EXPLORING POSSIBLE RAMIFICATIONS OF HUMAN DIRECTIONAL DEFICIENCY IN COMPUTER SCIENCE

By

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IN COMPUTER SCIENCE

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PREFACE

Cognitive scientists, psychologists, and other researchers have endeavored over the past three decades to identify the cognitive functions underpinning human navigation and its possible correlations to other characteristics. The answer to the basic question of how/why some people are good at finding directions and some people are not, is yet to be determined conclusively. It has been reported that a certain percentage of people in the United States and Canada (as the target audience) suffer from what is variously referred to as directional deficiency, direction dyslexia, direction dysfunction, geographical dyslexia, human homing deficiency, or geographic insensitivity.

Part of the objective of this thesis work was to investigate the ramifications of this deficiency, to explore what this deficiency may correlate with (with a special focus on spatial cognitive skills, programming, and debugging), and to suggest ways of detecting this deficiency. The scope of the thesis work included both theoretical and empirical studies of human direction sensitivity and the cognitive tests that attempt to test hypotheses about individual differences in spatial/temporal attention spans as well as a set of program comprehension questionnaire-based tests about the debugging/testing of computer programs and program comprehension. This was done in the context of the relevant cognitive-based perceptual and spatial tests. The tests results obtained suggest that the programmers' directional detection skills might have some correlations with their program comprehension abilities.

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CHAPTER I

INTRODUCTION

Modern science tries to reveal the secrets of human understanding and knowledge, but still science has to go a long way to unravel even the seemingly narrow question of human direction detection skills. It has been reported that a certain percentage of the people in United States and Canada (as the target audience) are affected by directional deficiency also known as directional disability or geographical dyslexia. At first glance, considering the common beliefs and myths about the general sense of direction and the enquiries made by males and females about directions while driving to an unfamiliar location, the issue appears to be a simplistic one. However, upon further scrutiny, it becomes clear that this is a non-trivial and actually profound question with potentially significant ramifications.

Some people can find their way around easily and quickly, and navigate themselves without difficulty in new surroundings. Others cannot perform the navigational tasks as simply and easily. The question of why some people can find their way around easily while others struggle to accomplish the same task is a rather baffling and interesting research topic. For example, it is a mysterious phenomenon why/how some people can follow cardinal compass directions where visual cues such as the sun, the moon, the stars, landmarks, or of course maps are not available. This ability in humans is known as magneto reception or magnetic sensitivity [Baker 1980].

Scientists have discovered that birds, honeybees, and sea turtles have magnetic receptors and they use this receptivity for their orientation and navigation [Gould 1984]. A large amount of research work has already been carried out on bird navigation and orientation [Gould 1981]. Scientists have found that the Earth's magnetic field affects the orientation method of birds. However, it is as yet an unproven hypothesis that human beings can recognize and use the Earth's magnetic poles for their orientation by depending on the magnetite iron deposit in the ethmoid bone that is in the bone structure behind the upper part of the human nose [Coutsoukis 2008].

Individuals with iron deficiency in their ethmoid bone might lack or possess poor navigational skills because of their inability to conceptually relate to the main compass directions and/or to conceptually retain and maintain the main compass directions even when they are reminded of them or look them up. The afflicted people typically exhibit a weakness or lack of ability in telling and/or conceptually maintaining the general compass directions. Hence, they may have difficulty in understanding and processing spatial information or determining directions accurately.

This research work aims to investigate the ramifications of this deficiency, to explore what this deficiency may correlate with, and hopefully to suggest ways of possibly detecting this deficiency. It can be argued that the people afflicted with direction dyslexia would have difficulty with visualization and/or conceptualization. Consequently, it could be argued that if a person cannot visualize and retain directions well, she/he may not have an easy time of debugging and testing programs.

CHAPTER II

EARTH'S MAGNETIC EFFECT ON BIRDS, HONEY BEES, AND THE HUMAN NAVIGATION SYSTEM

This section briefly covers two topics related to Earth's magnetic effect on migratory birds, honey bees, and the human navigation system. The first subsection describes previous studies on magnetic receptivity in honey bees and migratory birds. In the second subsection, the previous experimental research work on the impact of Earth's magnetic reception in humans is described.

2.1 Earth's Magnetic Reception in Honey Bees and Migratory Birds

Some previous studies about magnetic reception in animals have shown that some birds, sea turtles, and honey bees use Earth's magnetic directions for their orientation [Gould 1984]. Although a variety of birds and sea turtles have magnetic receptivity, particularly honey bees have shown especially good magnetic receptivity for their homing orientation.

Sometimes honey bees, birds, and some other migratory species can orient themselves precisely even under overcast conditions, suggesting that most of the migratory species have some semblance of a magnetic compass [Gould 1984]. It could be argued that these species use their magnetic compass for their orientation whenever external cues such as the sun are absent.

2.2 Earth's Magnetic Reception in Humans is an Elusive Phenomenon

In the 1980s, a scientist from England proposed a hypothesis: a wide range of animals are able to orient themselves toward home when subjected to displacement release experiments [Baker 1980]. As far as humans are concerned, he further demonstrated that the goal-oriented approach is not always based on the mental maps that a person might have. Specifically, using bar magnets worn on the side of the head by the subjects, his experiments indicated the existence of a possible magnetic influence over the finding of directions by the subjects [Baker 1980].

Baker conducted an experiment with groups of between 5 and 11 university students. The subjects were blindfolded and driven by intricate routes to release points between 6 and 52 kilometers away. At each release point, the subjects were asked to state the compass directions while blindfolded. The results of this experiment showed that human beings have the ability to recognize directions when all external cues are absent [Baker 1980].

In view of the exciting nature of these results, researchers from Princeton University (James L. Gould) and the State University of New York (Kenneth P. Able) tried this experiment on eight different occasions. The results of their experiments neither supported nor refuted Baker's idea/conclusion of magnets' having an effect on the human homing orientation. They concluded that Baker's proposed hypothesis is neither simple nor robust [Gould 1981].

CHAPTER III

HYPOTHESES

In general, two types of navigation are possible: route based navigation and location based navigation [Westby and Partridge 1986]. Route based navigation always utilizes compass directions while location based navigation utilizes map directions. Typically, the majority of people follow the location based navigation system by reading maps, identifying familiar landmarks, and recalling familiar geographical structures. Some people follow the route based navigation system. Such individuals typically follow the compass directions and can easily identify the North part of the geomagnetic Earth. Route based navigation is a natural way of determining homing orientation. It could be argued that location based navigation is possible if a person has good backtracking skills and good visuo-spatial working memory, and route based navigation is possible if a person possesses the natural reception of Earth's magnetic field. The argument has been advanced that if a person is not able to follow the route based navigation system, it may be due to a shortage of iron in the ethmoid bone behind the upper part of the human nose. As a result, the lack or absence of iron particles in the ethmoid bone might lead to poor visualization ability and poor conceptualization ability in humans. People who cannot follow the route based navigation strategy may have a condition known as directional deficiency, directional dyslexia, or topographical amnesia. Afflicted individuals may not

be good at conceptually and visually challenging jobs such as program debugging and testing, program comprehension, medical triage, piloting, and sailing.

A subsidiary eventual goal of this research is to provide a means of identifying directional disability in people. This could be distinguishable as a natural deficiency since it may result in a diminished ability for visualizations and conceptualization. Such a disability may affect an individual's performance at certain tasks that require conceptual navigation, e.g., program debugging, or more generally, software maintenance.

CHAPTER IV

CORRELATION BETWEEN DIRECTIONAL DYSLEXIA AND HUMAN VISUALAIZATION

This chapter focuses on whether a person's good or poor perceptual ability can have any correlation with her/his directional detection skills. In the first section, the notion that poor navigators can have poor spatial visualization is described. In the second section, it is explained how good visualization and spatial cognition in people can be helpful for performing spatial oriented jobs.

4.1 Do Good Navigators Have Good Spatial Visualization?

The process of creating a mental image is known as visualization. Some people in general are good at retaining temporal information while others are good at retaining spatial information, and of course, some people are good at both. Some people are good at visualizing objects and making a mental representation of those objects. These people are typically good at seeing composite objects either in their minute detail or in their overall structure. This distinction can be observed in an individual's ability to focus on and either to detect the gestalt image in a typical optical illusion test, or to see the image implied by the details of the picture.

Just seeing an object is not necessarily the same as observing it. A person might see an object but not observe it. Observation requires natural attention. People who may

have a disability in discerning directions may not be able to process spatial information. This problem is not necessarily predicated on dismissive and questionable assumptions about the intellect or the skill sets of a particular individual. Even some educated, talented, and otherwise naturally gifted people may be burdened with directional deficiency. It is generally unfair to assume that if a person simply invests more time and attention, that person should be able to process spatial information. Even if an individual afflicted with directional dyslexia focuses her/his attention on spatial information, she/he might not be able to follow spatial information. Directional deficiency in an individual appears to be unrelated to the level of her/his cognitive abilities. Some other causes or as yet unknown factors may be lurking behind this problem.

4.2 Spatial Cognition and Visualization in Humans

Spatial cognition is the core competence required in the understanding of medical images such as X-rays, CT scans, and MRI images. These medical images are two dimensional representations of three dimensional objects. A surgeon/specialist has to interpret the 2D images and identifying the potential problems in the actual 3D internal organs. Interpretation of medical images critically relies on one's spatial ability [Hegarty et al. 2007].

Surgery in particular depends on the conceptual representation of spatial information. A surgeon must have the ability to develop a mental model of the images because the "surgical task requires a spatial process in order to plan, navigate, and reason using a complex representation of the task" [Hegarty et al. 2007].

Should a test of one's spatial ability be essential for admission to some medical practices? One can argue that the answer is in the affirmative because a test might be a

good way of identifying individuals with the natural ability to manage spatial information and hence of selecting more qualified candidates. In the United States, the dentistry admission test is based on the spatial abilities of the candidates. This spatial ability test is known as the perceptual test [ADA 2010]. The Dental Admission Test (DAT) attempts to measure the visualization ability of individuals as it pertains to specific medical procedures. The justification for the test is that success in the profession critically depends on the spatial ability of the candidates.

As discussed above, spatial representation of anatomical structures is essential to understanding anatomy. Students who have low spatial abilities could encounter more difficulties in an anatomy class than those with high spatial abilities. Provo and Newby stated that "spatial ability may be the core part of anatomical models" [Provo and Newby 2002].

The studies cited above indicate that visualization and spatial cognition are essential for most intricate and challenging tasks such as the study of anatomy and the debugging of computer programs. The goal of this research was finding the correlation between lack of spatial ability and directional deficiency. The contention is that perhaps directionally challenged people may not possess the spatial information management skills that a "normal" person does. Due to this deficiency, pursuing careers in certain areas (surgery, programming, piloting, or sailing) may not be the best option for them.

CHAPTER V

PROGRAM COMPREHENSION AND COGNITIVE SKILLS

This chapter focuses on program comprehension ability and its possible correlations with cognitive skills such as conceptual ability and spatial ability.

The human brain is probably the most complicated organ ever studied, and adopting a novel interdisciplinary approach might be a helpful inroad. In the context, investigating the spatial abilities of conceptualization and visualization could afford a new perspective.

Comprehension is one of the higher cognitive processes of the brain [Wang 2002]. Comprehension finds relationships between a given object or attribute and other objects [Letvosky 1987]. Comprehension relies on a number of cognitive functions such as spatial ability, perception, and navigation.

A thorough understanding of comprehension could help, among other things, in understanding human vision and cognition. The process of comprehension starts with the identification of an object (concept, formula, shape, picture, etc.). When a person starts looking at an object, the human brain tries to identify the object and find possible relationships between the existing object abstractions that are already in the memory and the input object from the external world [Wang 2003]. The published research results of

the comprehension process and the relevant theory could be applied to spatial information comprehension ability, visualization, and conceptualization.

Program comprehension is not a simple task. Investigating program comprehension could be helpful in clarifying the basic visual perceptional brain and memory functions in humans. Program understanding involves processes at different levels of temporal resolution and memory access. The understanding and study of both the conceptual ability and the spatial ability could lead to the understanding of the cognitive functions underpinning program comprehension.

CHAPTER VI

THE IMAPCT OF GENDER DIFFERENCES ON SPATIAL ORIENTATION AND PROGRAM COMPREHENSION IN HUMANS

This chapter focuses on spatial orientation and program comprehension ability in relation to gender differences. The first section describes gender differences with respect to spatial orientation in humans. The second section explains the different program navigational strategies that are followed by males and females, and how the diverse set of program navigation skills correlate with the typical male and female program debugging, testing, and navigational approaches.

6.1 Gender Difference and Spatial Orientation in Humans

Gender differences play an important role in spatial orientation and program comprehension. Experimental evidence supports gender-related differences in spatial ability [Dabs et al. 1998]. However, few studies have addressed this problem from a navigational perspective. Researchers have done research in the past showing that there exists a possible correlation between gender and spatial orientation [Richardson 1991]. In the study of sex differences in navigation strategies and spatial skills, Dabs and his fellow researchers from Georgia State University conducted an experiment with 90 men and 104 women in a navigation strategy test. On the spatial test, they found that men were better than women in mental rotation skills. In giving directions, men would process more abstract information such as North-South and left-right. On the other hand, women were

more likely to succeed in tasks involving object-finding methods that dealt with landmark navigation [Dabs et al. 1998].

6.2 Gender Differences in Program Navigation Strategies

Program comprehension plays a major role in software maintenance. Program comprehension directly or indirectly relies on the cognitive ability of the code readers or programmers. Exactly how programmers comprehend a program and "navigate" through the source code still does not have a strong scientific explanation. Generally, women may follow a low-risk bottom-up strategy for program comprehension analogous to a location-based navigation system. Men, on the other hand, may follow a high-risk top-down approach for program comprehension. Furthermore, it appears that women focus on a small part of a program at a time and attempt to debug a program incrementally as a cumulative result of frequent attempts. As reported, women in general could not reconstruct the overarching design of a program through program comprehension efforts. Men can in general detect and follow the overarching design of a program, and they can understand abstract information [Fisher et al. 2006].

When a programmer tries to navigate through a given piece of source code, she/he would typically start by attempting to comprehend the functions and data structures well. After that, she/he will try to construct the overall map of the given source code [Letovsky 1987]. This kind of program comprehension navigation is comparable with human directional navigation in new locations. It could be argued that cognitive ability tests such as the mental rotation test [Shepard and Metzler 1971] and source code navigation tests might be helpful in understanding how a programmer's source code navigation

skills/approaches and directional navigation skills/approaches rely on her/his comprehending ability.

Experimental studies have shown that the female subjects of a navigation test outperformed the males in object location tests, and that the females followed the landmark strategy for their navigation. According to Fisher et al., "females could follow concrete information and sequential search for both source code navigation as well as location finding tasks, but males could follow the abstract information approach and construct the overall map of both the source code and the geographical environment" [Fisher et al. 2006].

Visualization plays an important role in program comprehension, and poor visualization may lead to poor spatial understanding. A definitive response to the question of whether or not visualization comprehension correlates with the spatial ability of an individual might be helpful in better understanding how people handle the navigational task.

Spatial orientation is the ability to judge changes in the orientation of an object. This skill is evaluated with tests that present two-dimensional projections of a three-dimensional object (mental rotation). Spatial visualization ability is defined as the ability to imagine a result [Velez et al. 2005]. When a programmer is trying to debug a piece of code, she/he would imagine the expected result and then attempt to determine whether or not the given program will actually produce the desired result. It can be argued that when a person tries to find her/his way around, she/he might in effect be constructing a map leading to the place of destination. An individual afflicted with poor spatial visualization

might have a tough time with program comprehension, program debugging, or the orientation/navigation task in general.

CHAPTER VII

RESEARCH METHODOLOGY

This chapter briefly covers four topics related to the research methodology. The first section describes how the research study was designed. The second section details some information about the research participants. The third section describes the research material used. The final section explains how the test was carried out.

7.1 Research Design

A series of cognitive tests were used in this study to measure the spatial and visual ability of the participants. The cognitive tests involved in this research work were taken from the Kit of Factor-Referenced Cognitive Tests published by the Educational Testing Service (ETS).

Forty six tests from the Kit of Factor-Referenced Cognitive Tests, published by the Educational Testing Service, have been used in investigations of factors involved in cognitive tasks. The overall kit contains 72 fairly short tests that have been developed to serve as markers for 23 factors that appear in the literature on cognitive abilities. In this research work, four cognitive factors of the subjects, namely Visual Memory (MV), Spatial Orientation (SO), Spatial Scanning (SS), and Visualization (VZ), were measured. The Building Memory (MV-2) and the Map Memory (MV-3) tests were conducted to measure the visual memory capacity of the participants. The Cube Comparison test (S-2) was conducted to measure the spatial orientation ability of the participants, and the Maze

Tracing Speed test (SS-1) was conducted to measure the spatial scanning ability of the participant. Finally, the Paper Folding test (VZ-2) was conducted to measure the visualization ability of the participants.

A series of program comprehension tests were used to measure the program comprehending ability of the participants. The program comprehension tests involved in this research were taken from a dissertation titled Navigation and Comprehension of Procedural Language Programs [Mosemann 2000]. Two programs and a training program were used in the investigation of the factors involved in the program comprehension task. The test programs and the training program were written in the C++ programming language for the programmers to understand. The two programs were divided into five comprehension categories of statement sequential flow, control flow, data flow, interactions, and cross-referencing. Each program comprehension category has six questions. Statement sequential flow describes the physical order of the individual statements in a program. Control flow describes the logical ordering of the statements and modules in a program. Data flow knowledge provides an understanding of how data is used in a program. Interaction module provides an understanding of how different functions of a program interact within a program. Cross-referencing knowledge associates program details with the goals of a program.

A set of yes/no comprehension questions was used for each program. The comprehension questions were based on the five comprehension categories of statement sequential flow, control flow, data flow, interactions, and cross-referencing.

7.2 Research Participants

Thirty Participants were involved in this research study. The participants were recruited from the Oklahoma State University Computer Science Department and Management Information Systems Department. Participation in this study was voluntary. One copy of the Participant Information Sheet (APPENDIX B), one copy of the Background Information questionnaire (APPENDIX C), and one copy of the Survey questionnaire (APPENDIX D) were distributed to the participants during the study. Participation in the study was voluntary, but as a nominal incentive, participants were offered snacks and bottled water. The participants had taken a minimum of one course in the graduate school that involved computer programming. On average, participants had written 10 programs. All participants were familiar with the C++ programming language because it was the computer programming language used in their respective courses.

7.3 Research Material

Three factors of the Kit of Factor-Referenced Cognitive Tests were used in this study. These Three factors (Visual Memory, Spatial Orientation, and Visualization) were chosen to measure the cognitive factors involved in spatial navigation and visualization.

The Building Memory (MV-2) test was used in this study to test the participants' ability to remember the position of items on a street map. The Map Memory (MV-3) test was used in this study to measure the participants' ability to remember parts of a map. The Cube Comparison (S-2) test was used in this research work to measure the spatial navigation and mental rotation skills of the participants. The Maze Tracing Speed Test (SS-1) was used in this study to measure the participants' ability to find a path through a

maze quickly. The Paper Folding Test (VZ-2) was used to measure the participants' visualization skills.

The program comprehension session had a training program and two test programs that were written in the C++ programming language. The programs represented good programming style and structured approach to programming. The training program and the two tests programs did not contain any comments to describing the purpose and function of the programs.

The training program (APPENDIX F: training program and comprehension tests) was eighty lines in length. The purpose of the training program was to accept a temperature in Fahrenheit, convert it to an equivalent Celsius temperature, and print the result. The currency conversion program (APPENDIX F) was 360 lines in length and converted an amount in one currency into another currency. The discount program (APPENDIX F) was 310 lines and calculated the discount, the shipping, and the total cost based on the number of items purchased.

Three set of yes/no questions were used to test the participants' comprehension of the programs. The training program comprehension question set (APPENDIX F) contained six questions.

The two test program comprehension question sets (APPENDIX F) were designed based on each test program. Six questions were written for each of the five comprehension categories for a total of thirty questions. The six questions in each category were further divided into two groups. Three questions would be answered

correctly with a "yes" answer, and the rest of the three questions would be answered correctly with a "no" answer. The questions were independent of each other.

7.4 Test Procedure

A trial run of the testing part of the study was conducted with six participants in order to confirm the proper order of the tests, to determine if the time limit on each section of the experiment was reasonable, and to verify if the test could be completed within one hour and fifty minutes. No problems were identified during the trail run, and the time limit for each section was deemed to be appropriate for the study.

The actual testing part of this study was approximately one hour and fifty minutes. The test was conducted in room 237 of the MSCS (Mathematics, Statistics, and Computer Science) building, Oklahoma State University, Stillwater, Oklahoma. The study was performed in five separate sessions. After the students had arrived at the testing place, a brief explanation of the study was given. The test procedure was entirely anonymous. As a result, the participants were not asked to write their name, their gender, their age, nor any other personal information on their answer sheets. As the first step, the participants were asked to fill out the Background Information Sheet (APPENDIX C) followed by a Survey questionnaire (APPENDIX D). Then the participants had fifty three minutes to complete the visuo-spatial memory test, the visualization test, and the visualization test (APPENDIX E). Following that, the participants were given twelve minutes to read and understand a program (APPENDIX F). Next, the participants had seven minutes and thirty seconds to answer yes/no questions regarding their understanding and recollection of the program. The participants were asked to repeat this

process by viewing a second program for twelve minutes and then answering yes/no to questions about the program for seven minutes and thirty seconds.

The core of the study was grouped into two sessions. The first session of the test tested the visuo-spatial memory and the spatial navigation skills of the participants. The second session of the test measured the participant's program comprehension.

The first session of the test was divided into five phases. The first phase of the first session was the Building Memory (MV-2) test. There were two sections in each part of this test. During the first part of the test, the participants were given a map with streets, buildings, and other structures to study. They had 4 minutes to study the map. After they had perused the study page, they were asked to turn to a test page, and they had 4 minutes to complete the test page. The second part of this test was identical to the first part.

