THE INFLUENCE OF COGNTIVE STYLE ON

NAVIGATIONAL MAP READING

by

BENJAMIN WALTER METCALFE

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Student: Benjamin Walter Metcalfe

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This thesis has been accepted and approved in partial fulfillment of the requirements for the Master of Science degree in the Department of Geography by:

Amy Lobben	Chairperson
Christopher Bone	Member

and

Kimberly Andrews Espy	Vice President for Research & Innovation/Dean of the Graduate School

Original approval signatures are on file with the University of Oregon Graduate School.

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THESIS ABSTRACT

Benjamin Walter Metcalfe

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In this thesis, I discuss my recent research on the potential relationship between cognitive style and navigational map reading ability. Behavioral geography researchers investigate navigation and a person's knowledge of their environment. These activities have led to and continue to lead to theories about the underlying cognitive processes associated with map use and navigation. Previous research has shown a positive relationship between geographic education and a person's ability to understand the environment around them. Navigation, cognitive maps, mental rotation, map-based knowledge vs. route-based knowledge, and way-finding have all been identified as potential processes that people employ to travel around their environment. By understanding how people behave, process information, solve problems, and make decisions this research hopes to bring to light traits that may be useful in furthering geographic education and, as a result, environmental understanding.

CURRICULUM VITAE

NAME OF AUTHOR: Benjamin Walter Metcalfe

GRADUATE AND UNDERGRADUATE SCHOOLS ATTENDED:

University of Oregon, Eugene

DEGREES AWARDED:

Master of Science, Geography, (MARCH) 2013 University of Oregon
Bachelor of Science, Geography, (JUNE) 2009 University of Oregon with Honors

AREAS OF SPECIAL INTEREST:

Spatial Cognition and Cartographic Design
Geographic Information Systems

PROFESSIONAL EXPERIENCE:

Graduate Research Fellow, Spatial Mapping and Cognition Research Lab, University of Oregon, Department of Geography, 2012-Present

Graduate Teaching Fellow, University of Oregon, Department of Geography, 2010-2012

Graduate Research Fellow, InfoGraphics Lab, University of Oregon Department of Geography, 2008-2010

GRANTS, AWARDS, AND HONORS:

Phi Beta Kappa Honors Society member
Golden Key International Honour Society member
Gamma Theta Upsilon, International Geographic Honors Society member
Bill Loy Award for Cartographic Excellence, University of Oregon, 2010

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Dedicated to those that waited, supported, and pushed.

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CHAPTER I

INTRODUCTION

Do you have a good sense of direction? Can you look at a map and navigate easily to your destination? Or, perhaps, you get lost or turned around frequently while navigating? Do you find yourself having trouble locating yourself or things near you on a map?   Behavioral geography researchers investigate navigation and a person's knowledge of their environment. These activities have led to, and continue to lead to, theories about the underlying cognitive processes associated with map use and navigation (Montello et al. 1999). Reginald Golledge's research has shown a positive relationship between geographic education and a person's ability to understand the environment around them (Golledge et al. 1995). Navigation, cognitive maps, mental rotation, map-based knowledge vs. route-based knowledge, and way-finding have all been identified as potential processes that people employ to travel around their environment (Driscoll et al. 2005, Golledge et al. 1995, Lobben, 2004, Lyoyd and Bunch 2003, Montello et al. 1999). The processes that make up a person's decision in those topics are still being investigated (Cornell et al. 2003, Kulhavy and Stock 1996, Lobben, 2004 and 2007, Stankiewicz et al. 2006).

In order to better understand these processes we must focus some attention on the people that engage in map use and navigation activities. By understanding how people behave, process information, solve problems, and make decisions this research hopes to bring to light traits that may be useful in furthering geographic education and, as a result, environmental understanding. This thesis is situated within this general research area. My primary research question is:

> What is the relationship between age, gender, education level, spatial thinking ability, analytical thinking ability, creative thinking ability, cognitive style and navigational map reading?

In general, I am interested in identifying the potential differential relationship between several independent variables (age, gender, education level, spatial ability, analytical thinking ability, creative thinking ability, and cognitive style) and a single dependent variable (navigational map reading, specifically self-location). But, "measuring" how a person thinks about space can be a difficult endeavor to quantify with any certainty and conclusions are often questioned. To be sure the results are a measure of the constructs, multiple measures are required. As a result, the methods used involve recruiting a diverse sample, approximating the general public, who complete several different "tests" that I hypothesize represent the independent variables listed above (discussed more thoroughly in Chapter III: Methodology).

The diversity in work cited in this paper shows the wide range of topics and theories that contribute to our understanding of navigation and cognitive abilities. By utilizing more current measures of both spatial cognition and cognitive style, this research aims to create a profile of good navigational performers. My hope is that the results from this research will address suggestions to further investigate the characteristics of good map-reading and navigation performers in an effort to enhance the body of knowledge for cartographic and cognitive research. My research also aims to understand the relationship between cognitive style and the task being performed.

