correlated using the Pearson Product-Moment Coefficient of Correlation. The accuracy portion of the test had a correlation coefficient of .42 while the time portion had a .99 correlation coefficient. Using data from 202 subjects, both tests were found to be significant at better
than the one per cent level of confidence. To test the validity of the tumbling test is a sub-purpose of this study.

The Design of the Study

This study was carried out in the spring semester of 1970. The paper-and-pencil tests were administered in the multipurpose room of Placerita Junior High School. The testing environment was quiet and comfortable. The written tests were given in the following order; (1) The boat test; (2) The clock test, and (3) The cube test. Due to the fact that Placerita Junior High School operates on a rotation schedule, it was not feasible to give the Tumbling-Target Test to all subjects in the same order. Three of the six class periods completed the paper-and-pencil tests before participating in the tumbling test, while the other three classes took the tumbling test first.

The tumbling test was administered in an anti-room to the main gymnasium. This room was sealed off to make a secluded testing area. The testing conditions were duplicated from day to day.

Each student received a score from each test which was kept on a data sheet. The scores on the boat and clock tests were recorded as the number of correct responses less one fourth of the incorrect responses. The cube test was scored as the number of correct responses. The score on the tumbling test was computed as follows. The accuracy score for the second and third trials were averaged. The time scores for the second and third trials were averaged. Z scores for the average accuracy and average time scores were computed and these Z scores were added together. By this means, the two components, time
and accuracy, were given equal weight in computing the subjects total or combined score.

Instrumentation for The Tumbling-Target Test

The subjects executed the tumbling movements on two five by ten foot regulation tumbling mats. The target used in this test was attached to the wall of the testing room at one end of the tumbling mats and to the left side of the two mats. The target was aligned at shoulder height for each subject. The target was drawn on a large piece of poster board and consisted of eight concentric circles. (Appendix B) The inner circle was one inch in diameter with each consecutive circle being one inch larger in radius than the previous one. The inner circle was given the value of one point. The value of the other circles was increased by one whole number for each circle away from the center. The apron of the target was valued at nine points.

Statistical Design

The raw scores for each of the paper-and-pencil tests were converted to Z scores. The combined Z score of time and accuracy was used as the tumbling test score. The Pearson Product-Moment Method of Correlation was used to determine the intercorrelations between the four tests.
Summary

The four tests were given to a total of 202 boys in the grades seven, eight and nine. The Pearson Product-Moment Method of Correlation was used to determine the relationship between the four tests.

In Chapter IV the data will be presented. An analysis and discussion of the data will be included in that chapter.
CHAPTER IV

ANALYSIS AND DISCUSSION OF DATA

Following the completion of all testing involved in this study, the raw data was presented to the San Fernando Valley State College Computer Center for processing. Data cards were processed for 202 students. Each subject had the following numerical scores on his card: (1) Age in months, (2) The boat test, (3) The clock test, (4) The cube test, (5) The tumbling test - time, (6) The tumbling test - accuracy. The computer was programmed to print out a seventh variable which was a combination of standard Z scores from the tumbling test - time and accuracy scores. Thus each subject had seven variables each of which was correlated with each other variable using the Pearson Product-Moment Method of Correlation.

Table I presents the correlation matrix produced by the computer. Each of the correlation coefficients involving variables five, six and seven cited above are shown to be negative due to the nature of the scoring of the tumbling test. The best performance in the tumbling test, both in time and accuracy, was the smallest number. The best score on the other three tests was the largest number.
TABLE 1

CORRELATION MATRIX

<table>
<thead>
<tr>
<th>Test Names</th>
<th>Age</th>
<th>Boat</th>
<th>Clock</th>
<th>Cube</th>
<th>Time</th>
<th>Acc.</th>
<th>Comb.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Age</td>
<td>1.000</td>
<td>.114</td>
<td>*181</td>
<td>.162</td>
<td>-.092</td>
<td>-.100</td>
<td>-.135</td>
</tr>
<tr>
<td>Boat</td>
<td>1.000</td>
<td></td>
<td>*621</td>
<td>*443</td>
<td>-.060</td>
<td>-.008</td>
<td>-.048</td>
</tr>
<tr>
<td>Clock</td>
<td></td>
<td>1.000</td>
<td></td>
<td>*618</td>
<td>-.039</td>
<td>-.051</td>
<td>-.007</td>
</tr>
<tr>
<td>Cube</td>
<td></td>
<td></td>
<td>1.000</td>
<td></td>
<td>-.055</td>
<td>.009</td>
<td>-.032</td>
</tr>
<tr>
<td>Time</td>
<td></td>
<td></td>
<td></td>
<td>1.000</td>
<td>.006</td>
<td></td>
<td>*709</td>
</tr>
<tr>
<td>Accuracy</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>1.000</td>
<td></td>
<td>*709</td>
</tr>
<tr>
<td>Combined</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>1.000</td>
</tr>
</tbody>
</table>

KEY

*Significant at one percent level of confidence

Example of table use - The clock test has a correlation coefficient of .621 with the boat test.
Analysis of the Data

There were three separate relationships found which greatly exceeded the one percent level of significance. The correlation coefficient between the boat test and the clock test was .621. A correlation coefficient of .443 was found between the boat test and the cube test. The clock test had a .618 correlation coefficient with the cube test. The significance of all these correlations far exceeded the one percent level of confidence (28:231).