The second phase of the first session was the Map Memory (MV-3) test. There were two sections in each part of this test. During the first part of the test, the participants were given a map to study. They had 3 minutes to study the map. After they had perused the study page, they were asked to turn to a test page, and they had 3 minutes to complete the test page. The second part of this test was identical to the first part.

The third phase of the first session was the Cube Comparison (S-2) test. There were two sections in each part of this test. During the first part of the test, the participants were given pairs of cubes to identify whether a pair of cubes was the same or different. The participants had 3 minutes to complete all 21 questions. The second part of this test was identical to the first part.

The fourth phase of the first session was the Maze Tracing Speed Test (S-2). There were two sections in each part of this test. During the first part of the test, the participants were given a maze trace and were asked to find a path through the maze quickly. The participants had 3 minutes to complete all 24 maze trace square boxes. The second part of this test was identical to the first part.

The fifth phase of the first session was the Paper Folding Test (VZ-2). There were two sections in each part of this test. During the first part of the test, the participants were asked to imagine the folding and unfolding of pieces of paper. The participants had 3 minutes to answer all 10 questions. The second part of this test was identical to the first part.

The second session of the test study was divided into three identical phases, which were further divided into two activities. The first activity was the navigation of a program. The second activity was the completion of the comprehension questions for the program just navigated.

The first phase of the second session was a training phase. The participants were given a training program sheet. They had 4 minutes to study the program. At the end of the time, the participants were asked to return the program sheet, and the question phase of the activity began. The participants had exactly one minute and thirty seconds to complete the training program comprehension test section. At the end of the question/answer answer activity phase, the participants were asked to wait for everyone to finish before starting the next phase.

The remaining two phases followed the same pattern. For the next phase, a currency conversion program was given to the participants. They had 12 minutes to study

the program. At the end of the allotted time, the participants were asked to return the program sheet, and the question phase of the activity began. The participants had exactly seven minutes and thirty seconds to complete the currency conversion program comprehension questionnaire. At the end of the question/answer activity, the participants were asked to wait for everyone to finish before starting the subsequent phase.

The third phase was identical to the second phase. The second test program (the discount program) was given to the subjects, and the participants were asked to navigate the program. At the end of the 12 minutes, the participants were asked to return the program sheet, and the question phase of the activity began with thirty questions. At the end of the study, the participants were asked to return their test questionnaire, and were free to leave. The results were then collected for analysis.

CHAPTER VIII

RESULTS AND ANALYSIS

This chapter contains a discussion of the different scoring methods and the interpretation of the results. Section one explains the analysis of evaluating the test results. Section two described the correctness of scoring method.

8.1 Analysis of evaluating test results

Throughout the study, data were collected about the performance of the participants. One set of results consisted of the visuo-spatial memory test results, visualization test results, and the program comprehension test results. Before performing any statistical analysis, the percentage of unanswered questions in each test was calculated. Of the 30 participants, participant number 13 had an unusually high percentage of unanswered questions in eight out of twelve tests (APPENDIX G). Hence, participant number 13 was considered an outlier and excluded from the result analysis and further consideration.

The participants' responses were tabulated for the visuo-spatial memory test and the visualization test. For initial analysis, correctness values were calculated as the percentage of the number of questions answered correctly over the total number of answered questions (C/C+I). Correctness values were also calculated as a percentage of the number of questions answered correctly over the total number of questions (C/T). The

most challenging part in evaluating the test results was to determine the most appropriate scoring method to evaluate the participants' test score.

Neither the percentage of the number of questions answered correctly over the total number of answered questions (C/C+I) nor or the percentage of the number of questions answered correctly over the total number of questions (C/T) penalized the participants for their random guesses in answering test questions. Scoring method for guessing answers were calculated by the percentage of the number of questions answered correctly minus the number of questions answered incorrectly over the total number of answered questions (C-I/C+I), or the percentage of the number of questions answered correctly over the total number of questions (C/T). For evaluating the different scoring methods, experts input in educational psychology and statistics were sought [Barnes 2010] [Chandler 2010] [Warde 2010].

The Formula Scoring method (FS) has been used in educational research for evaluating the subjects' score with penalizing the subjects for their random guesses in answering questions. The Omitted Corrected Score (OCS) has been used in educational psychology for evaluating the unanswered or omitted questions in educational tests [Barnes 2010].

Eight different scoring methods (C/C+I, C/T, C-I/C+I, C-I/T, FS/C+I, FS/T, OCS/T, OCS+P/T) were used to evaluate the visuo-spatial memory and the visualization test results (Part1) and the results were tabulated (APPENDIX H).

Scoring Formula:

C/C+I:

C = Correct answer

I = Incorrect answer

C+I = total number of answered questions

C/T:

C = Correct answer

T = total number of questions

FS (Formula Scoring):

FS = R – W/(C-1)

FS = formula score

R = number of items answered right

W = number of items answered wrong

C = number of choices per item

OCS (Omitted Corrected Score):

Omitted corrected score = 1/A* O+ total

A = number of alternatives available

O = number of omitted items

total = total number of items answered correctly

OCS+P (Omitted Corrected Score + Penalty)

Omitted Corrected Score with Penalty:

Omitted corrected score with penalty = 1/A * O + FS

A = number of alternatives available

O = number of omitted items

FS = formula scoring

8.2 Comparison of the Scoring Methods

Eight different scoring methods (C/C+I, C/T, C-I/C+I, C-I/T, FS/C+I, FS/T, OCS/T, OCS+P/T) were used in evaluating the visuo-spatial memory and the visualization test results (Part1) (APPENDIX H). Pearson's Correlation method was used in this study to find the correlation coefficient values among the eight different scoring methods. The correlation coefficient is a number between 0 and 1. The correlation coefficient value 0 represents no correlation, and the correlation coefficient value 1 represents high correlation [Warde 2010].

The SAS tool [SAS 2010] was used for calculating the correlation coefficient values for eight different scoring methods for the visuo-spatial memory and the visualization tests and the results were tabulated (APPENDIX I). The correlation coefficient values were high for the eight different scoring methods. Two scoring methods (C/T and C-I/T) were used to evaluate the test results [Barnes 2010] [Chandler 2010]. The results were tabulated (APPENDIX J) and line graphs were drawn (APPENDIX K).

8.3 Statistical Analysis

Three statistical tools were available: SAS [SAS 2010], GRAPHPAD PRISM [Prism 2010], and SPSS [SPSS 2010]. Of the three, the SAS tool was used in calculating the correlation coefficient values for the visuo- spatial memory and the visualization tests (Building Memory Test (MV-2), Map Memory test (MV-3), Cube Comparison Test (S-2), Maze Tracing Speed Test (SS-1), and Paper Folding Test (VZ-2)) and the program comprehension tests (Currency Conversion Program (CP), Discount Program (DP)). The

correlation coefficient values for two scoring methods (C/T, C- I/T) were calculated and tabulated (Table 1 and Table 2 below).

	MV-2	MV-3	S-2	SS-1	VZ-2	CP	DP
MV-2		0.34	0.11	0.28	0.55	0.13	0.19
MV-3	0.34		0.44	0.33	0.54	0.17	0.18
S-2	0.11	0.44		0.51	0.52	0.24	0.19
SS-1	0.28	0.33	0.51		0.70	0.32	0.06
VZ-2	0.55	0.54	0.52	0.70		0.38	0.21
CP	0.13	0.17	0.24	0.32	0.38		0.36
DP	0.19	0.18	0.19	0.06	0.21	0.36	

Table 1: Correlation coefficient values (C/T scoring method)

	MV-2	MV-3	S-2	SS-1	VZ-2	CP	DP
MV-2		0.34	0.27	0.41	0.63	0.23	0.26
MV-3	0.34		0.51	0.44	0.59	0.38	0.32
S-2	0.27	0.51		0.49	0.61	0.54	0.28
SS-1	0.41	0.44	0.49		0.68	0.39	0.17
VZ-2	0.63	0.59	0.61	0.68		0.50	0.20
CP	0.23	0.38	0.54	0.39	0.50		0.36
DP	0.26	0.32	0.28	0.17	0.20	0.36	

Table 2: Correlation coefficient values (C- I/T scoring method)

From Table 1, the correlation coefficient values were high for VZ- 2 and SS-1 (0.70), VZ-2 and MV-2 (0.55), VZ-2 and MV-3 (0.54), and VZ-2 and S-2 (0.52). Hence, the participants' visualization skills and spatial skills exhibited a strong positive correlation.

From Table1, the correlation coefficient values for Visualization (VZ- 2) and the program comprehension tests (CP, DP) were 0.38 and 0.21, and the correlation coefficients values for the Cube Comparison Test (S- 2) and the program comprehension tests (CP, DP) were 0.24 and 0.19. Therefore, the Visualization ability (VZ-2) of the participant and the mental rotating ability (S-2) were highly correlated with program comprehension.

From Table 2, the correlation coefficients values were high for VZ- 2 and SS-1 (0.68), VZ-2 and MV-2 (0.63), VZ-2 and MV-3 (0.59), and VZ-2 and S-2 (0.52). Hence, the participants' visualization skills and spatial skills showed a strong positive correlation.

From Table 2, the correlation coefficients values for Visualization (VZ- 2) and the program comprehension tests (CP, DP) were 0.50 and 0.20, and the correlation coefficients values for the Cube Comparison Test (S- 2) and the program comprehension tests (CP, DP) were 0.54 and 0.28. Therefore, the Visualization ability (VZ-2) of the participants' and the mental rotating ability (S-2) were highly correlated with program comprehension.

From Tables 1 and 2, the spatial test (S-2) and the visualization test (VZ-2) exhibited strong positive correlations with the currency conversion program

comprehension test (CP). However, the spatial test (S-2) and the visualization test (VZ-2) had weak correlation with the discount program comprehension test (DP).

From Tables 1 and 2, the Visual Memory (MV-2, MV-3) and the Spatial Scanning test (SS-1) showed weak correlations with the program comprehension tests (CP and DP).

CHAPTER IX

SUMMARY AND FUTURE WORK

9.1 Summary

Part of the objective of this thesis work was to identify the possible correlations that might exist between the participants' spatial ability, visualization ability, and program comprehension ability. Based on this investigation, the main thrust of this thesis work was correlating human directional deficiency issues with program comprehension and debugging. A hypothesis was formulated, an experimental was carried out, and the results were analyzed.

Chapter I discussed the possible ramifications of directional deficiency in humans. Chapter II described the effect of Earth's magnetic field on birds, honey bees, and the human navigation system. Chapter III explained the hypothesis statement involved in this thesis work. Chapter IV discussed the correlation between direction dyslexia and human visualization. Chapter V described the correlation between program comprehension and cognitive skills. Chapter VI explained the impact of gender differences on spatial orientation and program comprehension in humans. Chapter VII explained the methods and materials used in this thesis work. Chapter VIII discussed the results and analysis of the results.

It is widely accepted that magnetic orientation is possible in migratory birds, sea turtles, and honey bees, but it is still considered an elusive phenomenon in humans.

Human homing orientation is still a mystery to psychologists, cognitive scientists, and other researchers. One of the objectives of this research work was attempting to find correlations between visual memory, spatial skills, and visualization ability on the one hand with program comprehension skills on the other hand. The conventional categorization of navigation into route based and location based navigation was used as the framework. The participants' spatial skills and visualization ability played a major role in route based navigation system and were suggestive of some correlations with program comprehension. Also, the participants' visual memory and backtracking skills played a major role in location based navigation system, but exhibited weak correlations with program comprehension. Overall, it appears that the prototypical experiment results support the hypothesis statement that route based navigation system in humans (i.e., the reliance on compass directions) has some correlations with program comprehension skills in human.

9.2 Future Work

This work touched on theories about human directional deficiency and the cognitive processes involved in program comprehension. For future work, this study could be given to larger sample size of subjects and the behavior of programmers could be observed while carrying out typical program comprehension tasks. This work tried to find correlations among the eight scoring methods through statistical analyses. One could explore analytical/formulaic dependencies among the eight scoring methods. As an alternative to addressing program comprehension test that were utilized in this study, one could consider tests similar to the ones used in introductory programming courses by selecting a set of representative programs and using their data flow graphs, control flow

graphs, contour diagrams, Nassi-Shneiderman charts, etc. (as graphical representation) to gauge the special navigation and comprehension of the subjects. In this study, the correlation between visual memory and backtracking skills of the programmers with program comprehension and visualization of the programmers was inconclusive, however, intuitively, the programmers' spatial and visualization skills seem to have some correlations with program comprehension. Further research is required to refine the results and trends found in this study.

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APPENDICES

APPENDIX A

GLOSSARY

Directional Deficiency:	A natural deficiency that occurs in humans. Individuals who cannot follow and maintain directional information suffer from directional deficiency.
Ethmoid Bone:	A bone in the human skull that is light and spongy, and cubical in shape. It is located at the roof of the nose between the two orbits [Coutsoukis 2008]. Some migratory birds and other migratory animals have deposits of biological magnetite in their ethmoid bones which allow them to sense the Earth's magnetic field.
Magnetic Orientation:	The natural reception of Earth's magnetic field for orientation purposes by migratory birds, honey bees, sea-turtles, and higher mammals.
Magneto Reception:	The natural reception of Earth's magnetic field (North-South) in migratory birds, honey bees, sea-turtles, and higher mammals.
Spatial Cognition:	Acquisition, organization, utilization, and revision of knowledge about spatial settings.

Visuo-Spatial Memory:	The ability that allows humans to navigate in the environment, imagine how objects would look if rotated at different angles, and remember the location of objects.

APPENDIX B

Participant Information Sheet

Project Title:
Exploring Possible Ramifications of Human Directional Deficiency in Computer Science

Investigators:
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Professor
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Purpose:
This research work will compare the results of the spatial navigation task and the program comprehension task. You are invited to participate in this study because of your background/experience in programming.

Procedures:
This test will take approximately 1 hour and 50 minutes. The testing will be conducted in 310 MSCS Building, Oklahoma State University, Stillwater, Oklahoma. After a brief introduction, you will be asked to fill out a survey. Then you will have 53 minutes to complete the visuo-spatial memory tests and the visualization test. Following that, you will be given 12 minutes to read and understand a program. Next, you will have 7 minutes and 30 seconds to answer yes/no questions regarding your understanding and recollection of the program. You will repeat this process by viewing a second program for 12 minutes and then answering yes/no questions about the program for 7 minutes and 30 seconds.

Risks of Participation:
There are no risks associated with this project.

Benefits:
You may find the testing process interesting in that you may be introduced to a new way of viewing the information in a program that might be helpful to you when trying to comprehend a program. The information gained from this study may help us to better understand the correlation between spatial navigation and program comprehension.

Confidentiality:
Information obtained from this study will be kept strictly confidential. The data will be stored in a locked cabinet in the principal investigator's office and will only be seen by the investigator during the study and for 3 months after the study is completed. The information obtained in this study may be published in scientific journals or peer-reviewed full-text conference proceedings, but the data will be reported as aggregated data only.

Compensation:
For the participants in this study, snacks and soft drinks will be provided.

Contacts:
You may ask any questions concerning this research before agreeing to participate or during the experiment. You may also call the Primary investigator, Senthilrajan Moorthy at 405-338-5220, or you may email your questions to senthim@okstate.edu, or/ and you may also call the adviser, Dr. M.H.Samadzadeh at 405-744-5668, or you may email your questions to samad@cs.okstate.edu

If you have questions about your rights as a research volunteer, you may contact Dr. Shelia Kennison, IRB Chair, 219 Cordell North, Stillwater, OK 74078, 405-744-3377 or irb@okstate.edu.

Participant Rights:
You are free to decide not to participate in this study or to withdraw at any time. Your decision will not result in any loss of benefits to which you are otherwise entitled.

APPENDIX C

BACKGROUND INFORMATION

A) Computer Experience – Check one box for each question

a. Your highest level of education is:

☐ high school ☐ some college ☐ bachelors degree ☐ work on masters ☐ masters degree ☐ work on doctorate

b. The number of programming courses that you have completed in high school and college is:

☐ 0 ☐ 1 ☐ 2 ☐ 3 ☐ 4 ☐ 5 or more

c. The number of years you have worked as a professional programmer is:

☐ never ☐ less than 1 ☐ 1-2 ☐ 3-5 ☐ 6-10 ☐ more than 10

d. The number of computer programs you have written is approximately:

☐ 0-5 ☐ 6-10 ☐ 11-20 ☐ 21-50 ☐ 51-100 ☐ more than 100

e. The number of courses you have completed that used the C programming language is:

☐ 0 ☐ 1 ☐ 2 ☐ 3 ☐ 4 ☐ 5 or more

f. The number of courses you have completed that used the C++ programming language is:

☐ 0 ☐ 1 ☐ 2 ☐ 3 ☐ 4 ☐ 5 or more

g. The number of courses you have completed that used the Java programming language is:

☐ 0 ☐ 1 ☐ 2 ☐ 3 ☐ 4 ☐ 5 or more

h. The number of courses you have completed that used the Perl programming language is:

☐ 0 ☐ 1 ☐ 2 ☐ 3 ☐ 4 ☐ 5 or more

B) How familiar are you with the following programming languages?

Language	Not at all	A little	Fair amount	Quite a bit	Very
Ada					
Basic					
C					
C++					
COBOL					
FORTRAN					
HASKELL					
Java					
LISP					
MIRANDA					
Pascal					
Perl					
PHP					
PROLOG					
Smalltalk					
Other					

APPENDIX D

SURVEY

Please read the following questions carefully and answer all the questions by encircling the appropriate option.

1. Do you usually have to ask for directions when driving to an unfamiliar location?
   a. Very often
   b. Often
   c. Occasionally
   d. Never

2. Are you comfortable with the main compass directions (North/South/East/West) that you are given when asking for directions?
   a. Most Comfortable
   b. Comfortable
   c. Uncomfortable

3. Do you find it hard to navigate while driving, especially in an unfamiliar location?
   a. Hard
   b. Manageable
   c. Easy

4. Do you consciously observe and memorize landmarks in order to find your way around?
   a. Very often
   b. Often
   c. Occasionally
   d. Never

5. Do you find solving maze puzzles hard?
   a. Very often
   b. Often
   c. Occasionally
   d. Never

6. Do you lose your bearing when exiting a large building through a door that you do not normally use?
   a. Very often
   b. Often
   c. Occasionally
   d. Never

7. Do you feel lost and disoriented when the street you are traveling through (while walking or driving) curves and loops?
   a. Very often
   b. Often
   c. Occasionally
   d. Never

8. When you are in a new location at night, can you identify the North/South/East/West directions without any external cues such as a map, a compass, or a directional sign?
   a. Hard
   b. Manageable
   c. Easy

9. When in a new town on vacation or on a business trip, do you feel uncomfortable leaving your hotel room because you may have a hard time finding your way back to the hotel?
   a. Very often
   b. Often
   c. Occasionally
   d. Never

APPENDIX E

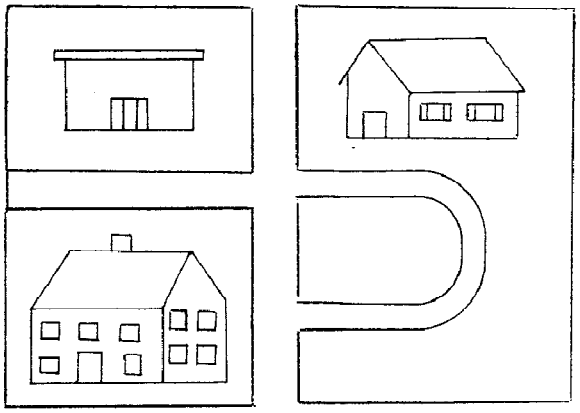
VISUO-SPATIAL MEMORY AND VISUALIZATION TESTS

BUILDING MEMORY -- MV-2

This is a test of your ability to remember the position of things on a street map.

You will be given a map with streets and buildings and other structures to study. After you have had some time to learn the street layout and the different kinds of structures, you will be asked to turn to a test page. On that page you will find the street map and numbered pictures of some of the structures. You will be asked to put an x on the letter that shows where each of the structures was located on the study map.

Now look at this simple and enlarged sample:



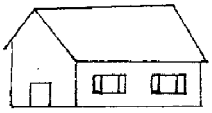
After you have studied the sample above for a minute, turn to the next page.

Look at the numbered houses on the left. For each item mark an X on the letter below each building that corresponds with where each house was located on the study map.

1.

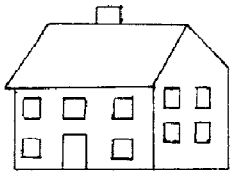
A B C D E

2.

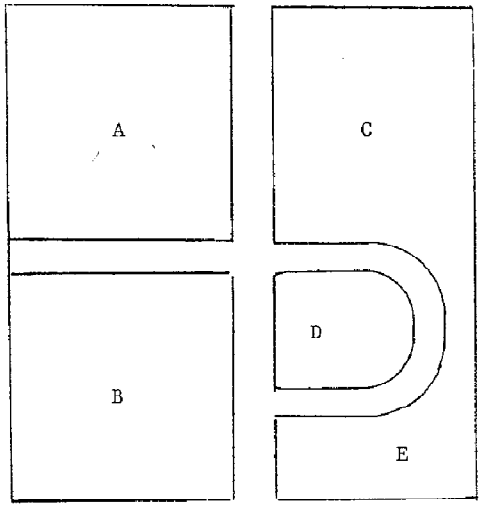


A B C D E

3.



A B C D E



Your answers for sample item 1 should be A, for 2, C, and for 3, B.

Your score on this test will be the number of buildings placed correctly minus a fraction of the number wrong. Therefore, it will not be to your advantage to guess unless you can eliminate some of the locations as definitely wrong.

There are two sections to each part of this test. The first section is a map which you will study for 4 minutes. The second is the test section and contains 12 structures to be located on the map. You will have 4 minutes to mark your answers. Mark A, B, C, D, or E for each building. In the test section, the buildings will be mixed up and not necessarily near the part of the map where you first saw them.

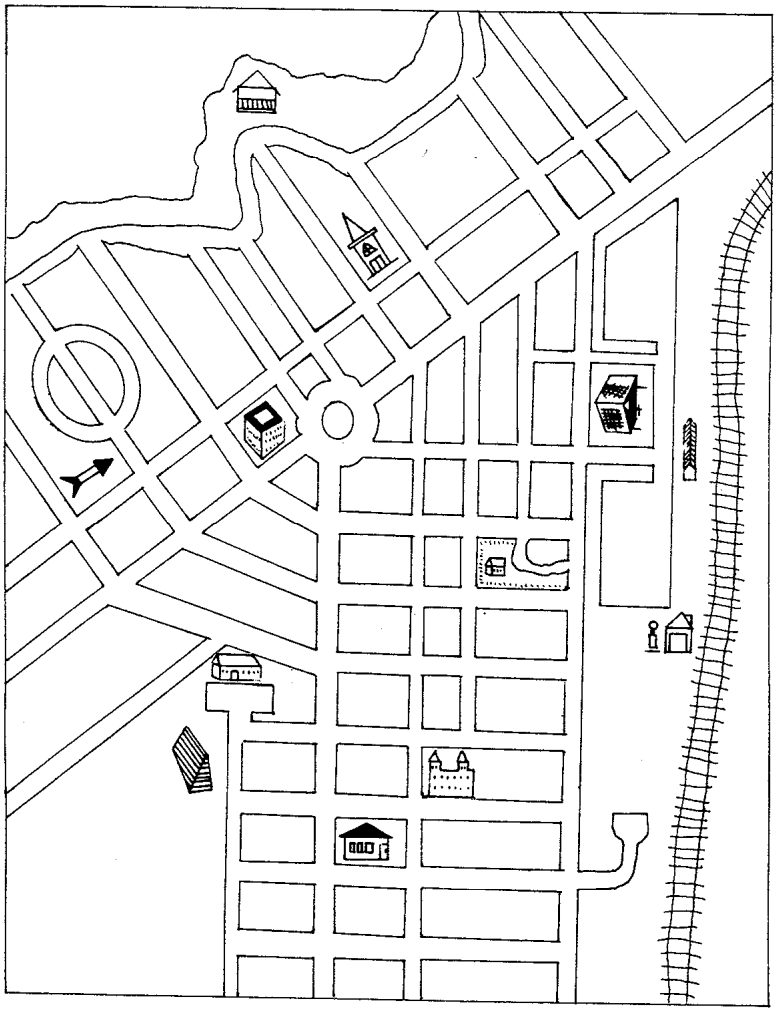
This test has two parts. When you have finished Part 1, STOP. Please do not go on to Part 2 until you are asked to do so.

DO NOT TURN THIS PAGE UNTIL ASKED TO DO SO

STUDY PAGE

Part 1 (4 minutes)

Study this map so you can remember where each building is located.



DO NOT TURN THIS PAGE UNTIL ASKED TO DO SO

STOP

TEST PAGE

Part 1 (4 minutes)

Mark an X on the letter below each building that shows where it was seen on the map.

1.  A B C D E

2.  A B C D E

3.  A B C D E

4.  A B C D E

5.  A B C D E

6.  A B C D E

7.  A B C D E

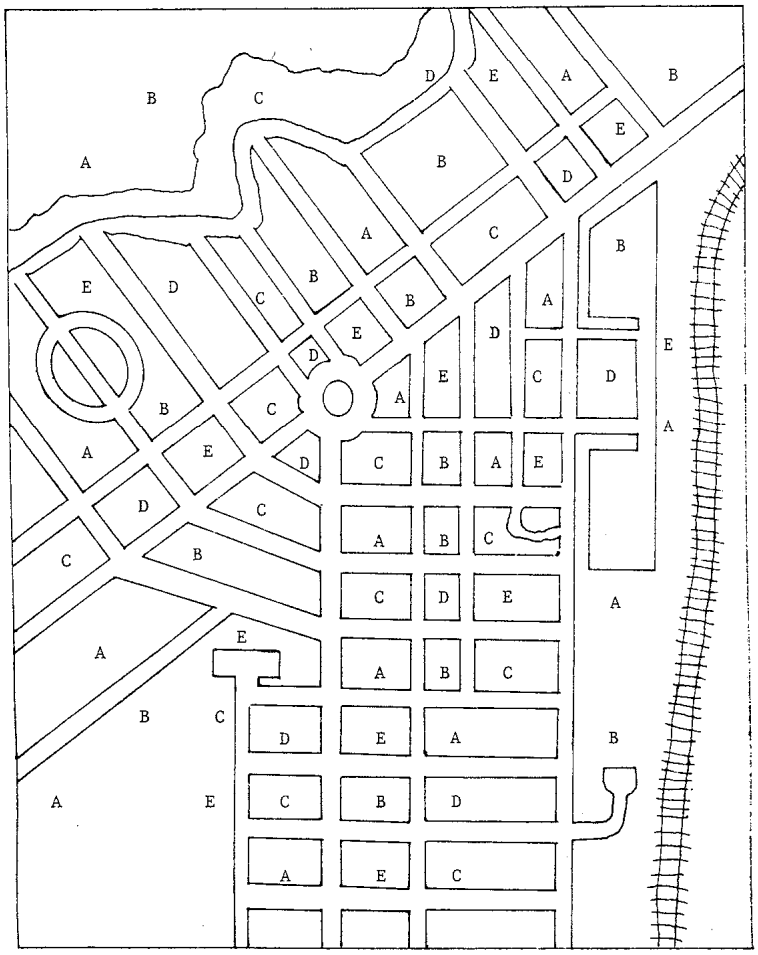
8.  A B C D E

9.  A B C D E

10.  A B C D E

11.  A B C D E

12.  A B C D E



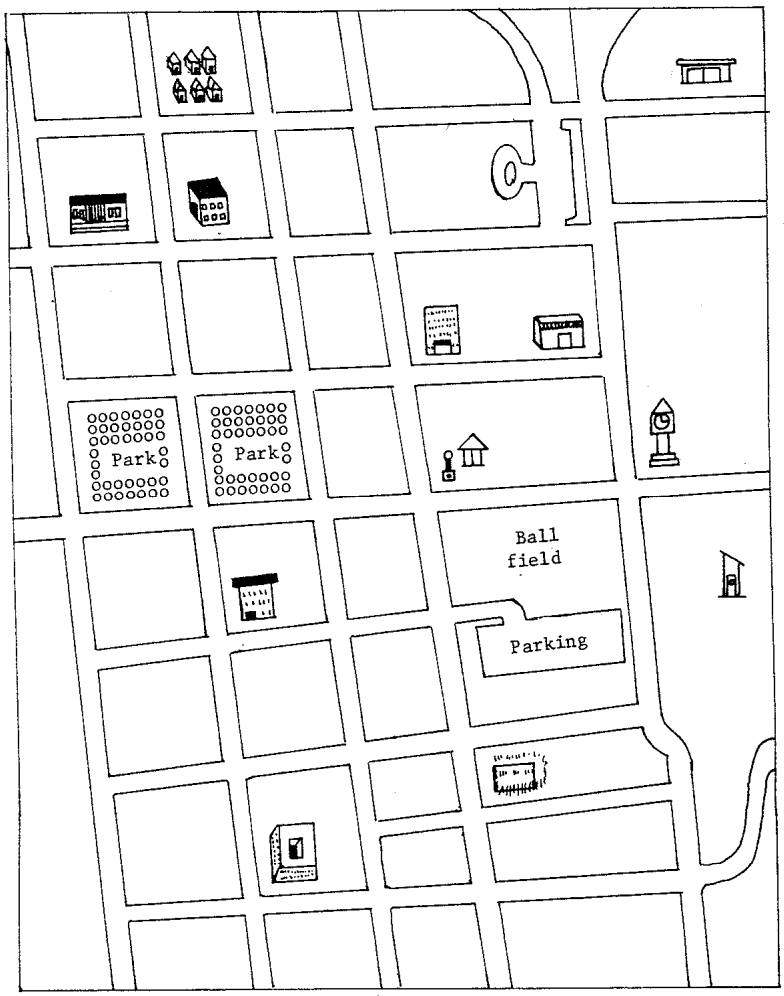
DO NOT TURN THIS PAGE UNTIL ASKED TO DO SO

STOP.

STUDY PAGE

Part 2 (4 minutes)

Study this map so you can remember where each building is located.



DO NOT TURN THIS PAGE UNTIL ASKED TO DO SO

STOP.

TEST PAGE

Part 2 (4 minutes)

13. 
A B C D E

14. 
A B C D E

15. 
A B C D E

16. 
A B C D E

17. 
A B C D E

18. 
A B C D E

19. 
A B C D E

20. 
A B C D E

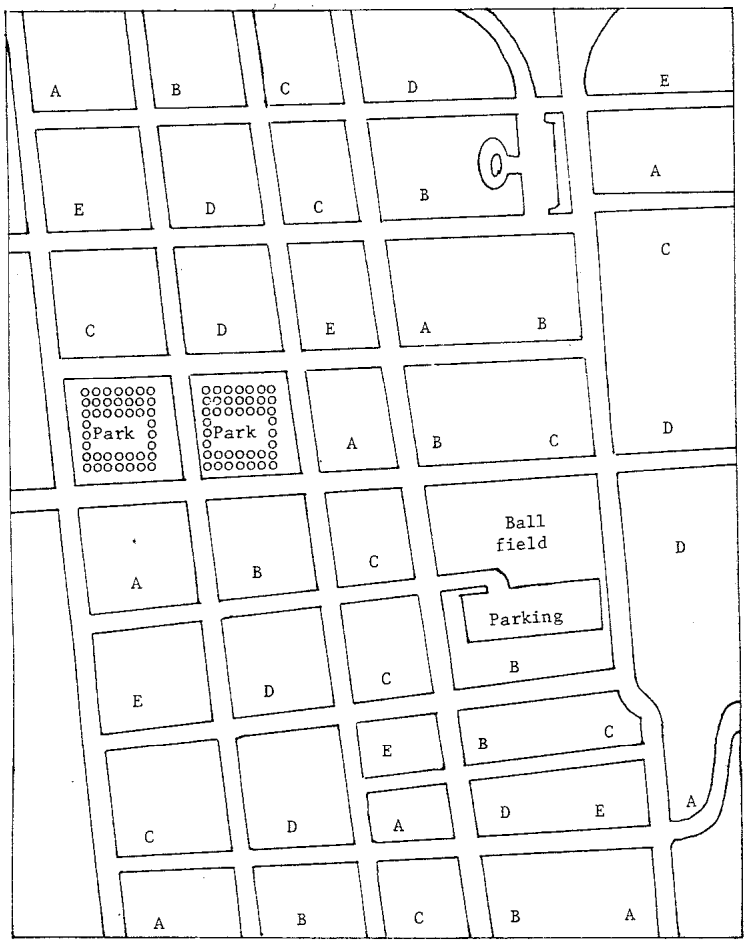
21. 
A B C D E

22. 
A B C D E

23. 
A B C D E

24. 
A B C D E

Mark an X on the letter below each building that shows where it was seen on the map.



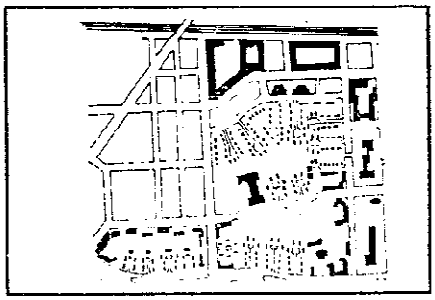
DO NOT GO BACK TO PART 1 AND DO NOT GO ON TO ANY OTHER TEST

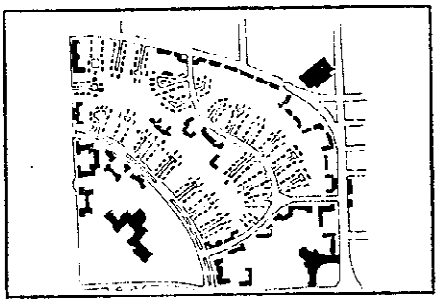
STOP.

MAP MEMORY -- MV-3

This is a test of your ability to remember part of a map so that you can recognize it when you see it again.

Study the sample item below. You have 1 minute.

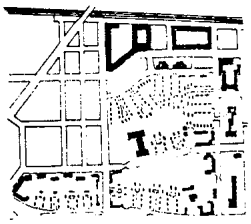




Now turn the page.

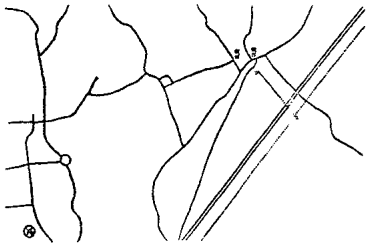
Which two of these four maps are the ones you saw on the study page? Mark the Y (yes) beneath the maps you studied. Mark the N (no) beneath the maps you have not seen before.

a.



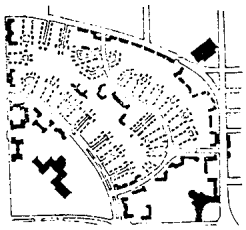
Y N

b.



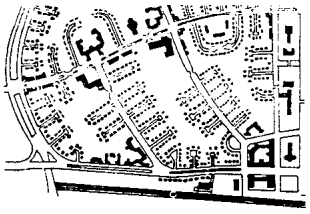
Y N

c.



Y N

d.



Y N

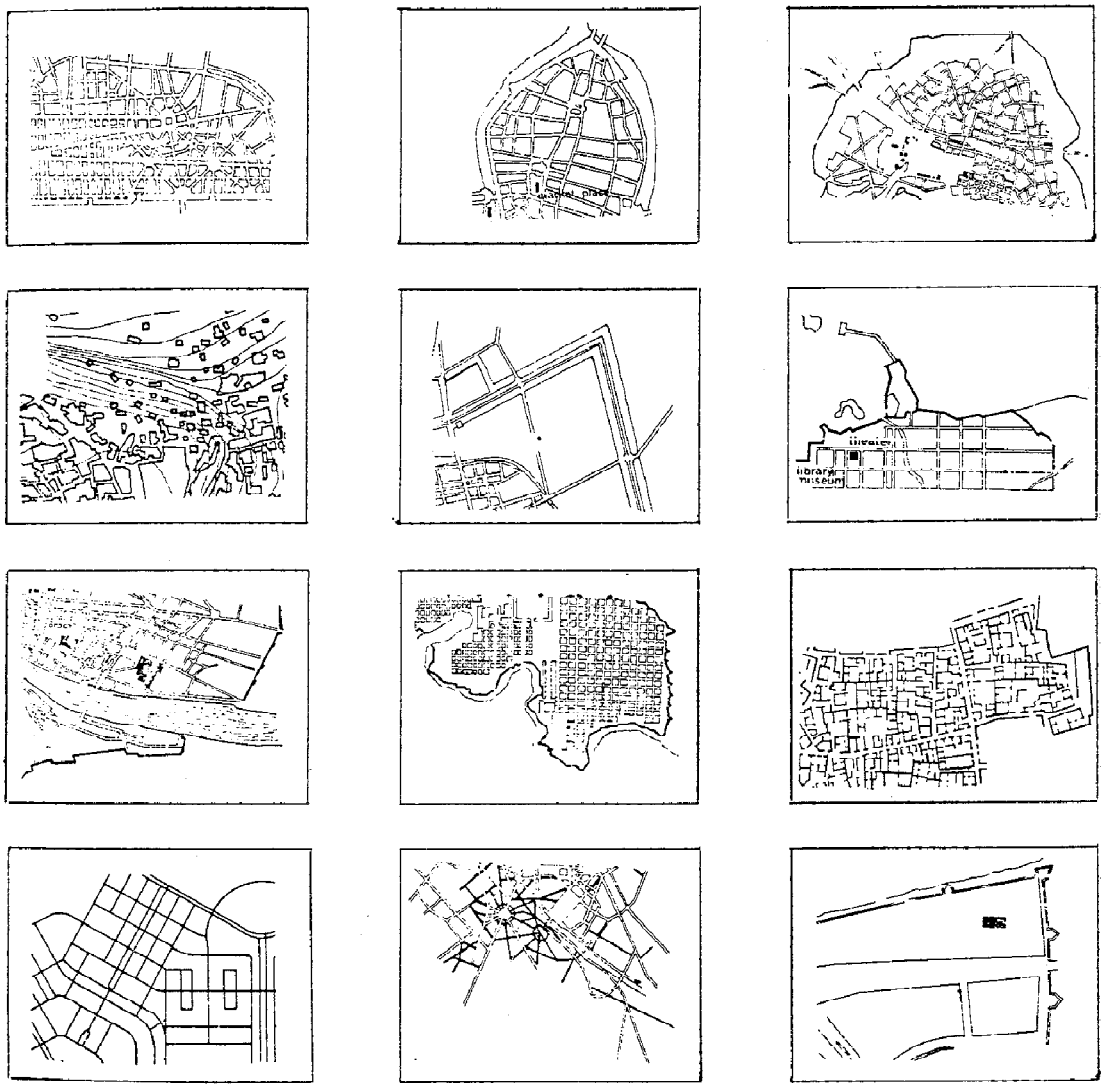
You should have marked "Y" under maps a and c, "N" under maps b and d.

Each of the two parts of this test will have two sections: (1) a page for you to study for 3 minutes and (2) a memory page which you will have 3 minutes to complete.

Your score will be the number of maps which you identify correctly minus the number which you identify incorrectly. Therefore, it will not be to your advantage to guess unless you have some idea of whether or not you have studied the map.

DO NOT TURN THIS PAGE UNTIL ASKED TO DO SO.

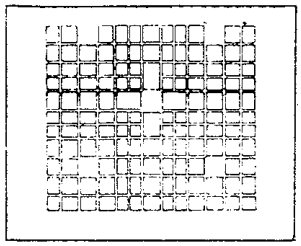
Part 1 (3 minutes)

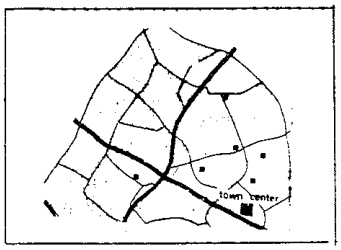


DO NOT TURN THIS PAGE UNTIL ASKED TO DO SO.

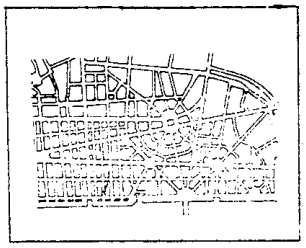
STOP.

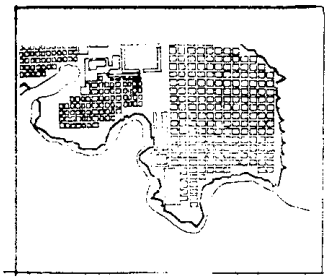
Part 1 (3 minutes)

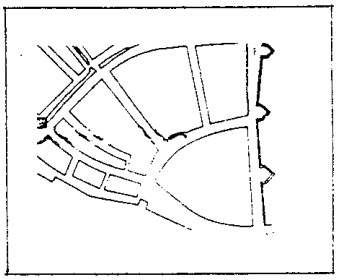
1. 
Y N

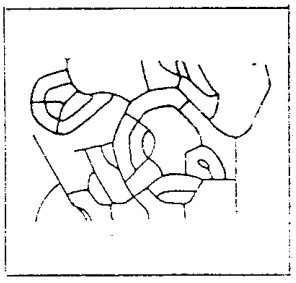
2. 