There were two relationships with low coefficients, but which were still statistically significant. The age of the subjects had a correlation coefficient of .18 with the clock test and a .16 correlation coefficient was found between the cube test and the subjects' ages. This .18 correlation is significant at the one percent level of confidence while the .16 is significant at better than the five percent level of confidence.

All other relationships appear to be due to chance alone. The high relationships noted between the time, accuracy, and combined scores of the tumbling test were obviously due to the fact that time and accuracy were both components of the combined score.

Discussion of the Data

The high correlation coefficients found between the boat test, the clock test and the cube test indicate that the three tests are testing portions of the same factor. Both parts of the aptitude survey are measuring spatial-relations and visualization factors (33:208). The significant relationships found between these two tests and the
cube test seem to indicate that the cube test is testing both spatial-relations and visualization factors also. However, the data indicates that a different factor is being emphasized in each of the three tests. Guilford and Zimmerman (32) have shown that the boat test is most heavily loaded in spatial-relations measurement and that the clock test is loaded in visualization measurement. It seems that both of these factors in addition to some other factor are measured by the cube test. Both of the aptitude survey tests require that the subject visually manipulate an inanimate object. The box test requires the subject to mentally manipulate his own body. Perhaps this is the missing factor:

The cube test had a greater correlation coefficient, .618, with the clock test than with the boat test, .443. This indicates that the cube test is more highly loaded in visualization factors than in spatial-relations factors. The requirement of mentally twisting and turning the clock in the clock test is similar to mental twisting and somersaulting of one's own body required in the cube test. It is perhaps this similarity that brought about the rather high degree of relationship. The boat test requires the subject to picture himself sitting in a boat looking out at a changing horizon. The cube test also requires the subject to imagine how the scene inside the cube is changing as various movements of the body are being imagined. This feeling of actual body movement may be one of the common factors which results in the relationship between the cube test and the boat test. The fact that the boat test, the clock test and the cube test are all paper-and-pencil tests may be another important
factor in their relationship.

The cube test was designed to measure the subject's spatial ability or his ability to remain unconfused while moving about the three axes of the body within an imagined environment. The tumbling test was also designed to measure this ability in an actual movement situation. The cube test is a paper-and-pencil test attempting to measure a body movement ability while the tumbling test is an actual performance test. A very low coefficient of correlation was found between the cube test and all three components of the tumbling test. This indicates that the two tests are actually testing different abilities.

The tumbling test measured the individual's ability to roll and twist rapidly down a length of mat and then strike the center of a target. The purpose of the tumbling movements was to disorient the subject. The purpose of the target striking was to tell how spatially oriented the subject remained during the movement portion of the test. It would seem that this test would make the best measure of actual spatial orientation ability since it was the only test attempting to disorient the subject with actual body movement. This test did not have a significant coefficient of correlation with either of the established tests of spatial ability.

The insignificant relationships between the tumbling test and the three paper-and-pencil tests may indicate that paper-and-pencil tests are not adequate predictors of motor performance abilities. Or this lack of significant positive relationship may indicate that the tumbling test does not encompass spatial-relations or visualization
facts. It is the opinion of the author that the former conclusion is more plausible than the latter.
CHAPTER V

SUMMARY, CONCLUSIONS AND RECOMMENDATIONS

Summary

The purpose of this study was to investigate the relationships between selected tests of spatial orientation ability. Two standardized tests which have been used as predictors of spatial ability and two newly devised tests designed to predict that same ability were given to 202 junior high school boys ages eleven through fifteen. Three of these tests were of the paper-and-pencil type while one was a physical performance test.

The two known tests of spatial ability were the Guilford-Zimmerman Aptitude Survey - Part V (the boat test) and Part VI (the clock test). Part V, titled Spatial Orientation, is weighted toward measuring spatial-relations factors. Part VI, titled Spatial Visualization, is weighted toward measuring visualization factors. Both of these tests are paper-and-pencil type tests.

The Cube Test of Spatial Ability used was devised by Vincent (29) and was designed to measure spatial ability. This is also a paper-and-pencil type test.