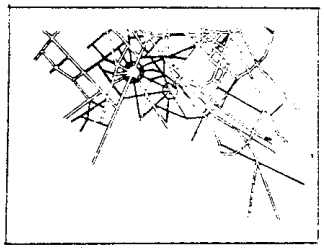
Y N

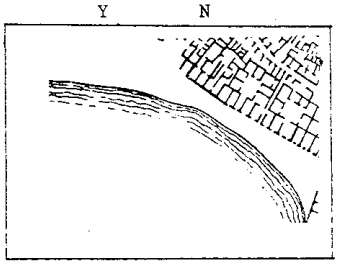
3. 
Y N

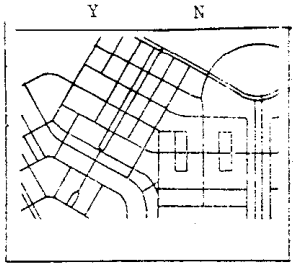
4. 
Y N

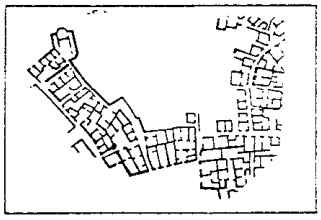
5. 
Y N

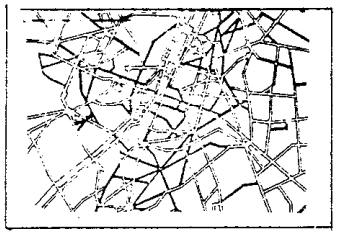
6. 
Y N

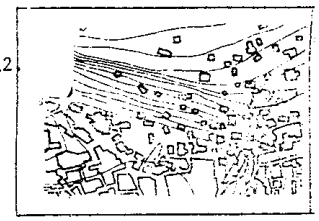
7. 
Y N

8. 
Y N

9. 
Y N

10. 
Y N

11. 
Y N

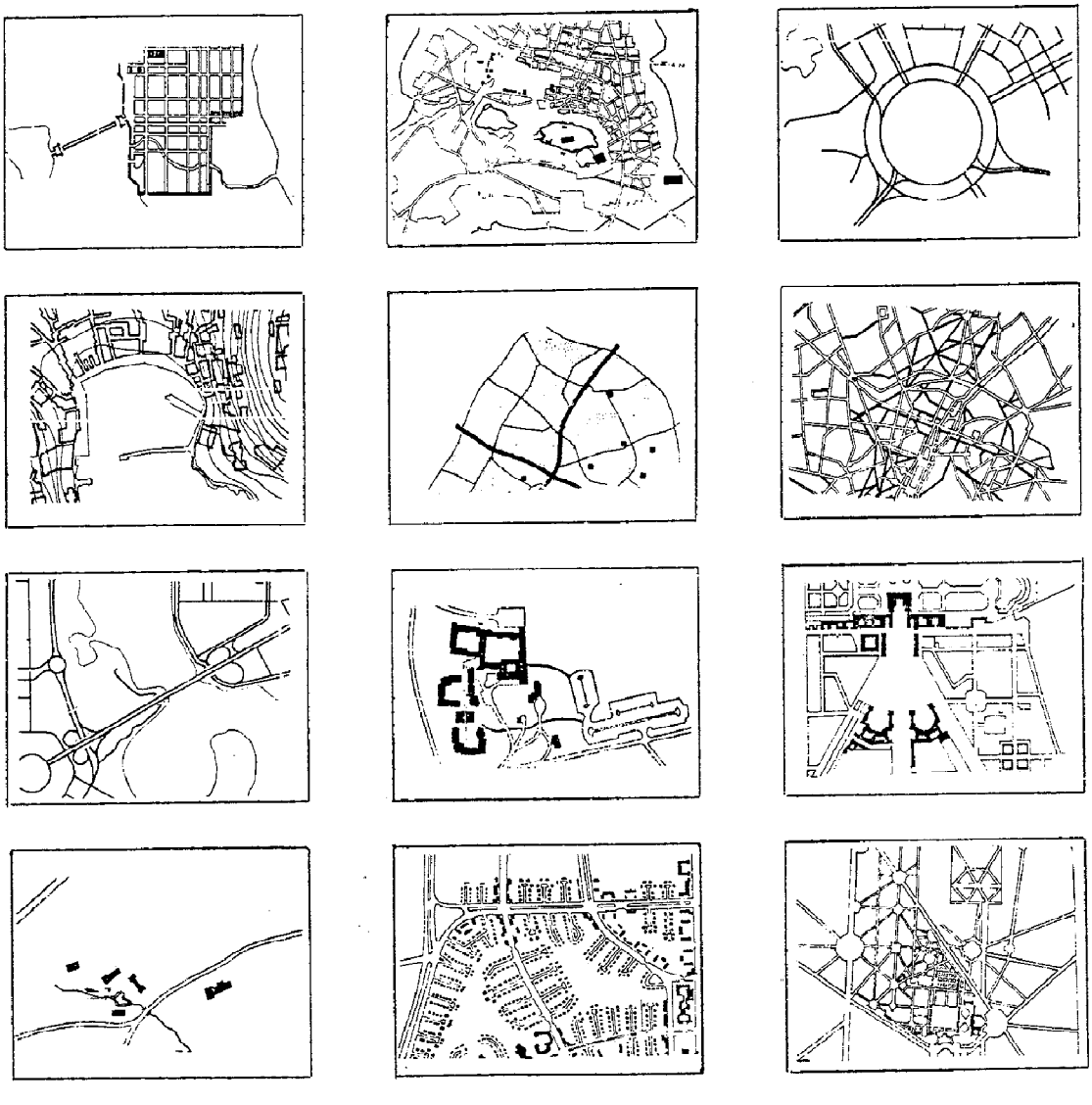
12. 
Y N

DO NOT GO ON TO PART 2 UNTIL ASKED TO DO SO.

STOP.

STUDY PAGE

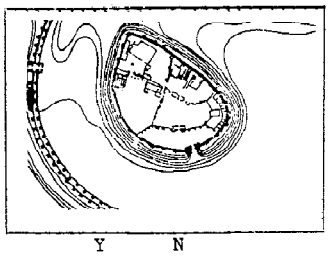
Part 2 (3 minutes)

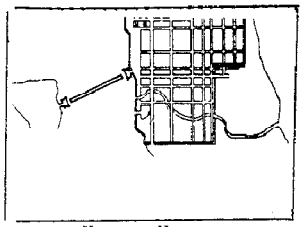


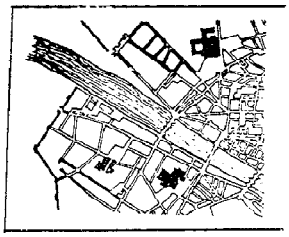
DO NOT TURN THIS PAGE UNTIL ASKED TO DO SO.

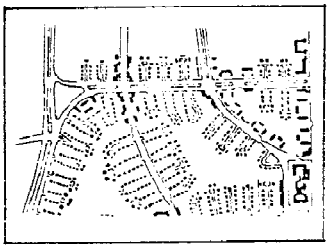
STOP.

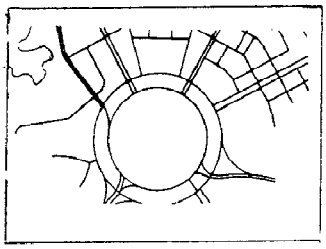
Part 2 (3 minutes)

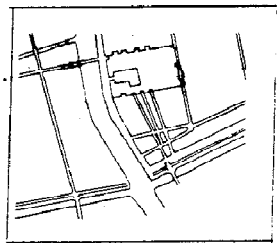
13. 
Y N

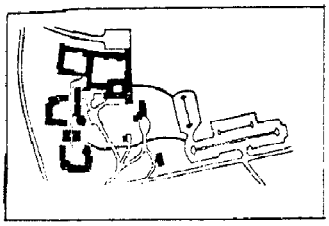
14. 
Y N

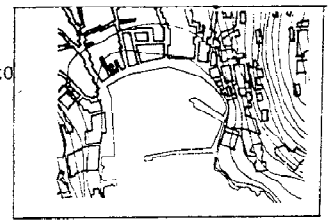
15. 
Y N

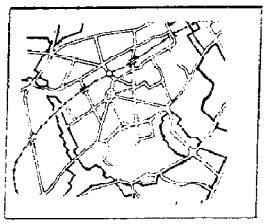
16. 
Y N

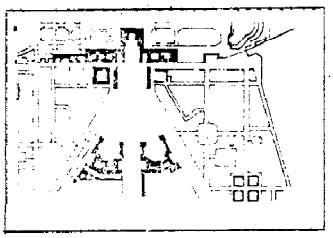
17. 
Y N

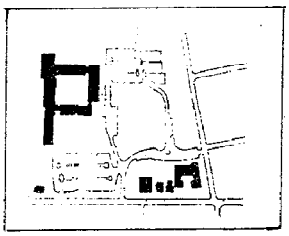
18. 
Y N

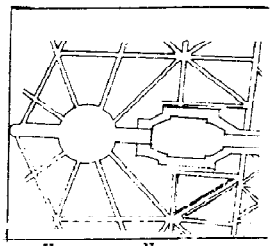
19. 
Y N

20. 
Y N

21. 
Y N

22. 
Y N

23. 
Y N

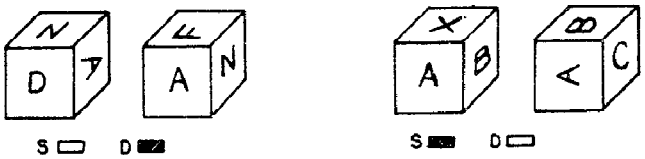
24. 
Y N

DO NOT GO BACK TO PART 1 AND
DO NOT GO ON TO ANY OTHER TEST UNTIL ASKED TO DO SO.

STOP.

CUBE COMPARISONS TEST -- S-2 (Rev.)

Wooden blocks such as children play with are often cubical with a different letter, number, or symbol on each of the six faces (top, bottom, four sides). Each problem in this test consists of drawings of pairs of cubes or blocks of this kind. Remember, there is a different design, number, or letter on each face of a given cube or block. Compare the two cubes in each pair below.

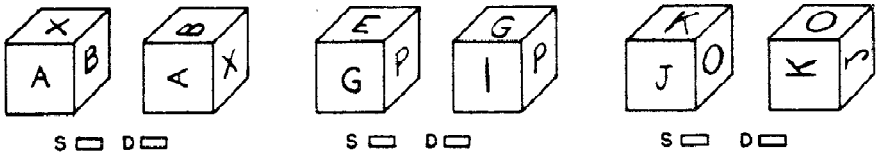


The first pair is marked D because they must be drawings of <u>different</u> cubes. If the left cube is turned so that the A is upright and facing you, the N would be to the left of the A and hidden, not to the right of the A as is shown on the right hand member of the pair. Thus, the drawings must be of different cubes.

The second pair is marked S because they could be drawings of the same cube. That is, if the A is turned on its side the X becomes hidden, the B is now on top, and the C (which was hidden) now appears. Thus the two drawings could be of the same cube.

<u>Note</u>: No letters, numbers, or symbols appear on more than one face of a given cube. Except for that, <u>any</u> letter, number or symbol can be on the hidden faces of a cube.

Work the three examples below.



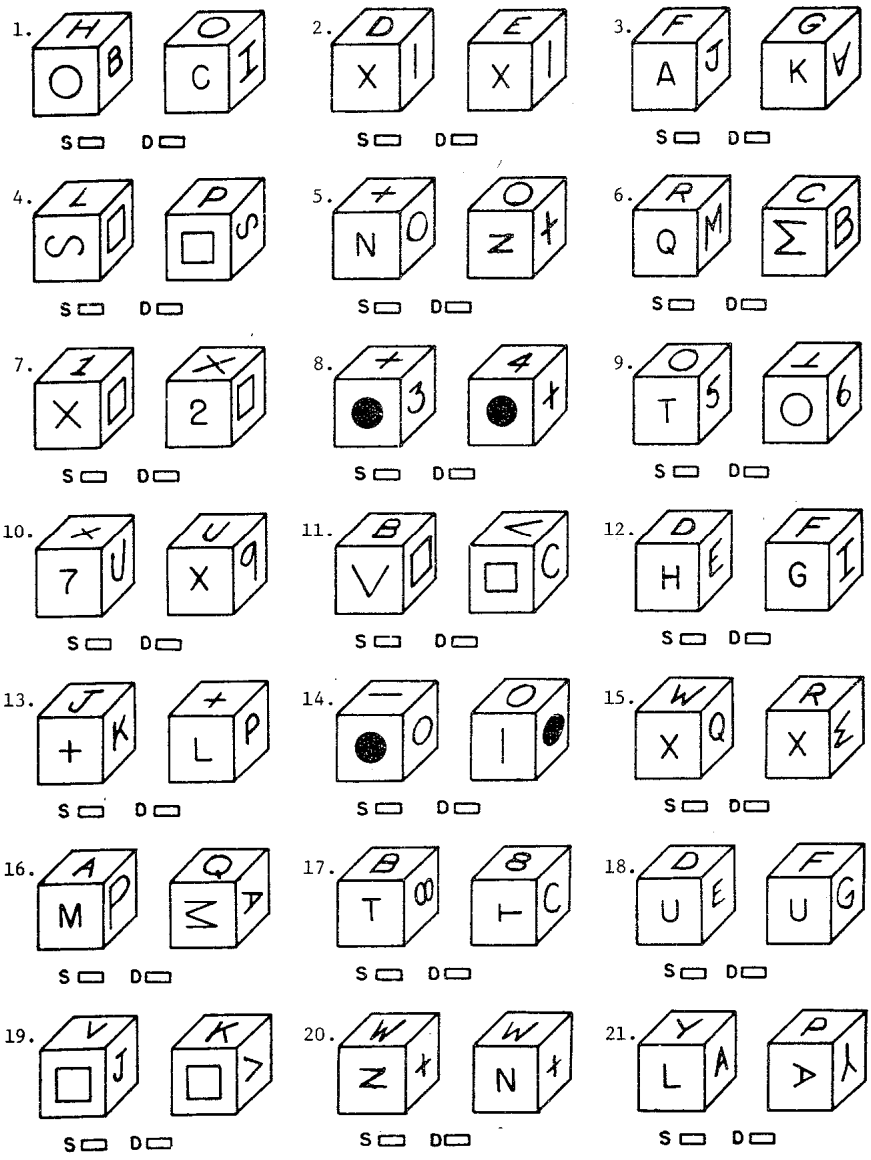
The first pair immediately above should be marked D because the X cannot be at the peak of the A on the left hand drawing and at the base of the A on the right hand drawing. The second pair is "different" because P has its side next to G on the left hand cube but its top next to G on the right hand cube. The blocks in the third pair are the same, the J and K are just turned on their side, moving the O to the top.

Your score on this test will be the number marked correctly minus the number marked incorrectly. Therefore, it will <u>not</u> be to your advantage to guess unless you have some idea which choice is correct. Work as quickly as you can without sacrificing accuracy.

You will have <u>3 minutes</u> for each of the two parts of this test. Each part has one page. When you have finished Part 1, STOP.

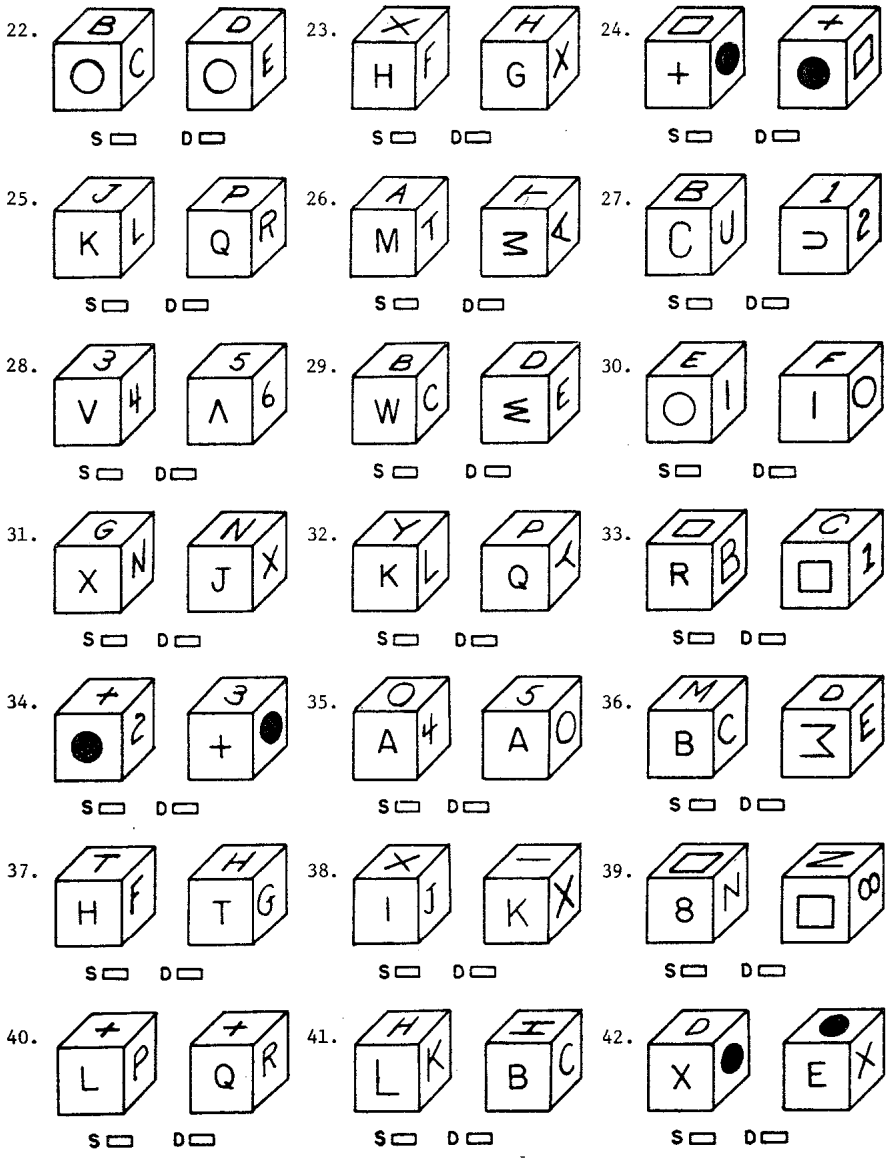
DO NOT TURN THE PAGE UNTIL YOU ARE ASKED TO DO SO.

Part 1 (3 minutes)



DO NOT GO ON TO THE NEXT PAGE UNTIL ASKED TO DO SO. STOP.

Part 2 (3 minutes)

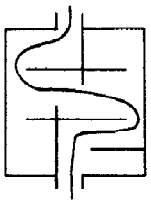
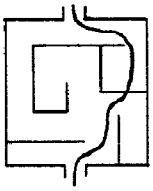


DO NOT GO BACK TO PART 1 AND
DO NOT GO ON TO ANY OTHER TEST UNTIL ASKED TO DO SO. STOP.

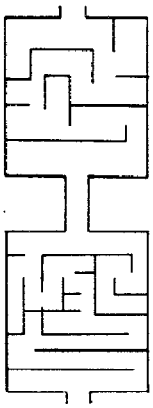
MAZE TRACING SPEED TEST — SS-1

This is a test of your ability to find a path through a maze quickly. You are to draw a pencil line through each maze without having to cross any printed lines.

Look at the two drawings below. In the left square a pencil line has been drawn to show the correct path from top to bottom. The square on the right shows an incorrect path. It is incorrect because the pencil line crosses a printed line.

CORRECT  INCORRECT 

Practice for speed on the squares below. Remember, you must make a pencil line through each square without having to cross a printed line.

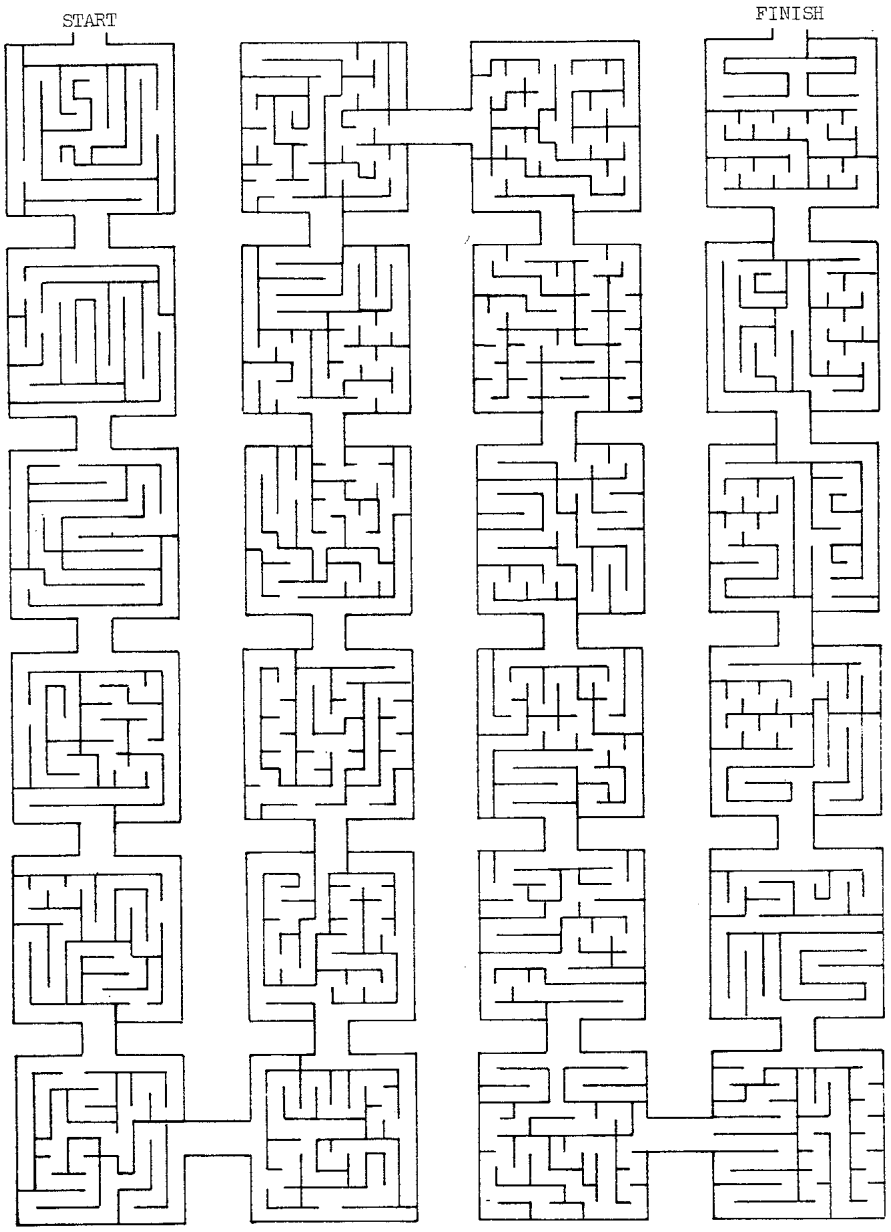


Your score on this test will be the number of squares through which a line has been correctly drawn. If you should become stuck in any square, you may skip to the following one. You should try to avoid making mistakes, but you will not be penalized for lifting your pencil, for retracing a path that leads to a dead end, or for accidentally crossing lines at the sides of the path being taken. Work as quickly as you can without sacrificing accuracy. On the test, follow the squares around the page the way that they are connected, starting at the top of the left-hand column.

You will have 3 minutes for each of the two parts of this test. Each part has 1 page. When you have finished Part 1, STOP. Please do not go on to Part 2 until you are asked to do so.