The Tumbling-Target Test was a performance test devised by the investigator. This test was designed to measure the subject's ability to remain spatially oriented during a disorienting type activity. This test required that the subject use his spatial orientation senses.
Each subject was given a score on each test and this data was programmed to produce a correlation matrix using the Pearson-Product Moment method of correlation. Each test was correlated with each other test. The paper-and-pencil tests correlated with each other at the one percent level of confidence, but the tumbling test did not correlate significantly with any of the other tests.

Conclusions

Within the scope and limitations of this study the following conclusions were drawn:

1. The Cube Test of Spatial Ability was found to be a valid test of spatial ability when compared to the boat and the clock test.

2. The Cube Test of Spatial Ability was found to test a factor or factors not found in the boat or the clock test. The nature of these factors could not definitely be determined with the evidence obtained in this study, but it appeared that the use of one's own body in the cube test may account for some of the variance.

3. Imagining one's own body in space may differ conceptually from imagining an inanimate object in space.

4. The spatial factors tested by paper-and-pencil tests may be different from the factors tested by a physical performance test.

5. The null hypothesis that stated there would be no significant relationship existing between any two of the four tests was rejected for the boat, clock and cube tests but accepted for the tumbling test. A significant positive relationship does exist between the cube test and both the boat test and the clock test.
Recommendations

When comparing the four tests used in this study to performance of springboard diving and gymnastic skills, it appears reasonable to assume that the tumbling test is more similar and that the three paper-and-pencil tests are less similar to these specific skills. It is the opinion of the author that the paper-and-pencil tests will not predict actual gymnastics or diving abilities.

With this in mind and based upon the findings of this study the following suggestions are offered for further investigation:

1. A battery of physical performance tests of spatial ability should be devised as possible predictors of gymnastic ability.

2. A study to determine the degree of relationship between intelligence and spatial ability as identified by paper-and-pencil tests should be made.

3. A study to determine the degree of relationship between the ability to perform skills which require spatial ability, found in gymnastics and springboard diving, and performance in existing tests of spatial ability should be conducted.

4. A study to determine the generality and/or specificity of the improvement observed when a subject practices spatial orientation tasks should be made.
BIBLIOGRAPHY


APPENDIX A

THE CUBE TEST OF SPATIAL ABILITY
THE CUBE TEST OF SPATIAL ABILITY

Name ___________________ Period ___ Roll call number ___

Grade _____ Age in months _____
Directions To Students For Cube Test

This is a test of your ability to mentally picture your own body in various positions in space. This test is not connected with your grade in physical education in any way. Read the directions to yourself as they are read to you.

On the front sheet of this test is a picture of a hollow cube. Imagine that it is the size of a large room and that you are inside it, floating in mid air. On the inside of each wall is a number. You can only read the numbers correctly from the inside of the cube. On the floor of the cube is the number 1. On the ceiling is the number 2. On the wall in front of you is the number 3. Behind you is the number 4. To the left is the number 5. To the right is the number 6.

Definition of terms:

Somersault - To flip completely head over heels and return to the original position. This may be done forward, backward, or sideward to either the left or right.

Twist - To turn your body to the right or left as in RIGHT FACE or LEFT FACE in squad order. A full twist would be a complete turn with your body returning to its original position.

Imagine that you are weightless and can float in the middle of the cube. You can move your body so that you can twist left or right, somersault forward and backward, and somersault sideward to the left or right.
In this test you will be asked to picture yourself doing various somersaults and twists inside of this cube. The following is an example of the type of test item you will be asked to complete.

You will be given a starting position for each test item: You are facing 3, your head is toward 2 and your feet are toward 1 (you are in a standing position in the cube). Now you will be given a movement to complete, for example: Full somersault backward. You are now asked to decide which wall you now face: 1, 2, 3, 4, 5, or 6. You may look at the picture of the cube at any time.

In the above example the correct answer is wall number 3, because you would have made one complete somersault backward and returned to your starting position. Now try three more examples to see if you understand. The correct answer has been crossed out as you will do with the actual test items.

<table>
<thead>
<tr>
<th>Starting Position</th>
<th>Movement</th>
<th>Answer</th>
</tr>
</thead>
<tbody>
<tr>
<td>A. Facing 4, head toward 2, feet toward 1.</td>
<td>1/4 twist right</td>
<td>1 2 3 4 5 6</td>
</tr>
<tr>
<td>B. Facing 2, head toward 4, feet toward 3.</td>
<td>1/2 somersault right.</td>
<td>1 2 3 4 5 6</td>
</tr>
<tr>
<td>C. Facing 6, head toward 3, feet toward 4.</td>
<td>1/2 somersault forward.</td>
<td>1 2 3 4 5 6</td>
</tr>
</tbody>
</table>

If you do not agree with the answers given or if you do not understand, raise your hand.