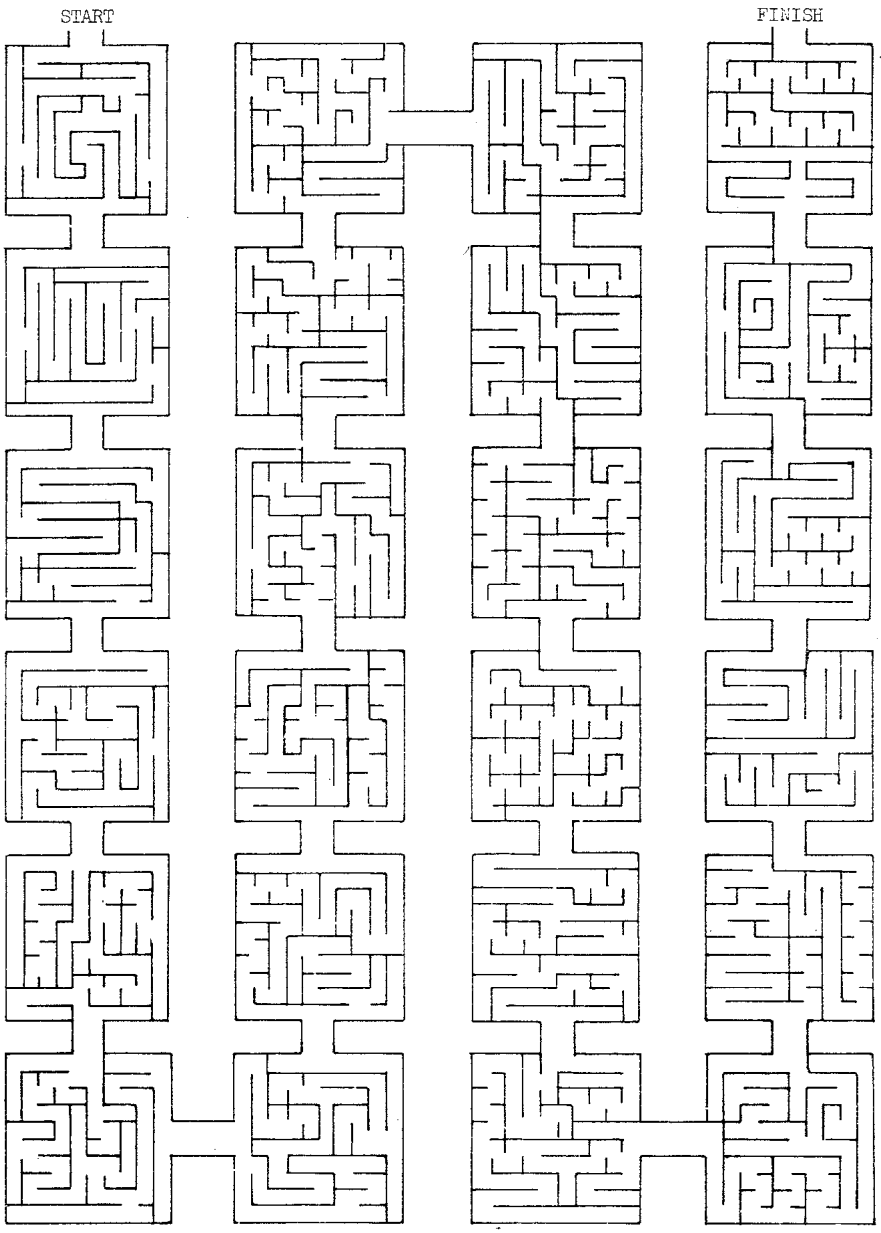
DO NOT TURN THIS PAGE UNTIL ASKED TO DO SO.

Part 1 (3 minutes)



DO NOT GO ON TO THE NEXT PAGE UNTIL ASKED TO DO SO. STOP.

Part 2 (3 minutes)

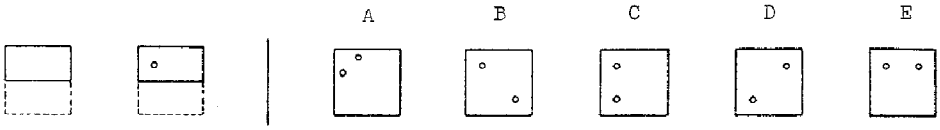


DO NOT GO BACK TO PART 1, AND
DO NOT GO ON TO ANY OTHER TEST UNTIL ASKED TO DO SO. STOP.

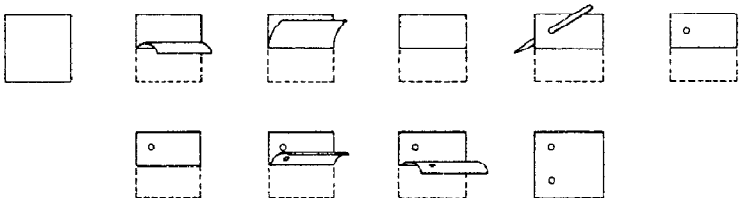
PAPER FOLDING TEST — VZ-2

In this test you are to imagine the folding and unfolding of pieces of paper. In each problem in the test there are some figures drawn at the left of a vertical line and there are others drawn at the right of the line. The figures at the left represent a square piece of paper being folded, and the last of these figures has one or two small circles drawn on it to show where the paper has been punched. Each hole is punched through all the thicknesses of paper at that point. One of the five figures at the right of the vertical line shows where the holes will be when the paper is completely unfolded. You are to decide which one of these figures is correct and draw an X through that figure.

Now try the sample problem below. (In this problem only one hole was punched in the folded paper.)



The correct answer to the sample problem above is C and so it should have been marked with an X. The figures below show how the paper was folded and why C is the correct answer.



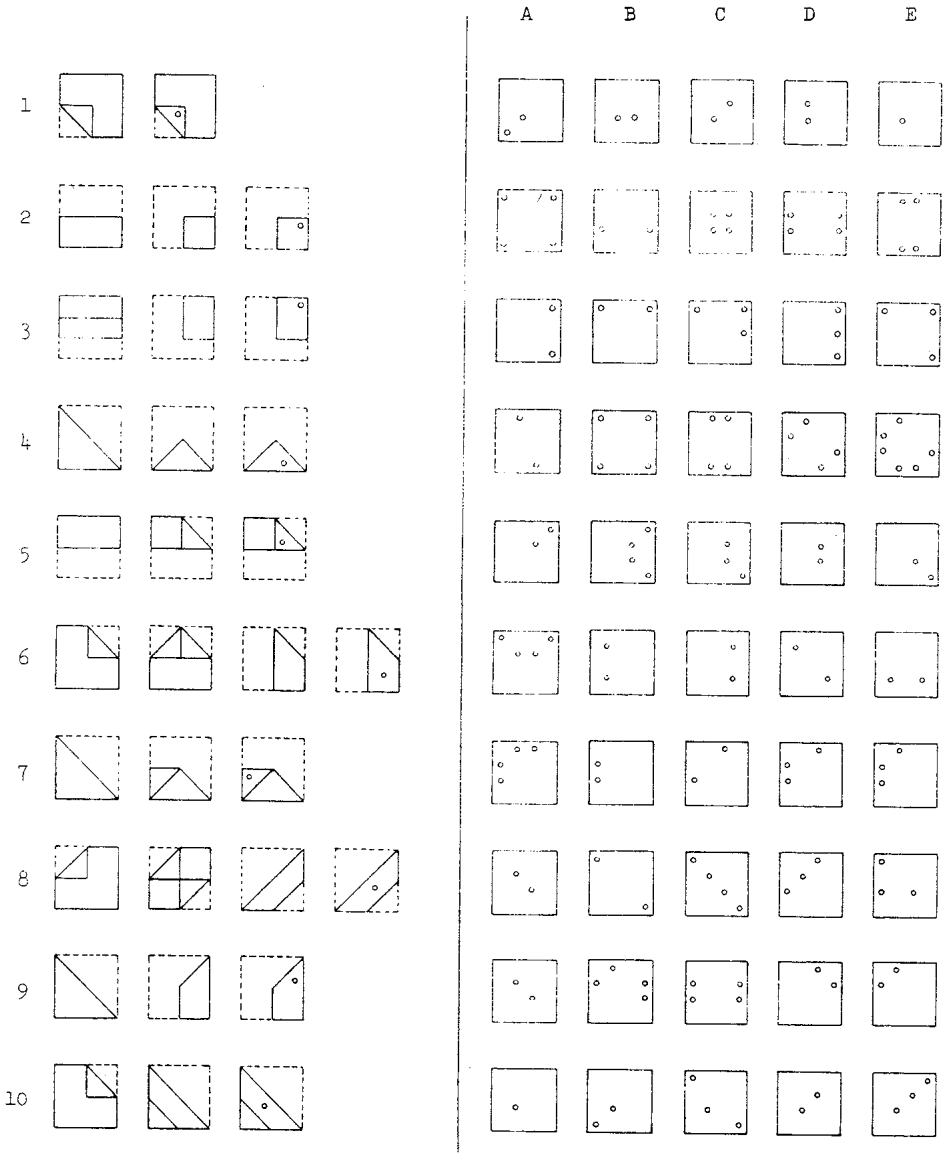
In these problems all of the folds that are made are shown in the figures at the left of the line, and the paper is not turned or moved in any way except to make the folds shown in the figures. Remember, the answer is the figure that shows the positions of the holes when the paper is completely unfolded.

Your score on this test will be the number marked correctly minus a fraction of the number marked incorrectly. Therefore, it will not be to your advantage to guess unless you are able to eliminate one or more of the answer choices as wrong.

You will have 3 minutes for each of the two parts of this test. Each part has 1 page. When you have finished Part 1, STOP. Please do not go on to Part 2 until you are asked to do so.

DO NOT TURN THIS PAGE UNTIL ASKED TO DO SO.

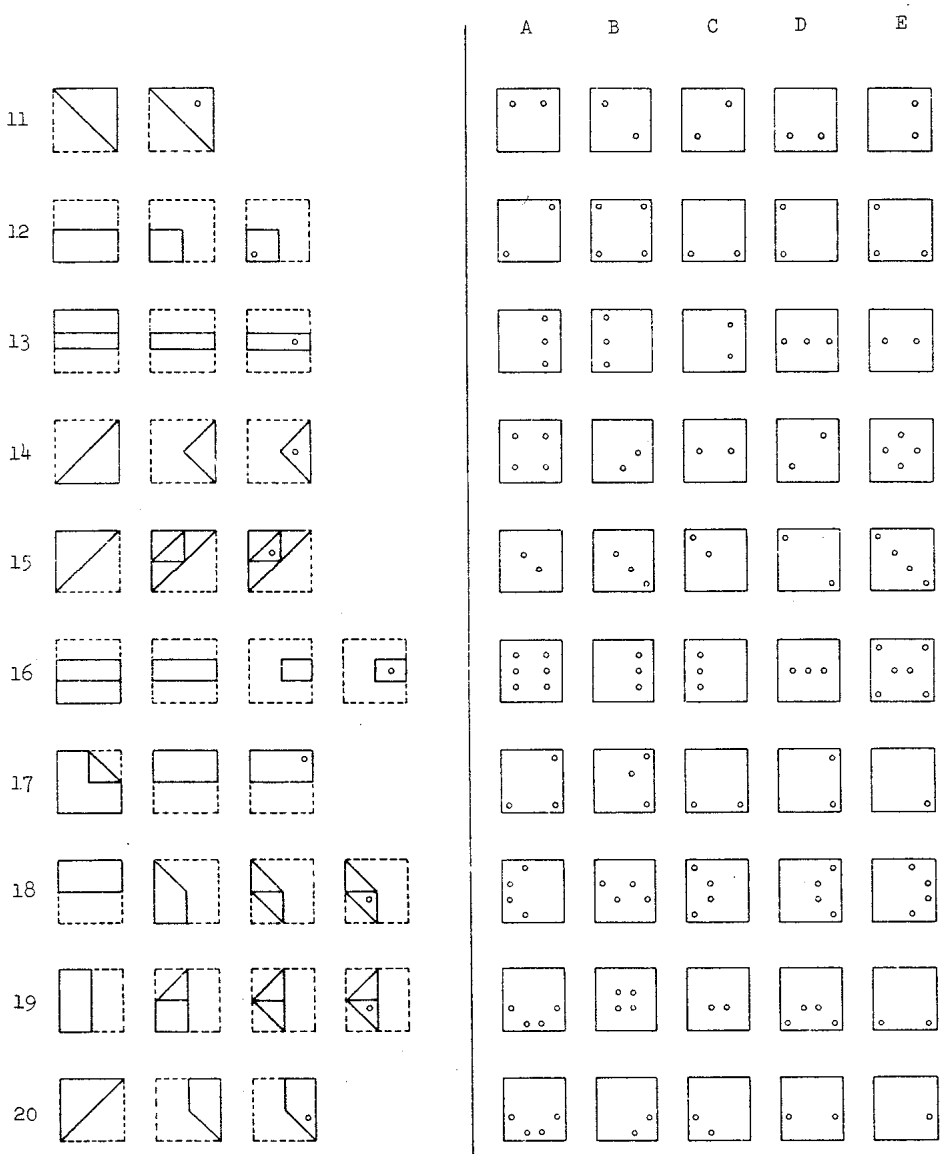
Part 1 (3 minutes)



DO NOT GO ON TO THE NEXT PAGE UNTIL ASKED TO DO SO.

STOP.

Part 2 (3 minutes)



DO NOT GO BACK TO PART 1, AND

DO NOT GO ON TO ANY OTHER TEST UNTIL ASKED TO DO SO. STOP.

APPENDIX F

PROGRAMS AND COMPREHENSION TESTS

This appendix contains a training program (temperature conversion) followed by a number of comprehension questions, and two test programs (currency conversion and discounts) followed by their respective comprehension questions.

Training Program

The purpose of the following program is to ask the user for a temperature in degrees Fahrenheit, convert it to the equivalent temperature in degrees Celsius, display the values, and print the state of water at that temperature. You will have 4 minutes to read and understand the program.

Source Code

```
# include <stdio.h>
int main( )
{
     double f_temp;
     double c_temp;
     char answer;

     do
     {
          f_temp = Get_Temp( );
          c_temp = Convert_Temp(f_temp);
          Print_State (f_temp, c_temp);
     cout << endl << "Convert another temperature(y/n) ? ";
          cin >> answer;
     } while (( answer == 'y') || (answer == 'Y'));

     return (0);
}

double Get_Temp ( )
{
     const double ABSOLUTE_ZERO =  - 459.67;
```

```
     double temperature;

     do
     { cout << "What is the Fahrenheit temperature? "

           cin >> temperature;
           if (temperature < ABSOLUTE_ ZERO)

{
             cout << "Please enter a temperature greater
than or"<< endl;
             cout << "equal to absolute zero (" <<
                     ABSOLUTE_ZERO << ") ."<< endl;
         }
     } while (temperature < ABSOLUTE_ZERO);

      return (temperature);
}

double Convert_Temp (double fahrenheit)
{
     double celsius;
     celsius = (fahrenheit -32) * 5 / 9;
     return (celsius);
}

void Print_State (double fahr, double cels)
{
     cout << endl << fahr << "degrees Fahrenheit is
approximately" << endl;
     count<< cels << " degrees Celsius. The state of water
at that" << endl;
     cout << "temperature is ";

     if ( cels < 0)
          cout << "solid";
     else if ( cels == 0)
          cout << "indeterminate";
     else if ( cels < 100)
          cout << "liquid";
     else if ( cels == 100)
          cout << "indeterminate";
     else
          cout <<"gas";
     cout<< "."<< endl;
     return;
}
```

Training Program Comprehension Questions

Please read the following questions carefully and answer all the questions by encircling the appropriate options. You will have 1 minute and 30 seconds to complete this section.

1. Is the user asked for a Fahrenheit temperature, again, if the entered temperature is below absolute zero?
   a. Yes
   b. No

2. Is it a goal of the program to print values for the freezing point and the boiling point of water?
   a. Yes
   b. No

3. Does the value of c_temp affect the value of f_temp?
   a. Yes
   b. No

4. Is the Print_State() function located near the end of the program than the beginning?
   a. Yes
   b. No

5. When getting the temperature from the user, is the state of water at that temperature printed?
   a. Yes
   b. No

6. Does the statement "celsius = (fahrenheit – 32) *5/9" appear in the program?
   a. Yes
   b. No

Currency Conversion Program

The purpose of the following program is to accept an amount of currency (e.g., dollars) from the user, convert it to a different currency (e.g., French Francs), and display the results. You will have 12 minutes to read and understand the program.

Source Code

```
#include <iostream.h>
#include <math.h>
#include <iomanip.h>

int main()
{
     int src_currency;
     double src_amount;
     int dst_currency;
     double dst_amount;
     double dollars;
     char answer;

     do
     {
          Get_Currency (src_currency, src_amount,
dst_currency);
          dollars = TO_Dollars (src_currency, src_amount);
          dst_amount = From_Dollars (dst_currency,dollars);
          Print_Amounts (src_currency, src_amount,
                         dst_currency, dst_amount);
          cout<< endl << "Would you like to exchange more
currency (y/n)? ";
          cin>> answer;
     } while ((answer == 'Y' || (answer == 'y'));
     return (0);
}

void Get_Currency (int & from_type, double & from_amount,
int & to_type)
{
     const int MAX_TYPE = 3;
```

```
     do
     {
          Types_Menu ();
          cout<< endl <<"What currency do you have?";
          cin>>from_type;
     } while ((from_type <=0) || (from_type > MAX_TYPE));

     do
     {
          cout<<endl << "What amount would you like to
exchange ?";
          cin>> from_amount;
     } while (from_amount <=0);
     from_amount = floor (from_amount);

     do
     {
          Types Menu ();
          cout <<endl << "What currency would you like?";
          cin>> to_type;
     } while ((to_type <=0) || (to_type > MAX_TYPE));

     return;
}

void Types_Menu()
{
     cout<< endl << endl << "Currency Types"<< endl <<endl;
     cout<< " 1) Dollars"<< endl;
     cout<< " 2) French Francs"<<endl;
     cout<< " 3) Netherland Guilders"<<endl;
     return;
}

double To_Dollars (int cur_type, double orig_amount)
{
     const double FF_RATE = 0.1563;
     const double NLG_RATE = 0.5128;
     double dollar_amount;
     dollar_amount =0;
```

```
     if (cur_type == 1)
          dollar_amount = orig_amount;
     else if (cur_type == 2)
          dollar_amount = orig_amount * FF_RATE;
     else if (cur_type == 3)
          dollar_amount = orig_amount * NLG_RATE;
     else
          cout<< "No rate for currency type" << cur_type
<<endl;
     return (dollar_amount);
}

double From_Dollars (int cur_type, double dollar_amount)
{
     const double FF_RATE = 0.1563;
     const double NLG_RATE = 0.5128;
     double new_amount;

     new_amount =0;
     switch (cur_type)
     {
          case 1:
               new_amount = dollar_amount;
               break;
          case 2:
               new_amount = dollar_amount/ FF_RATE;
               break;
          case 3:
               new_amount = dollar_amount/ NLG_RATE;
               break;
          default:
               cout<< "No rate for currency type \""
<<cur_type<<"\""<<endl;
               break;
     }
     new_amount = floor(new_amount);
     return (new_amount);
}
```

```
Void Print_Amounts(int from_type, double from_amount, int
to_type, double to_amount)
{
     const int LABEL_WIDTH =15;
     const int DATA_WIDTH = 10;
     double commission;
     double total;

     cout.setf(ios::showpoint);
     cout.setf(ios::fixed);
     cout.precision(2);
     cout<< endl << endl;
     Print_Type(from_type);
     cout<< endl << setw(LABEL_WIDTH) << "Original amount";
     cout<< setw(DATA_WIDTH) << from_amount <<endl;
     commission = from_amount / 100;
     cout<< setw(LABEL_WIDTH) <<"Commission";
     cout<< setw(DATA_WIDTH) << commission <<endl;
     total = commission + from_amount;
     cout<< setw(LABEL_WIDTH) <<"Total";
     cout<< setw(DATA_WIDTH) << total<<endl;
     cout<<endl <<endl;
     Print_Type(to_type);
     cout<<endl << setw(LABEL_WIDTH) << "New amount";
     cout<<setw(DATA_WIDTH) << to_amount;
     cout<<endl;
     Print_Denominations (to_type, to_amount);

     return;
}

void Print_Type(int currency_type)
{
     cout<<"Currency:";
     switch (currency_type)
     {
          case 1:
               cout<<"Dollars";
               break;

          case 2:
```

```
                cout<<"French_Francs";
                break;
          case 3:
                cout<<"Netherland_Guilders";
                break;
          default:
                cout<<"unknown";
                break;
     }

     cout<<endl;

     return;
}


Void Print_Denominations(int currency_type, double
curency_amount)
{
     cout<<endl << "You will receive the following
denominations:"<<endl;
     switch (currency_type)
     {
          case 1:
                Denom_Dollars(currency_amount);
                break;
          case 2:
                Denom_French_Francs(currency_amount);
                break;
          case 3:
                Denom_Netherland_Guilders(currency_amount);
                break;
          default:
                cout<< "Unknown currency type for
denominations"<<endl;
                break;
     }

     return;
}
```

```
void Denom_Dollars (double orig_dollars)
{
     const int NUM_WIDTH =5;
     int whole_dollars;
     int num_bills;

     whole_dollars = int(orig_dollars);
     num_bills = whole_dollars /1000;
     whole_dollars %= 1000;
     if (num_bills)
          cout<<"1000 dollar bills"<<setw(NUM_WIDTH)<<
num_bils<<endl;

     num_bills = whole_dollars/ 500;
     whole_dollars %= 500;
     if (num_bills)
         cout<<"500 dollar bills"<<setw(NUM_WIDTH)<<
num_bils<<endl;

     num_bills = whole_dollars/ 100;
     whole_dollars %= 100;
     if (num_bills)
          cout<<"100 dollar bills"<<setw(NUM_WIDTH)<<
num_bils<<endl;

     num_bills = whole_dollars/50;
     whole_dollars %= 50;
     if (num_bills)
          cout<<"50 dollar bills"<<setw(NUM_WIDTH)<<
num_bils<<endl;

     num_bills = whole_dollars/ 20;
     whole_dollars %= 20;
     if (num_bills)
          cout<<"20 dollar bills"<<setw(NUM_WIDTH)<<
num_bils<<endl;

     num_bills = whole_dollars/ 10;
     whole_dollars %= 10;
     if (num_bills)
```

```
          cout<<"10 dollar bills"<<setw(NUM_WIDTH)<<
num_bils<<endl;

     num_bills = whole_dollars/ 5;
     whole_dollars %= 5;
     if (num_bills)
          cout<<"5 dollar bills"<<setw(NUM_WIDTH)<<
num_bils<<endl;

     if (whole_dollars)
          cout<<" 1 dollar bills"<<setw(NUM_WIDTH) <<
whole_dollars<<endl;
     return;
}


void Denom_French_Francs (double orig_francs)
{
     const int NUM_WIDTH = 5;
     int whole_francs;
     int num_bills;

     whole_francs = int(orig_francs);
     num_bills = whole_francs/ 500;
     whole_francs %= 500;
     if (num_bills)
          cout<<"500 franc notes " <<setw(NUM_WIDTH) <<
num_bills<< endl;

     num_bills = whole_francs/ 200;
     whole_francs %= 200;
     if (num_bills)
          cout<<"200 franc notes " <<setw(NUM_WIDTH) <<
num_bills<< endl;

     num_bills = whole_francs/ 100;
     whole_francs %= 100;
     if (num_bills)
         cout<<"100 franc notes " <<setw(NUM_WIDTH) <<
num_bills<< endl;
```

```
     num_bills = whole_francs/ 50;
     whole_francs %= 50;
     if (num_bills)
         cout<<"50 franc notes " <<setw(NUM_WIDTH) <<
num_bills<< endl;

     num_bills = whole_francs/ 20;
     whole_francs %= 20;
     if (num_bills)
         cout<<"20 franc notes " <<setw(NUM_WIDTH) <<
num_bills<< endl;

     num_bills = whole_francs/ 10;
     whole_francs %= 10;
     if (num_bills)
         cout<<"10 franc notes " <<setw(NUM_WIDTH) <<
num_bills<< endl;


     num_bills = whole_francs/ 5;
     whole_francs %= 5;
     if (num_bills)
         cout<<"5 franc notes " <<setw(NUM_WIDTH) <<
num_bills<< endl;

     num_bills = whole_francs/ 2;
     whole_francs %= 2;
     if (num_bills)
          cout<<"2 franc notes " <<setw(NUM_WIDTH) <<
num_bills<< endl;

     if (whole_francs)
          cout<<" 1 franc notes"<<setw(NUM_WIDTH) <<
whole_francs<<endl;
     return;
}

void Denom_Netherland_Guilders (double orig_guilders)
{
     const int NUM_WIDTH = 5;
     int whole_guilders;
```

```
     int num_bills;

     whole_guilders = int(orig_guilders);
     num_bills = whole_guilders/ 500;
     whole_guilders %= 500;
     if (num_bills)
          cout<<"500 guilder notes " <<setw(NUM_WIDTH) <<
num_bills<< endl;

     num_bills = whole_guilders/ 250;
     whole_guilders %= 250;
     if (num_bills)
          cout<<"250 guilder notes " <<setw(NUM_WIDTH) <<
num_bills<< endl;


     num_bills = whole_guilders/ 100;
     whole_guilders %= 100;
     if (num_bills)
          cout<<"100 guilder notes " <<setw(NUM_WIDTH) <<
num_bills<< endl;

     num_bills = whole_guilders/ 50;
     whole_guilders %= 50;
     if (num_bills)
          cout<<"50 guilder notes " <<setw(NUM_WIDTH) <<
num_bills<< endl;

     num_bills = whole_guilders/ 25;
     whole_guilders %= 25;
     if (num_bills)
          cout<<"25 guilder notes " <<setw(NUM_WIDTH) <<
num_bills<< endl;

     num_bills = whole_guilders/ 10;
     whole_guilders %= 10;
     if (num_bills)
          cout<<"10 guilder notes " <<setw(NUM_WIDTH) <<
num_bills<< endl;

     num_bills = whole_guilders/ 5;
```

```
     whole_guilders %= 5;
     if (num_bills)
          cout<<"5 guilder` notes " <<setw(NUM_WIDTH) <<
num_bills<< endl;

     if (whole_guilders)
          cout<<" 1 guilder notes"<<setw(NUM_WIDTH) <<
whole_guilders<<endl;
     return;
}
```

Currency Conversion Program Comprehension Questions

Please read the following questions carefully and answer all the questions by encircling the appropriate options. The following questions are classified as five modules and each module has six questions. You will have 7 minutes and 30 seconds to complete this section.

A) Statement Sequential

1. Is the statement that calculates the commission physically located after the statement which prints the original amount?
   a. Yes
   b. No

2. Is the statement that calculates the number of 50 dollar bills physically located after the statement that calculates the number of 20 dollar bills?
   a. Yes
   b. No

3. Is the statement which converts Netherland Guilders to dollars physically located after the statement that converts French Francs to dollars?
   a. Yes
   b. No

4. Is the statement that prints dollars as a choice of currency physically located after the statement that prints Netherland Guilders as a choice of currency?
   a. Yes
   b. No

5. Is the statement that asks for the amount of the original currency physically located after the statement that asks for the types of original currency?
   a. Yes
   b. No

6. Is the statement that prints the commission physically located after the statement that prints the amount of the new currency?
   a. Yes
   b. No

B) Control Flow

1. Is the new currency type compared to French Francs after the comparison with dollars fails when converting to dollars?
   a. Yes
   b. No

2. Is the number of 500 dollar bills in a dollar amount calculated after the number of 100 dollars bills is calculated?
   a. Yes
   b. No

3. Is the amount of the original currency obtained from the user after the type of the original currency is obtained?
   a. Yes
   b. No

4. Is the new currency amount printed after the denominations of the new currency amount are printed?
   a. Yes
   b. No

5. Is “French Francs” printed after “Netherland Guilders” when printing the menu of currency types?
   a. Yes
   b. No

6. Is the original currency amount always converted to dollars after the type and amount of the original currency are entered?
   a. Yes
   b. No

C) Data Flow

1. Does the value of dollar_amount affect the value of new_amount?
   a. Yes
   b. No

2. Does the value of to_amount affect the value of commission?
   a. Yes
   b. No

3. Does the value of src_amount affect the value of dst_amount?
   a. Yes
   b. No

4. Does the value of answer affect the value of to_type?
   a. Yes
   b. No

5. Does the value of src_currency affect the value of dst_currency?
   a. Yes
   b. No

6. Does the value of dst_amount affect the value of whole_dollars?
   a. Yes
   b. No

D) Interactions

1. When the original currency type is entered by the user, is that used in the step that calculates the new currency amount?
   a. Yes
   b. No

2. When the denominations for French Francs are calculated and printed, is the original currency amount used in those steps?
   a. Yes
   b. No

3. When dollars are converted to another currency, is the converted amount used in printing the denominations?
   a. Yes
   b. No

4. When the currency types and amounts are printed, are denominations calculated and printed?
   a. Yes
   b. No

5. When the user is asked for the new currency type, are the possible currency types displayed in alphabetic order?
   a. Yes
   b. No

6. When the original currency amount is converted to dollars, is that dollars amount also printed in the output?
   a. Yes
   b. No

E) Cross-referencing

1. When converting the original currency amount to dollars, is an error message displayed if there is no match for the currency type?
   a. Yes
   b. No

2. When getting the currency information from the user, is the user asked for the percentage of the commission?
   a. Yes
   b. No

3. When determining the denominations for French Francs, are the smallest denominations calculated first?
   a. Yes
   b. No

4. When printing the denominations for Netherland Guilders, is 500 Guilders the largest denomination calculated?
   a. Yes
   b. No

5. When converting Guilders to Guilders, is the original currency amount simply copied to the new currency amount?
   a. Yes
   b. No

6. When the output is displayed, is a commission calculated for the exchange?
   a. Yes
   b. No

Discounts Program

The purpose of the following program is to ask the user for the number of units to be sold, the cost per unit, the weight of each unit, and the choice for shipping method. A percentage of discount is determined and then costs are calculated and displayed. You will have 12 minutes to read and understand the program.

Source Code

```
# include <iostream.h>
# include<iomanip.h>

int main()
{
      int num-units;
      double unit_cost;
      double unit_weight;
      int ship_choice;
      double ship_cost;
      int discount_percent;
      double total_cost;
      double discount_cost;
      double new_cost;
      char response;
      do
      {
            Get_Unit_Info(num_units, unit_cost, unit_weight,
ship_choice);
            discount_percent = Find_Discount (num_units,
unit_cost);
            Calcualte_Costs (num_units, unit_cost,
discount_percent, total_cost,
            discount_amount, new_cost);
            Print_Costs ( num_units, unit_cost,
discount_percent, total_cost,
            discount_amount, new_cost);
            Print_Shipping (num_units, unit_weight,
ship_choice, ship_cost);
            cout<<endl << " The total cost including shipping
            is $" <<
            new_cost + ship_cost<<"."<<endl;
            cout<<endl <<"Would you like to enter another
```

```
          unit (y/n)? ";
           cin>>response;

     }while ((response = = 'Y' ) || (response = = 'y'));

     return (0);
}

void Get_Unit_Info (int & units, double &cost, double
&weight, int &ship)
{
     const int MAX_SHIP_CHOICE =4;
     do
     {
          cout<<endl <<"How many units are being sold?";
          cin>> units;
          if (units <= 0)
               cout<<"Please enter a value greater than
                       0."<<endl <<endl;
     } while(units <=0);

     do
     {
          cout<<endl <<"What is the cost per unit?";
          cin>> cost;
          if (cost <= 0)
               cout<<"Please enter a cost greater than
                     0."<<endl <<endl;
     } while(costs <=0);

     do
     {
          cout<<endl <<"What is the weight per unit?";
          cin>> weight;
          if (weight<= 0)
               cout<<"Please enter a weight greater than
                      0."<<endl <<endl;
     } while(weight <=0);

     do
     {
```

```
            Ship_Menu();
            cout<<"Choice?";
            cin>>ship;
            if ((ship <= 0) || (ship > MAX_SHIP_CHOICE))
                 cout<<"Please enter a choice from the
                        menu"<<endl;
      } while ((ship <= 0) || (ship> MAX_SHIP_CHOICE));
      return;
}


void Ship_Menu()
{
      cout<<endl <<endl <<"Shipping choices"<<endl;
      cout<<" 1) Next-day air" <<endl;
      cout<<" 2) Second-day air" <<endl;
      cout<<" 3) One week delivery <<endl;
      cout<<" 4) Overland express" <<endl;
      return;
}

int Find_Discount (int units, double cost)
{
      int rate;

      if (units < 10)
            rate= Level_One(cost);
      else if (units < 20)
            rate = Level_Two(cost);
      else if (units < 50)
            rate = Level_Three(cost);
      else if (units < 100)
            rate = Level_Four(cost);
      else
            rate = Level_Five(cost);

      return(rate);
}

int Level_One(double level_cost)
{
```

```
     int lelvel_rate;

     if (level_cost < 10)
          level_rate = 0;
     else if (level_cost < 100)
          level_rate= 2;
     else if (level_cost < 500)
          level_rate = 5;
     else
          level_rate = 7;

     return (level_rate);
}

int Level_Two(double level_cost)
{
     int lelvel_rate;

     if (level_cost < 10)
          level_rate = 5;
     else if (level_cost < 100)
          level_rate= 7;
     else if (level_cost < 500)
          level_rate = 9;
     else
          level_rate = 11;

     return (level_rate);
}

int Level_Three(double level_cost)
{
     int lelvel_rate;

     if (level_cost < 10)
          level_rate = 9;
     else if (level_cost < 100)
          level_rate= 15;
     else if (level_cost < 500)
          level_rate = 21;
     else
```

```
          level_rate = 27;

     return (level_rate);
}

int Level_Four(double level_cost)
{
     int lelvel_rate;

     if (level_cost < 10)
          level_rate = 14;
     else if (level_cost < 100)
          level_rate= 23;
     else if (level_cost < 500)
          level_rate = 32;
     else
          level_rate = 41;

     return (level_rate);
}

int Level_Five(double level_cost)
{
     int lelvel_rate;

     if (level_cost < 10)
          level_rate = 21;
     else if (level_cost < 100)
          level_rate= 32;
     else if (level_cost < 500)
          level_rate = 43;
     else
          level_rate = 54;

     return (level_rate);
}

void Calculate_Costs(int units, double cost_per_unit, int
discount_rate, double &  extended_cost,
                                        double &
reduced_amount, double & dsicounted_cost)
```

```
{
     extended_cost = units * cost_per_unit;
     reduced_amount = (extended_cost * discount_rate) /
100;
     discounted_cost = extended_cost -  reduced_amount;
     return;
}

void Print_Costs(int units, double cost_per_unit, int
discount_percent, double
              extended_cost, double reduced_amount, double
discounted_cost)
{
     const int LABEL_WIDTH = 20;
     const int DATA_WIDTH =10;

     cout.setf(ios::showpoint);
     cout.setf(ios::fixed);
     cout.precision(2);
     cout<< endl << endl;
     cout<<setw(LABEL_WIDTH) << "Units:";
     cout<<setw(DATA_WIDTH) << units <<endl;
     cout<<setw(LABEL_WIDTH) << "Unit cost:";
     cout<<setw(DATA_WIDTH) << cost_per_unit<<endl;
     cout<<setw(LABEL_WIDTH) << "Discount:";
     cout<<setw(DATA_WIDTH) << discount_percent<<endl;
     cout<<setw(LABEL_WIDTH) << "Wholesale cost:";
     cout<<setw(DATA_WIDTH) << extended_cost <<endl;
     cout<<setw(LABEL_WIDTH) << "Discount Amount:";
     cout<<setw(DATA_WIDTH) << reduced_amount <<endl;
     cout<<setw(LABEL_WIDTH) << "Total_Cost:";
     cout<<setw(DATA_WIDTH) << discounted_cost<<endl;

     return;
}

void Print_Shipping(int units, double weight, int ship,
double &cost)
{
     const int LABEL_WIDTH = 20;
     const int DATA_WIDTH = 10;
```

```
      const double ONEDAY_RATE = 8.00;
      const double TWODAY_RATE = 4.00;
      const double FIVEDAY_RATE = 1.00;
      const double OVERLAND_RATE = 0.25;
      double toatl_weight;

      cout<<endl <<endl;
      cout<<setw (LABEL_WIDTH) << "Unit Weight:";
      cout<<setw(DATA_WIDTH)  << weight <<endl;
      total_weight =units * weight;
      cout<<setw (LABEL_WIDTH) << "Total Weight:";
      cout<<setw(DATA_WIDTH)  << total_weight <<endl;
      cost = 0;
      switch (ship)
      {

            case 1:
                  cost = total_weight * ONEDAY_RATE;
                  break;
            case 2:
                  cost = total_weight * TWODAY_RATE;
                  break;
            case 3:
                  cost = total_weight * FIVEEDAY_RATE;
                  break;
            case 4:
                  cost = total_weight * OVERLAND_RATE;
                  break;
            default:
                  cout<<"Unknown shipping choice"<<
ship<<endl;
                  break;
      }

      cout<<setw (LABEL_WIDTH) << "Shipping Cost:";
      cout<<setw(DATA_WIDTH)  << cost<<endl;
      cout<<setw (LABEL_WIDTH) << "Ship Method";
      cout<<setw(DATA_WIDTH) ;
      switch (ship)
      {
            case 1:
```

```
                cout<< "next-day air";
                break;
           case 2:
                cout<< "two-day air";
                break;
           case 3:
                cout<< "one week delivery";
                break;

           case 4:
                cout<< "overland express";
                break;
           default:
                cout<<"Unknown shipping choice"<<
                      ship<<endl;
                break;
     }

     cout<<endl;

     return;
}
```

Discounts Program Comprehension Questions

Please read the following questions carefully and answer all the questions by encircling the appropriate options. The following questions are classified as five modules and each module has six questions. You will have 7 minutes and 30 seconds to complete this section.

A) Statement Sequential

1. Is the statement that asks for the cost of a unit physically located after the statement asks for the shipping method?
   a. Yes
   b. No

2. Is the statement that calculates the discount cost physically located after the statement that calculates the reduced amount?
   a. Yes
   b. No

3. Is the statement that prints the shipping method physically located after the statement that prints the shipping cost?
   a. Yes
   b. No

4. Is the statement that calculates the extended cost physically located after the statement that calculates the discounted cost?
   a. Yes
   b. No

5. Is the statement that asks for the weight of each unit physically located after the statement that asks for the number of units?
   a. Yes
   b. No

6. Is the statement that prints the total weight physically located after the statement that prints the shipping cost?
   a. Yes
   b. No

B) Control flow

1. Is the shipping method printed after the shipping cost is printed?
   a. Yes
   b. No

2. Is the weight of the unit asked after the user enter 0 (zero) for the cost of the unit?
   a. Yes
   b. No

3. Is the number of units checked after the unit cost is checked when finding the discount?
   a. Yes
   b. No

4. Is the warning message printed after the user enters 0 (zero) for the number units?
   a. Yes
   b. No

5. Is the extended cost calculated after the discount cost?
   a. Yes
   b. No

6. Is the percent of the discount found after all of the information about the unit has been entered by the user?
   a. Yes
   b. No

C) Data Flow

1. Does the value of extended_cost affect the value of reduced_amount?
   a. Yes
   b. No

2. Does the value of unit cost affect the value of discount percent?
   a. Yes
   b. No

3. Does the value of ship_choice affect the value of discount_amount?
   a. Yes
   b. No

4. Does the value of unit_weight affect the value of unit_cost?
   a. Yes
   b. No

5. Does the value of ship_cost affect the value of total_cost?
   a. Yes
   b. No

6. Does the value of cost_per_unit affect the value of extended_cost?
   a. Yes
   b. No

D) Interactions

1. When finding the discount, is the rate of the discount finally determined from the cost of the unit?
   a. Yes
   b. No

2. When getting the information from the user, is list of the possible shipping methods displayed?
   a. Yes
   b. No

3. When calculating the costs, are the shipping cost printed?
   a. Yes
   b. No

4. When getting the information from the user, is the discount percentage determined?
   a. Yes
   b. No

5. When printing the shipping information, is the user asked for the shipping method?
   a. Yes
   b. No

6. When printing the shipping cost, is that amount also used elsewhere to display a final, combined cost?
   a. Yes
   b. No

E) Cross – referencing

1. When finding the discount, is there a discount for fewer than 100 units?
   a. Yes
   b. No

2. When calculating the costs, is the amount of tax calculated?
   a. Yes
   b. No

3. When getting information from the user, is an error message displayed if ther is no match for the selected shipping method?
   a. Yes
   b. No

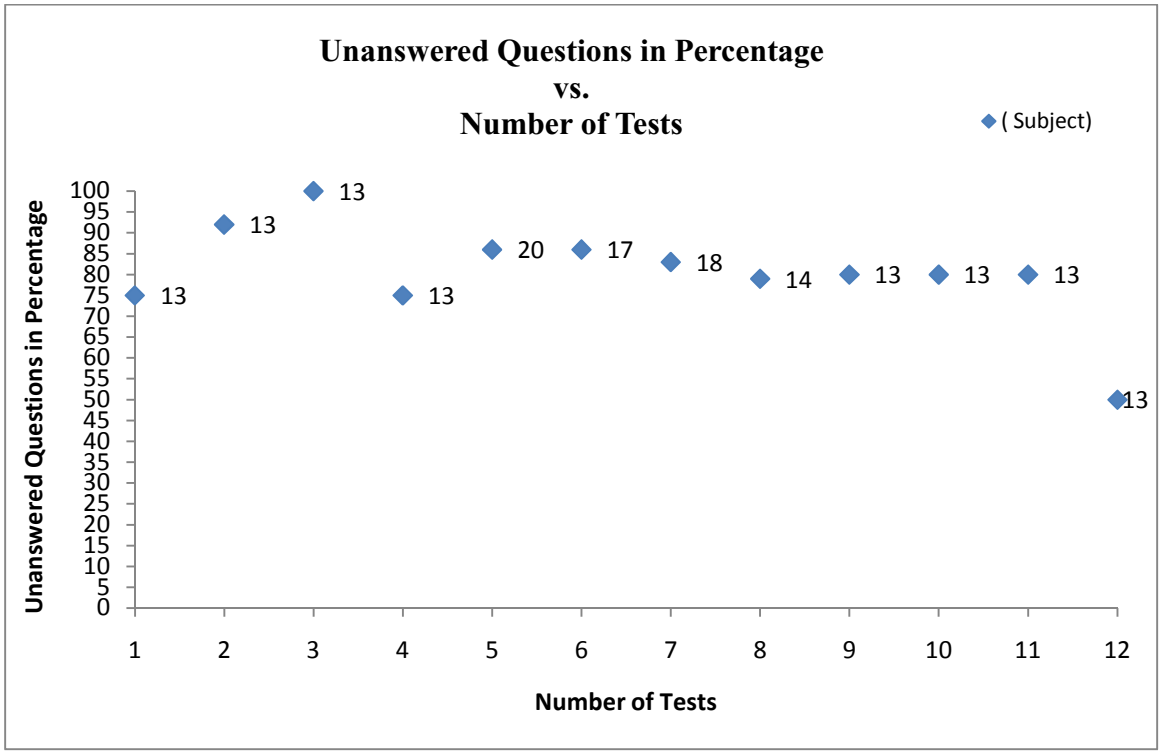
4. When printing the shipping information, is the shipping cost calculated?
   a. Yes
   b. No

5. When getting information from the user, is the weight for the total number of units printed?
   a. Yes
   b. No

6. When printing the costs, is the discounted cost calculated?
   a. Yes
   b. No

APPENDIX G

OUTLIER GRAPH



APPENDIX H

TEST RESULTS (SCORING ANALYSIS)