Answer the following questions by crossing out the number which you think will be on the wall that you will see after completing the movement. In some questions there will be more than one movement to complete. Always do the movements in your mind in the order they are given in the question. Work quickly. If you do not know an
answer for sure, guess. You are not expected to finish this test.

STOP. DO NOT TURN THE PAGE UNTIL YOU ARE TOLD TO DO SO.
Test Sheet

Mark all of your answers on this test.

<table>
<thead>
<tr>
<th>Starting Position</th>
<th>Movement</th>
<th>Answer</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Facing 3, head toward 2, feet toward 1.</td>
<td>1/2 twist right.</td>
<td>1 2 3 4 5 6</td>
</tr>
<tr>
<td>2. Facing 5, head toward 2, feet toward 1.</td>
<td>1/4 somersault backward.</td>
<td>1 2 3 4 5 6</td>
</tr>
<tr>
<td>3. Facing 6, head toward 1, feet toward 2.</td>
<td>1/2 somersault forward.</td>
<td>1 2 3 4 5 6</td>
</tr>
<tr>
<td>4. Facing 1, head toward 3, feet toward 4.</td>
<td>1/4 twist left.</td>
<td>1 2 3 4 5 6</td>
</tr>
<tr>
<td>5. Facing 4, head toward 6, feet toward 5.</td>
<td>1 somersault sideways left.</td>
<td>1 2 3 4 5 6</td>
</tr>
<tr>
<td>6. Facing 6, head toward 4, feet toward 3.</td>
<td>1/2 twist left. 1/2 somersault sideways right.</td>
<td>1 2 3 4 5 6</td>
</tr>
<tr>
<td>7. Facing 3, head toward 2, feet toward 1.</td>
<td>1 somersault backwards. 1/2 twist right.</td>
<td>1 2 3 4 5 6</td>
</tr>
<tr>
<td>8. Facing 5, head toward 2, feet toward 1.</td>
<td>1/2 somersault backwards. 1/4 twist left.</td>
<td>1 2 3 4 5 6</td>
</tr>
<tr>
<td>9. Facing 2, head toward 6, feet toward 5.</td>
<td>1 somersault backwards. 3/4 twist right.</td>
<td>1 2 3 4 5 6</td>
</tr>
<tr>
<td>10. Facing 3, head toward 5, feet toward 6.</td>
<td>3/4 somersault backwards 1/2 twist right.</td>
<td>1 2 3 4 5 6</td>
</tr>
</tbody>
</table>
11. Facing 2, head toward 4, feet toward 3.
   1/4 somersault backwards.
   1/4 twist right.

12. Facing 6, head toward 2, feet toward 1.
   1/2 somersault forwards.
   3/4 twist right.

13. Facing 5, head toward 4, feet toward 3.
   1 and 1/2 somersault backwards, 1/2 twist right.

14. Facing 6, head toward 3, feet toward 4.
   3/4 twist right.
   1 somersault backwards.

15. Facing 3, head toward 2, feet toward 1.
   2 somersaults backwards.
   1 twist left.

16. Facing 2, head toward 5, feet toward 6.
   1 and 3/4 twists left, 1 and 1/2 somersaults backwards.

17. Facing 4, head toward 1, feet toward 2.
   1/2 somersault forward. 1/2 twist left. 1/2 somersault backward.

18. Facing 6, head toward 1, feet toward 2.
   1 and 3/4 twists right. 3/4 somersault forwards.
19. Facing 1, head toward 6, feet toward 5.
   1/2 twist left.
   1/2 somersault backwards, 3/4 twist right.

20. Facing 4, head toward 1, feet toward 2.
   1 and 1/4 somersaults forward, 2 and 1/4 twists right.
APPENDIX B

DIAGRAM OF THE TUMBLING-TARGET TEST AREA
1. Starting position of subjects.
2. Two five by ten foot tumbling mats.
3. Target mounted on the wall. (Actual target composed of eight concentric circles, and ranked from one to nine.)
4. Position of the instructor.
APPENDIX C

INSTRUCTIONS FOR THE TUMBLING-TARGET TEST
INSTRUCTIONS FOR THE TUMBLING-TARGET TEST

This is a test to see how fast you can do a series of tumbling movements and then hit this target as near the center as possible. The tumbling movements that you will have to do are: one forward roll, two log rolls, one backward roll and finally two and three quarters twists to the left. I will now demonstrate how these movements are to be performed. I will do them once slowly and then once as fast as I can.

Are there any questions concerning what the movements are that you are to perform? Do you understand the order in which they must be performed?

You will get three attempts at this test. You are to go as fast as you can on each attempt. You must strike the target immediately upon finishing your last twist. Try to hit the center of the target. If your finger is on a line you will receive the next lower score. Time is of the utmost importance, do not take your time in order to get a higher target score.

Are there any questions?