Building Memory (MV-2) Part 1

Subject	C/C+I	C/T	C-I/C+I	C-I/T	FS/C+I	FS/T	OCS	OCS+P
1	100	100	100	100	100	100	100	100
2	64	58	27	25	56	52	60	53
3	92	92	83	83	90	90	92	90
4	64	58	27	25	56	52	60	53
5	42	42	-17	-17	30	30	42	30
6	42	42	-17	-17	30	30	42	30
7	67	67	33	33	60	60	67	60
8	83	83	67	67	80	80	83	80
9	92	92	83	83	90	90	92	90
10	44	33	-11	-8	33	25	38	30
11	42	42	-17	-17	30	30	42	30
12	92	92	83	83	90	90	92	90
14	55	50	9	8	45	42	52	43
15	92	92	83	83	90	90	92	90
16	100	92	100	92	100	92	93	93
17	67	67	33	33	60	60	67	60
18	25	25	-50	-50	10	10	25	10
19	100	100	100	100	100	100	100	100
20	92	92	83	83	90	90	92	90
21	100	83	100	83	100	83	87	87
22	45	42	-9	-8	35	32	43	33
23	25	17	-50	-33	10	7	23	13
24	78	58	56	42	73	55	63	60
25	60	50	20	17	52	43	53	47
26	50	17	0	0	40	13	30	27
27	100	100	100	100	100	100	100	100
28	100	75	100	75	100	75	80	80
29	71	42	43	25	66	38	50	47
30	83	83	67	67	80	80	83	80

Map Memory (MV-3) Part 1

Subject	C/C+I	C/T	C-I/C+I	C-I/T	FS/C+I	FS/T	OCS	OCS+P
1	92	92	83	83	88	88	92	88
2	92	92	83	83	88	88	92	88
3	92	92	83	83	88	88	92	88
4	100	100	100	100	100	100	100	100
5	83	83	67	67	75	75	83	75
6	83	83	67	67	75	75	83	75
7	75	75	50	50	63	63	75	63
8	100	100	100	100	100	100	100	100
9	100	100	100	100	100	100	100	100
10	100	100	100	100	100	100	100	100
11	83	83	67	67	75	75	83	75
12	100	100	100	100	100	100	100	100
14	92	92	83	83	88	88	92	88
15	92	92	83	83	88	88	92	88
16	73	67	45	42	59	54	71	58
17	92	92	83	83	88	88	92	88
18	75	75	50	50	63	63	75	63
19	83	83	67	67	75	75	83	75
20	92	92	83	83	88	88	92	88
21	58	58	17	17	38	38	58	38
22	92	92	83	83	88	88	92	88
23	64	58	27	25	45	42	63	46
24	100	58	100	58	100	58	79	79
25	100	100	100	100	100	100	100	100
26	100	83	100	83	100	83	92	92
27	92	92	83	83	88	88	92	88
28	100	100	100	100	100	100	100	100
29	100	100	100	100	100	100	100	100
30	100	83	100	83	100	83	92	92

Cube Comparison Test (S-2) Part 1

Subject	C/C+I	C/T	C-I/C+I	C-I/T	FS/C+I	FS/T	OCS	OCS+P
1	80	19	60	14	70	17	57	55
2	91	48	82	43	86	45	71	69
3	92	52	83	48	88	50	74	71
4	100	57	100	57	100	57	79	79
5	36	19	-27	-14	5	2	43	26
6	58	33	17	10	38	21	55	43
7	56	24	11	5	33	14	52	43
8	78	33	56	24	67	29	62	57
9	52	52	5	5	29	29	52	29
10	70	33	40	19	55	26	60	52
11	56	24	11	5	33	14	52	43
12	89	38	78	33	83	36	67	64
14	57	19	14	5	36	12	52	45
15	57	19	14	5	36	12	52	45
16	60	29	20	10	40	19	55	45
17	80	19	60	14	70	17	57	55
18	56	48	11	10	33	29	55	36
19	82	43	64	33	73	38	67	62
20	100	14	100	14	100	14	57	57
21	56	24	11	5	33	14	52	43
22	71	24	43	14	57	19	57	52
23	40	10	-20	-5	10	2	48	40
24	100	33	100	33	100	33	67	67
25	88	33	75	29	81	31	64	62
26	60	29	20	10	40	19	55	45
27	40	10	-20	-5	10	2	48	40
28	89	38	78	33	83	36	67	64
29	64	43	29	19	46	31	60	48
30	100	33	100	33	100	33	67	67

Maze Tracing Speed Test (SS-1)

Subject	C/C+I	C/T	C-I/C+I	C-I/T	FS/C+I	FS/T	OCS	OCS+P
1	100	25	100	25	100	25	63	63
2	100	21	100	21	100	21	60	60
3	100	50	100	50	100	50	75	75
4	100	58	100	58	100	58	79	79
5	86	25	71	21	79	23	60	58
6	100	38	100	38	100	38	69	69
7	100	38	100	38	100	38	69	69
8	100	25	100	25	100	25	63	63
9	100	63	100	63	100	63	81	81
10	25	8	-50	-17	-13	-4	42	29
11	100	21	100	21	100	21	60	60
12	86	25	71	21	79	23	60	58
14	60	13	20	4	40	8	52	48
15	100	21	100	21	100	21	60	60
16	100	50	100	50	100	50	75	75
17	100	33	100	33	100	33	67	67
18	100	17	100	17	100	17	58	58
19	91	42	82	38	86	40	69	67
20	89	33	78	29	83	31	65	63
21	80	17	60	13	70	15	56	54
22	100	25	100	25	100	25	63	63
23	63	21	25	8	44	15	54	48
24	80	33	60	25	70	29	63	58
25	85	46	69	38	77	42	69	65
26	91	42	82	38	86	40	69	67
27	100	25	100	25	100	25	63	63
28	100	25	100	25	100	25	63	63
29	100	42	100	42	100	42	71	71
30	100	29	100	29	100	29	65	65

Paper Folding Test (VZ-2) Part 1

Subject	C/C+I	C/T	C-I/C+I	C-I/T	FS/C+I	FS/T	OCS	OCS+P
1	100	80	100	80	100	80	84	84
2	100	30	100	30	100	30	44	44
3	100	100	100	100	100	100	100	100
4	100	100	100	100	100	100	100	100
5	80	40	60	30	76	38	50	48
6	25	20	-50	-40	10	8	24	12
7	67	60	33	30	60	54	62	56
8	86	60	71	50	83	58	66	64
9	100	80	100	80	100	80	84	84
10	17	10	-67	-40	0	0	18	8
11	75	30	50	20	70	28	42	40
12	100	60	100	60	100	60	68	68
14	60	30	20	10	52	26	40	36
15	100	40	100	40	100	40	52	52
16	100	60	100	60	100	60	68	68
17	80	40	60	30	76	38	50	48
18	63	50	25	20	55	44	54	48
19	100	70	100	70	100	70	76	76
20	80	40	60	30	76	38	50	48
21	75	30	50	20	70	28	42	40
22	100	50	100	50	100	50	60	60
23	50	20	0	0	40	16	32	28
24	88	70	75	60	85	68	74	72
25	88	70	75	60	85	68	74	72
26	67	20	33	10	60	18	34	32
27	100	80	100	80	100	80	84	84
28	83	50	67	40	80	48	58	56
29	80	80	60	60	76	76	80	76
30	100	70	100	70	100	70	76	76

APPENDIX I

CORRELATION ANALYSIS

Building Memory Test (MV-2)

	C/C+I	C/T	C-I/C+I	C-I/T	FS/C+I	FS/T	OCS	OCS+P
C/C+I		0.93	1.00	0.99	1.00	0.96	0.96	0.98
C/T	0.93		0.93	0.96	0.93	1.00	0.99	0.98
C-I/C+I	1.00	0.93		0.99	1.00	0.96	0.96	0.98
C-I/T	0.99	0.96	0.99		0.99	0.98	0.98	0.99
FS/C+I	1.00	0.93	1.00	0.99		0.96	0.96	0.98
FS/T	0.96	1.00	0.96	0.98	0.96		1.00	0.99
OCS	0.96	0.99	0.96	0.98	0.96	1.00		1.00
OCS+P	0.98	0.98	0.98	0.99	0.98	0.99	1.00	

Map Memory Test (MV-3)

	C/C+I	C/T	C-I/C+I	C-I/T	FS/C+I	FS/T	OCS	OCS+P
C/C+I		0.76	1	0.93	1	0.87	0.93	0.97
C/T	0.76		0.76	0.95	0.76	0.98	0.94	0.9
C-I/C+I	1	0.76		0.93	1	0.87	0.93	0.97
C-I/T	0.93	0.95	0.93		0.93	0.99	1	0.99
FS/C+I	1	0.76	1	0.93		0.88	0.93	0.97
FS/T	0.87	0.98	0.87	0.99	0.88		0.99	0.97
OCS	0.93	0.94	0.93	1	0.93	0.99		0.99
OCS+P	0.97	0.9	0.97	0.99	0.97	0.97	0.99	

Cube Comparison Test (S-2)

	C/C+I	C/T	C-I/C+I	C-I/T	FS/C+I	FS/T	OCS	OCS+P
C/C+I		0.76	1.00	0.93	1.00	0.87	0.93	0.97
C/T	0.76		0.76	0.95	0.76	0.98	0.94	0.90
C-I/C+I	1.00	0.76		0.93	1.00	0.87	0.93	0.97
C-I/T	0.93	0.95	0.93		0.93	0.99	1.00	0.99
FS/C+I	1.00	0.76	1.00	0.93		0.88	0.93	0.97
FS/T	0.87	0.98	0.87	0.99	0.88		0.99	0.97
OCS	0.93	0.94	0.93	1.00	0.93	0.99		0.99
OCS+P	0.97	0.90	0.97	0.99	0.97	0.97	0.99	

Maze Tracing Speed Test (SS-1)

	C/C+I	C/T	C-I/C+I	C-I/T	FS/C+I	FS/T	OCS	OCS+P
C/C+I		0.46	1.00	0.70	1.00	0.60	0.70	0.83
C/T	0.46		0.46	0.95	0.45	0.99	0.95	0.86
C-I/C+I	1.00	0.46		0.70	1.00	0.60	0.70	0.83
C-I/T	0.70	0.95	0.70		0.70	0.99	1.00	0.98
FS/C+I	1.00	0.45	1.00	0.70		0.59	0.70	0.83
FS/T	0.60	0.99	0.60	0.99	0.59		0.99	0.94
OCS	0.70	0.95	0.70	1.00	0.70	0.99		0.98
OCS+P	0.83	0.86	0.83	0.98	0.83	0.94	0.98	

Paper Folding Test (VZ-2)

	C/C+I	C/T	C-I/C+I	C-I/T	FS/C+I	FS/T	OCS	OCS+P
C/C+I		0.70	1.00	0.90	1.00	0.76	0.77	0.83
C/T	0.70		0.69	0.93	0.69	1.00	0.99	0.98
C-I/C+I	1.00	0.69		0.89	1.00	0.76	0.77	0.83
C-I/T	0.90	0.93	0.89		0.90	0.96	0.97	0.99
FS/C+I	1.00	0.69	1.00	0.90		0.76	0.77	0.83
FS/T	0.76	1.00	0.76	0.96	0.76		1.00	0.99
OCS	0.77	0.99	0.77	0.97	0.77	1.00		0.99
OCS+P	0.83	0.98	0.83	0.99	0.83	0.99	0.99	

APPENDIX J

TEST RESULTS (C/T, C- I/T ANALYSIS)

Building Memory (MV-2)

Part 1 Part2 Average of Part 1 & Part 2

Subject	C/T	C-I/T	C/T	C-I/T	Subject	C/T	C-I/T
1	100	100	58	25	1	79	63
2	58	25	58	17	2	58	21
3	92	83	83	67	3	88	75
4	58	25	75	58	4	67	42
5	42	-17	50	8	5	46	-4
6	42	-17	67	33	6	54	8
7	67	33	67	50	7	67	42
8	83	67	58	17	8	71	42
9	92	83	92	83	9	92	83
10	33	-8	67	50	10	50	21
11	42	-17	50	42	11	46	13
12	92	83	58	17	12	75	50
14	50	8	33	-33	14	42	-13
15	92	83	83	67	15	88	75
16	92	92	75	67	16	83	79
17	67	33	92	83	17	79	58
18	25	-50	42	-17	18	33	-33
19	100	100	83	67	19	92	83
20	92	83	83	83	20	88	83
21	83	83	67	67	21	75	75
22	42	-8	67	58	22	54	25
23	17	-33	67	42	23	42	4
24	58	42	75	50	24	67	46
25	50	17	33	17	25	42	17
26	17	0	25	0	26	21	0
27	100	100	100	100	27	100	100
28	75	75	75	75	28	75	75
29	42	25	50	33	29	46	29
30	83	67	100	100	30	92	83

Map Memory Test (MV-3)

	Part 1		Part2		Average of Part 1 & Part 2		
Subject	C/T	C-I/T	C/T	C-I/T	Subject	C/T	C-I/T
1	92	83	92	83	1	92	83
2	92	83	92	83	2	92	83
3	92	83	92	83	3	92	83
4	100	100	83	67	4	92	83
5	83	67	92	92	5	88	79
6	83	67	58	17	6	71	42
7	75	50	83	75	7	79	63
8	100	100	100	100	8	100	100
9	100	100	92	83	9	96	92
10	100	100	50	0	10	75	50
11	83	67	92	83	11	88	75
12	100	100	100	100	12	100	100
14	92	83	42	-17	14	67	33
15	92	83	83	67	15	88	75
16	67	42	67	42	16	67	42
17	92	83	83	75	17	88	79
18	75	50	83	67	18	79	58
19	83	67	83	75	19	83	71
20	92	83	83	75	20	88	79
21	58	17	58	17	21	58	17
22	92	83	42	0	22	67	42
23	58	25	50	0	23	54	13
24	58	58	42	25	24	50	42
25	100	100	100	100	25	100	100
26	83	83	50	25	26	67	54
27	92	83	100	100	27	96	92
28	100	100	92	92	28	96	96
29	100	100	92	83	29	96	92
30	83	83	100	100	30	92	92

Cube Comparison Test (S-2)

	Part 1		Part2		Average of Part 1 & Part 2		
Subject	C/T	C-I/T	C/T	C-I/T	Subject	C/T	C-I/T
1	19	14	24	5	1	21	10
2	48	43	67	62	2	57	52
3	52	48	81	81	3	67	64
4	57	57	95	90	4	76	74
5	19	-14	29	-5	5	24	-10
6	33	10	52	5	6	43	7
7	24	5	33	-33	7	29	-14
8	33	24	57	38	8	45	31
9	52	5	33	10	9	43	7
10	33	19	14	-38	10	24	-10
11	24	5	29	0	11	26	2
12	38	33	57	52	12	48	43
14	19	5	38	-24	14	29	-10
15	19	5	57	52	15	38	29
16	29	10	43	14	16	36	12
17	19	14	10	5	17	14	10
18	48	10	43	5	18	45	7
19	43	33	52	43	19	48	38
20	14	14	38	10	20	26	12
21	24	5	24	5	21	24	5
22	24	14	24	5	22	24	10
23	10	-5	19	-5	23	14	-5
24	33	33	14	-10	24	24	12
25	33	29	57	57	25	45	43
26	29	10	43	38	26	36	24
27	10	-5	57	29	27	33	12
28	38	33	33	24	28	36	29
29	43	19	33	19	29	38	19
30	33	33	24	10	30	29	21

Maze Tracing Speed Test (SS-1)

	Part 1		Part2		Average of Part 1 & Part 2		
Subject	C/T	C-I/T	C/T	C-I/T	Subject	C/T	C-I/T
1	25	25	33	33	1	29	29
2	21	21	29	29	2	25	25
3	50	50	58	58	3	54	54
4	58	58	58	46	4	58	52
5	25	21	21	21	5	23	21
6	38	38	42	42	6	40	40
7	38	38	46	42	7	42	40
8	25	25	21	21	8	23	23
9	63	63	67	58	9	65	60
10	8	-17	25	25	10	17	4
11	21	21	25	25	11	23	23
12	25	21	38	38	12	31	29
14	13	4	21	21	14	17	13
15	21	21	29	25	15	25	23
16	50	50	33	33	16	42	42
17	33	33	42	42	17	38	38
18	17	17	13	8	18	15	13
19	42	38	38	38	19	40	38
20	33	29	33	33	20	33	31
21	17	13	33	33	21	25	23
22	25	25	33	21	22	29	23
23	21	8	13	8	23	17	8
24	33	25	21	21	24	27	23
25	46	38	50	50	25	48	44
26	42	38	50	50	26	46	44
27	25	25	33	33	27	29	29
28	25	25	42	38	28	33	31
29	42	42	54	54	29	48	48
30	29	29	42	42	30	35	35

Paper Folding Test (VZ-2)

	Part 1		Part2		Average of Part 1 & Part 2		
Subject	C/T	C-I/T	C/T	C-I/T	Subject	C/T	C-I/T
1	80	80	80	70	1	80	75
2	30	30	60	50	2	45	40
3	100	100	80	60	3	90	80
4	100	100	80	60	4	90	80
5	40	30	40	-20	5	40	5
6	20	-40	60	20	6	40	-10
7	60	30	80	70	7	70	50
8	60	50	70	40	8	65	45
9	80	80	90	80	9	85	80
10	10	-40	10	-50	10	10	-45
11	30	20	50	30	11	40	25
12	60	60	70	70	12	65	65
14	30	10	50	0	14	40	5
15	40	40	50	40	15	45	40
16	60	60	70	40	16	65	50
17	40	30	50	40	17	45	35
18	50	20	30	-30	18	40	-5
19	70	70	70	40	19	70	55
20	40	30	70	60	20	55	45
21	30	20	30	20	21	30	20
22	50	50	50	40	22	50	45
23	20	0	40	20	23	30	10
24	70	60	50	20	24	60	40
25	70	60	80	80	25	75	70
26	20	10	50	30	26	35	20
27	80	80	70	40	27	75	60
28	50	40	60	50	28	55	45
29	80	60	60	30	29	70	45
30	70	70	70	50	30	70	60

Currency Conversion Program

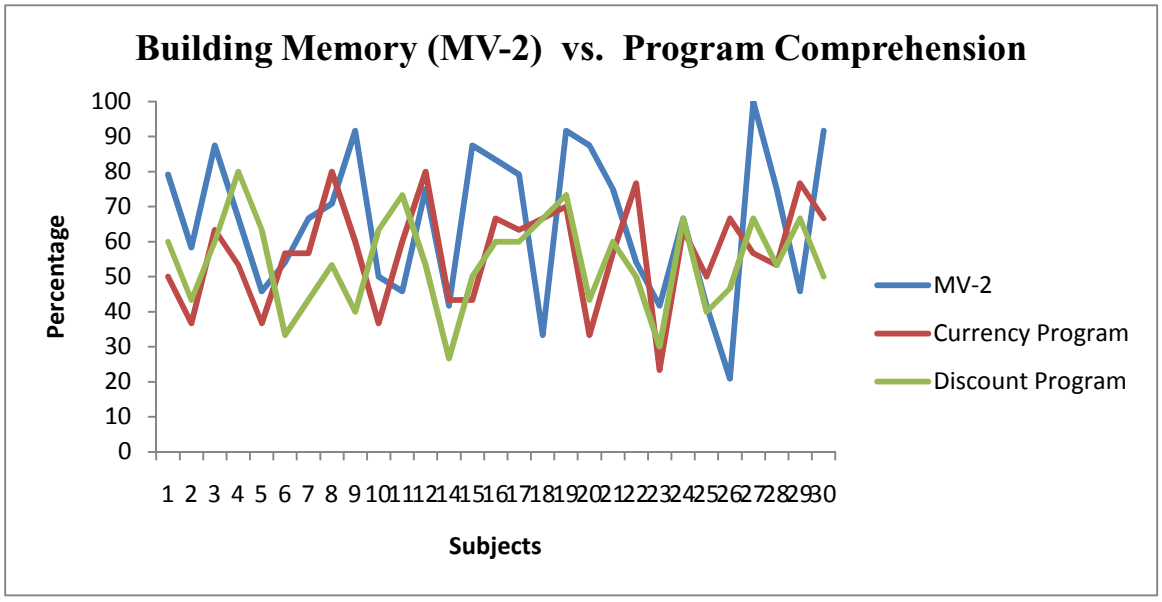
Subject	C/T	C-I/T
1	50	20
2	37	23
3	63	47
4	53	20
5	37	-3
6	57	17
7	57	13
8	80	60
9	60	20
10	37	-10
11	60	20
12	80	60
14	43	-13
15	43	23
16	67	33
17	63	27
18	67	33
19	70	40
20	33	3
21	57	23
22	77	53
23	23	0
24	63	47
25	50	43
26	67	50
27	57	37
28	53	33
29	77	53
30	67	33

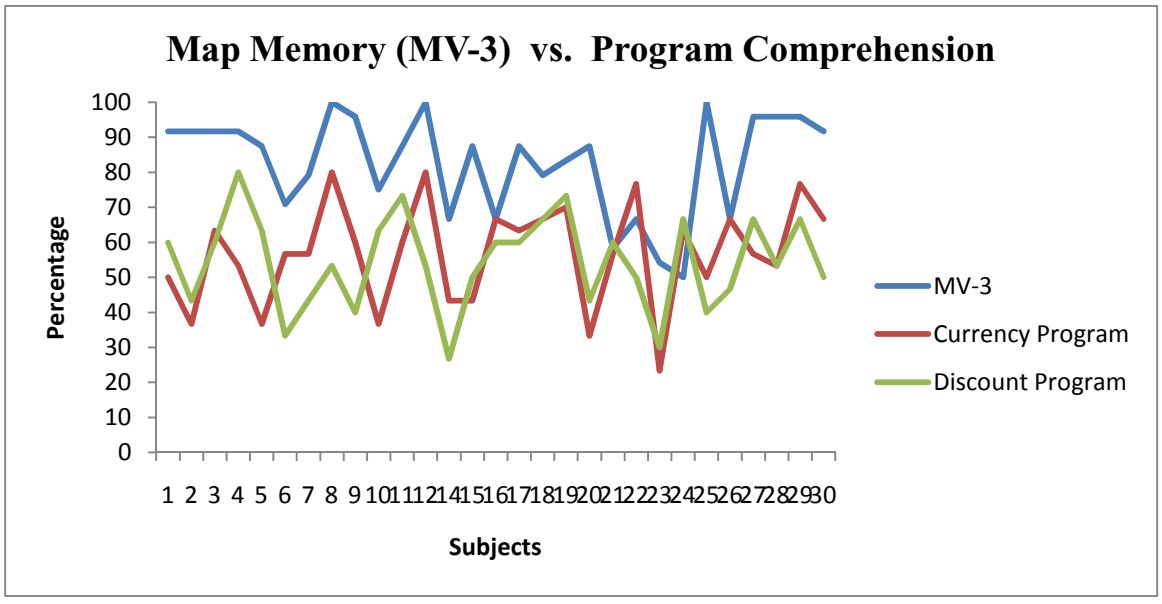
Discount Program

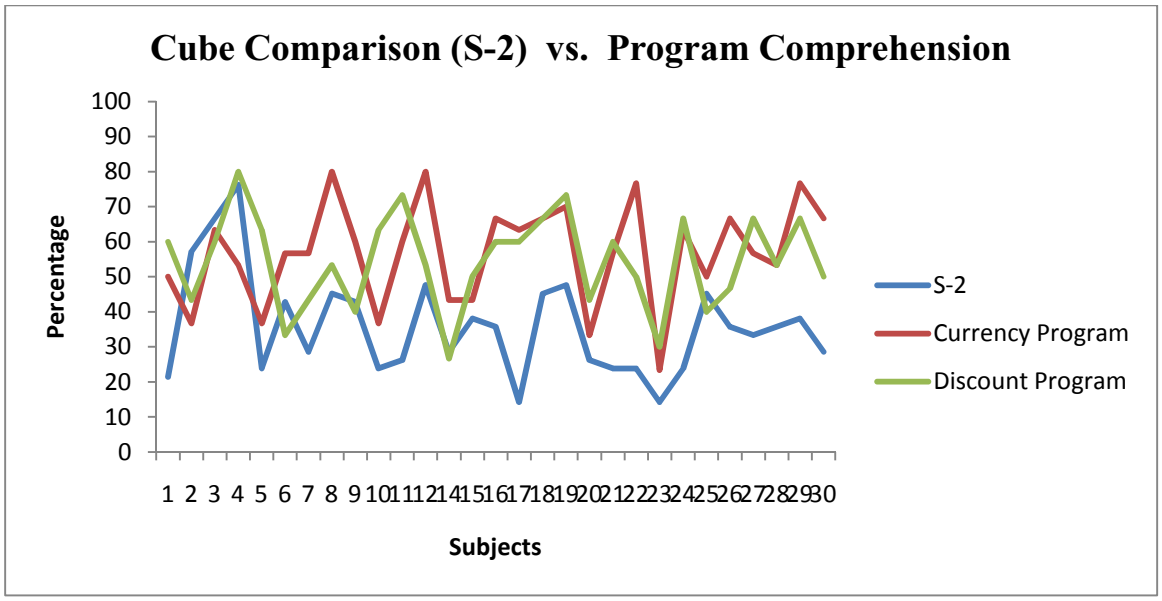
Subject	C/T	C-I/T
1	60	33
2	43	-23
3	60	27
4	80	63
5	63	37
6	33	-17
7	43	-7
8	53	10
9	40	-7
10	63	30
11	73	53
12	53	20
14	27	-43
15	50	10
16	60	23
17	60	27
18	67	43
19	73	63
20	43	13
21	60	23
22	50	17
23	30	-33
24	67	40
25	40	10
26	47	27
27	67	43
28	53	37
29	67	37
30	50	20

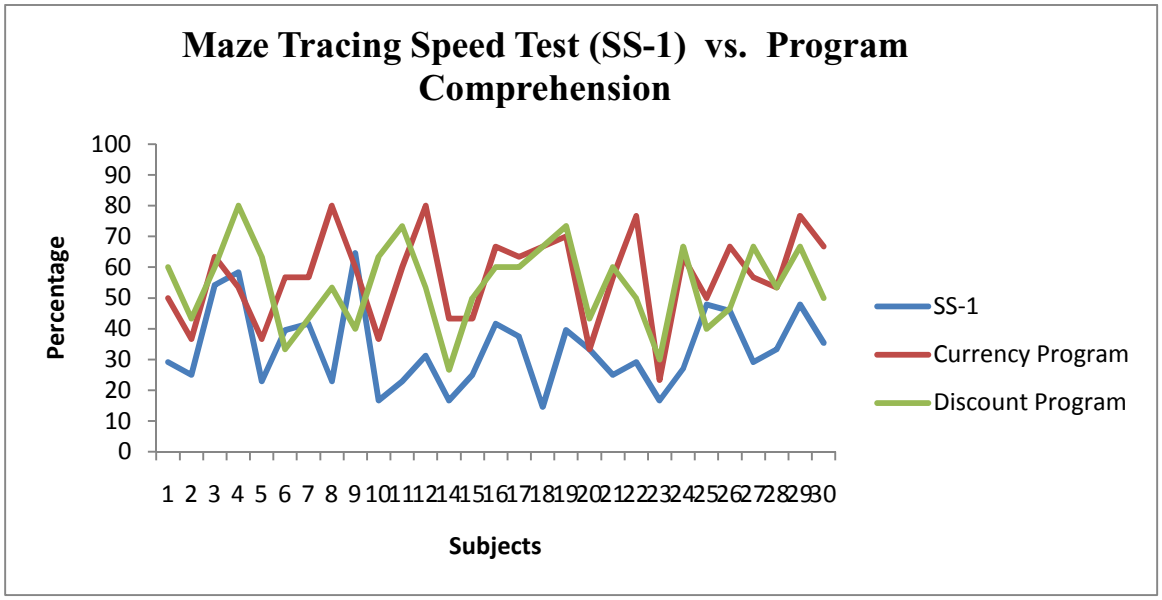
APPENDIX K

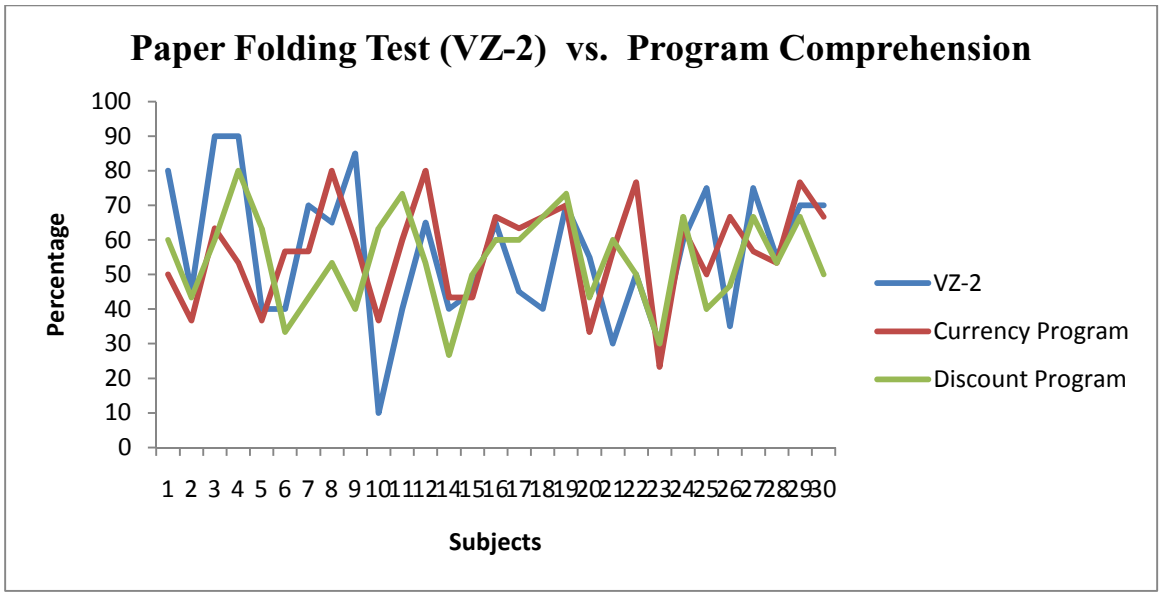
TEST RESULTS (GRAPH ANALYSIS FOR C/T SCORING METHOD)





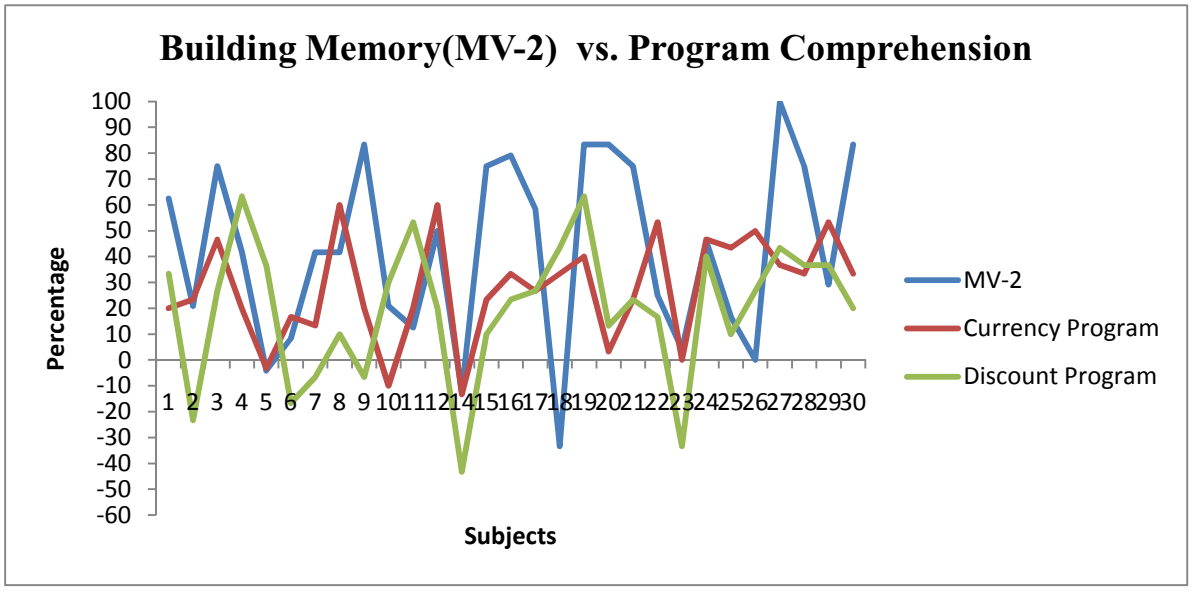


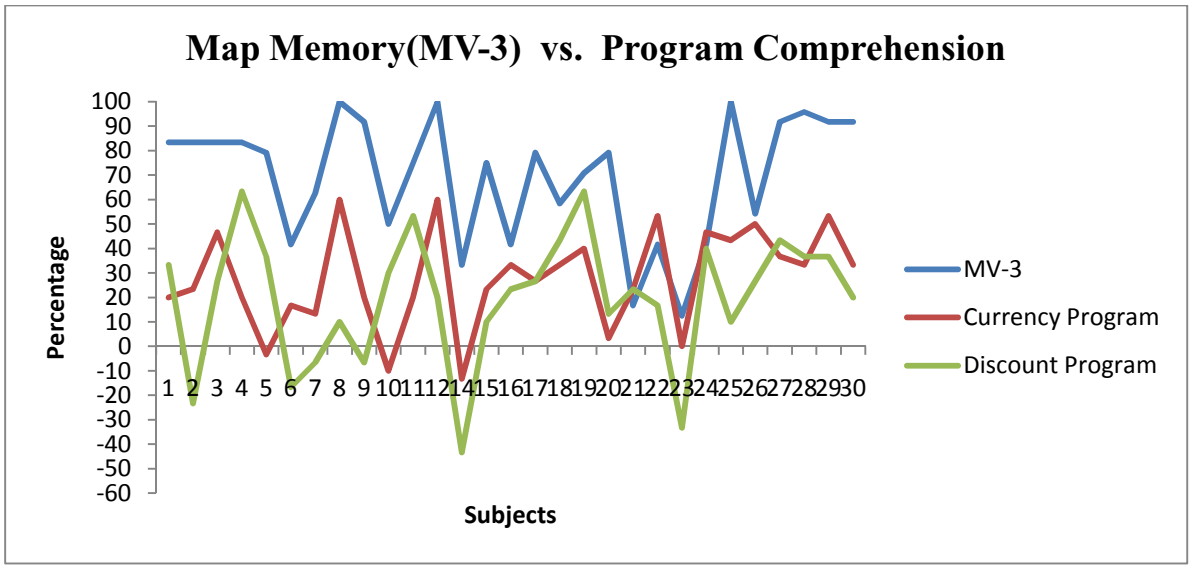


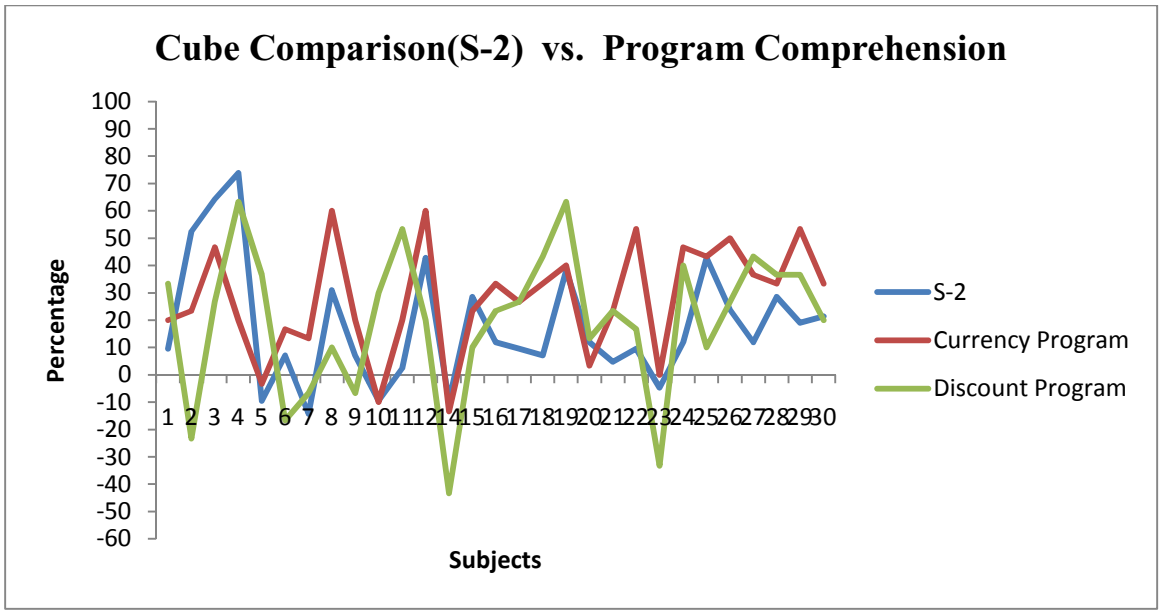


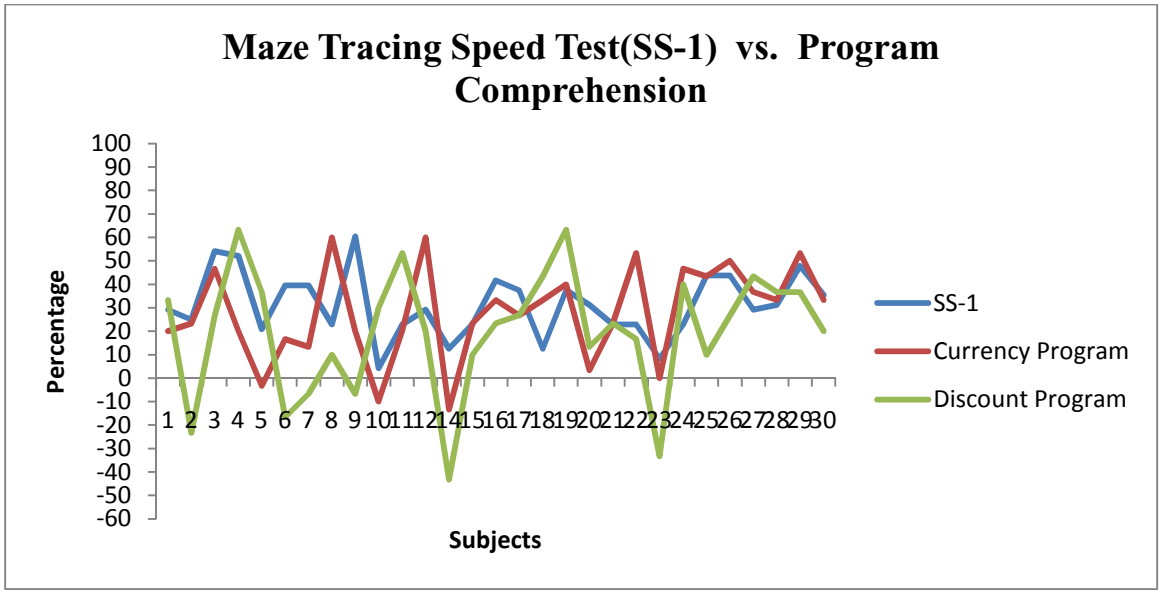
APPENDIX L

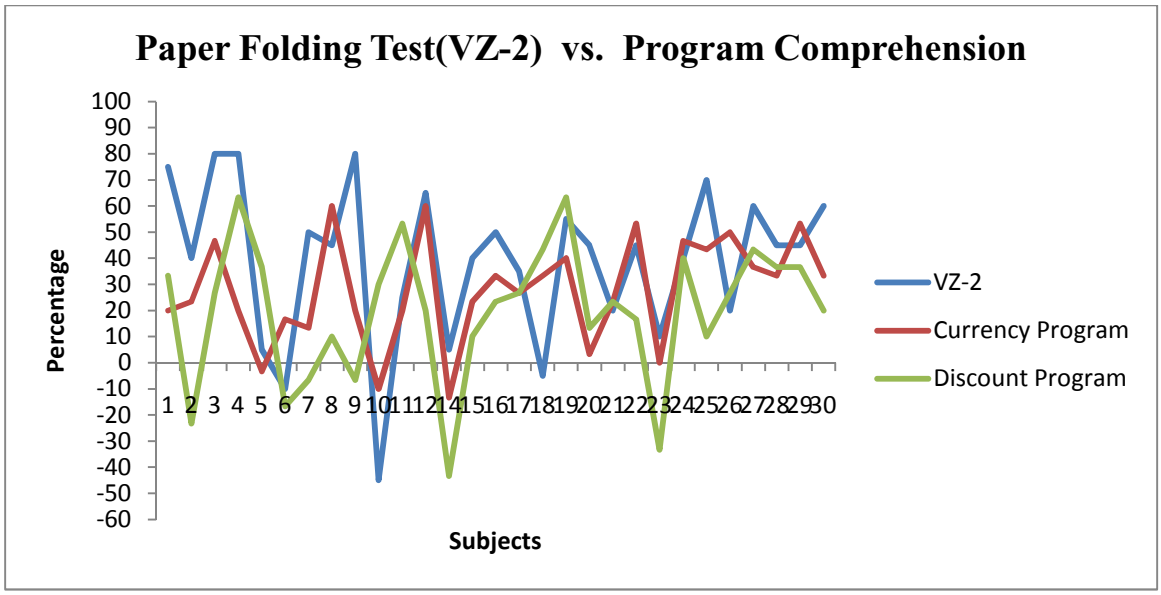
TEST RESULTS (GRAPH ANALYSIS FOR C-I/T SCORING METHOD)











VITA

SENTHILRAJAN MOORTHY

Candidate for the Degree of

Master of Science

Thesis: EXPLORING POSSIBLE RAMFICATIONS OF HUMAN DIRECTIONAL DIFICIENCY IN COMPUTER SCIENCE

Major Field: Computer Science

Education: Bachelor's degree in Computer Science from Madurai Kamaraj University, Madurai, Tamilnadu, India in July 2003; Completed the requirements for Master of Science in Computer Science at the Computer Science Department of Oklahoma State University, Stillwater, Oklahoma in December 2010.

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Name: Senthilrajan Moorthy Date of Degree: December 2010

Institution: Oklahoma State University Location: Stillwater, Oklahoma

Title of Study: EXPLORING POSSIBLE RAMFICATIONS OF HUMAN DIRECTIONAL DIFICIENCY IN COMPUTER SCIENCE

Pages in Study: 117 Candidate for the Degree of Master of Science

Major Field: Computer Science

Scope and Method of Study: Cognitive scientists, psychologists, and other researchers have endeavored over the past three decades to identify the cognitive functions underpinning human navigation and its possible correlations to other characteristics. The answer to the basic question of how/why some people are good at finding directions and some people are not, is yet to be determined conclusively. It has been reported that a certain percentage of people in the United States and Canada (as the target audience) suffer from what is variously referred to as directional deficiency, direction dyslexia, direction dysfunction, geographical dyslexia, human homing deficiency, or geographic insensitivity.

Findings and Conclusions: Part of the objective of this thesis work was to investigate the ramifications of this deficiency, to explore what this deficiency may correlate with (with a special focus on spatial cognitive skills, programming, and debugging), and to suggest ways of detecting this deficiency. The scope of the thesis work included both theoretical and empirical studies of human direction sensitivity and the cognitive tests that attempt to test hypotheses about individual differences in spatial/temporal attention spans as well as a set of program comprehension questionnaire-based tests about the debugging/testing of computer programs and program comprehension. This was done in the context of the relevant cognitive-based perceptual and spatial tests. The tests results obtained suggest that the programmers' directional detection skills might have some correlations with their program comprehension abilities.

ADVISER'S APPROVAL: Dr. M. H. Samadzadeh