Chapter II will address navigation concepts and findings in areas of spatial cognition, navigation, and map reading. This includes a brief overview of the Navigational Map Reading Ability Test (NMRAT) (Lobben, 2007) employed in this research. Following that is a discussion of the history and development of cognitive styles in psychology. The chapter concludes with an overview of the Cognitive Style Index (COSI) (Cools et al., 2007) that is an instrument in this research study.

Chapter III addresses the methodology used. The chapter begins with a description of the four research instruments being used. Following that is a review and analysis of the instrument reliability and validity. Chapter III also addresses the creation of the participant pool and the testing procedure. It concludes with information on the data recording methods and database storage protocol.

In chapter IV, the results are presented with information about the independent and dependent variables being reviewed. Also in chapter IV is the preliminary results of the linear regression analysis that was performed.

Following that chapter is the general discussion of results in chapter V. The results of the linear regression modeling are shown individually by variable and potential conclusions are suggested. This chapter also addresses some of the issues found in the methods and procedures as well as potential solutions for future research. Chapter V concludes with a brief summary of the findings.

CHAPTER II

BACKGROUND: SPATIAL COGNITION, NAVIGATION, MAP READING, AND COGNITIVE STYLES

In the 19th Century, Charles Darwin wrote about the idea that among a human's senses there may be a sense of direction. This sense was not necessarily a perceptual sense, like sight or smell, but rather a more abstract instinctual sense that humans and animals developed for survival. He theorized that this sense was a person's ability to understand the location of things and travel without getting lost (Darwin 1883). Of particular relevance to this thesis is geography and psychology research in spatial cognition, navigation, map reading, and cognitive styles. What follows is a brief overview of these selected topics pertinent to the research presented later in this thesis. Also included are descriptions of two of the test instruments used in the experiment, the Navigational Map Reading Ability Test and the Cognitive Style Index.

2.1. Spatial Cognition

Spatial cognition has been measured and tested for more than 100 years in numerous studies (see reviews by Mohler 2008, and Lobben 2004). In 1921, Thorndike published the first known reference to spatial ability, something he referred to as "mechanical intelligence", which he described as "the ability to visualize relationships among objects and understand how the physical world worked" (p.143) and that it was separate from both the numerical and verbal intelligence measures (Thorndike 1921).

The field of spatial cognition further expanded from the mid-20th century work by Edward Tolman. In 1948, he created the construct of a cognitive map as a metaphor for our understanding and representation of the environment around us. These mental representations of space are the result of countless scenes and pieces of information about the physical environment, in which these scenes are preserved and organized in our memories to create our working knowledge that allows us to move about (Montello 1992). We access this information in a dynamic manner as we move about and interact. As we gather more information about an area, our cognitive maps become more complete as pieces begin to connect and overlap incorporating information from different sources and scales.

Tests of spatial ability can be measured and recorded on several scales; each recruits a slightly different, but often overlapping set of psychological processes. Figural space, vista space, environmental space, and gigantic space are identified, small to large respectively, as scales of thought (Hegarty et al. 2002). Hegarty et al. (2002) also proposed that a self-reported "sense of direction", established by their Santa Barbra Sense of Direction Scale (SBSOD), reflects a person's ability to perform tasks on the environmental scale. That is to say, that when asked if they have a good or bad sense of direction, the subjects response was found to correlate to their abilities on the environmental scale. This scale combines the act of learning via locomotion or movement to integrate a series of views that change as you move through an environment (Hegarty et al. 2002). A person's rating of their sense of direction was found to be a reliable indicator of their performance on subsequent spatial tests (Cornell et al. 2003). Cornell and colleagues (2003) also wrote about the need to study people that exhibit good orientation skills as they "may reveal the cognitive processes attributed to a good sense of direction" (p. 399).

Researchers have used a wide range of tests and tools in efforts to accurately measure cognitive spatial ability. The recognition of scenes from a learned environment, retracing routes taken, sketching a map of the environment, route distance estimation, and pointing or orienting to nonvisible landmarks are some examples of tasks aimed to identify spatial thinking (Hegarty et al. 2002). From a psychometric testing perspective, tests were focused on tasks like the mental rotation of shapes, solving mazes, and finding hidden figures (Carroll 1993; Eliot and Smith 1983; Lohman 1988; McGee 1979). The goal of these tasks is to identify underlying cognitive processes associated with relevant task completion. These tests often focus on small figural cartographically large scale space that would include pictures and small objects (Hegarty et al. 2002).

As geographers and cartographers began encroaching on the realm of spatial abilities, many of the theories developed in psychology were adapted to better understand geospatial cognition (Golledge et al. 1992; MacEachren 1995; Lloyd 1997). Geographers were more interested in the cartographically smaller scale human-environment interactions that can help explain spatial behavior and the processes used to acquire, process, and use spatial knowledge. Geographers and cartographers, specifically, began to focus on "understanding spatial cognition as part of the overall cartographic process" (Lobben, 2004 p. 271). Behavioral geographers investigate processes that affect way finding, environmental behavior, and environmental learning (Kitchin et al., 1997). Loomis et al. (2010) argued that individuals understand and experience places differently;

and that these differences were the result of the varied ways of gathering, organizing, and processing information.

2.2. Navigation

Tolman's (1948) cognitive map construct was applied to explain the behavior of rats in a maze. He theorized that the rats learned not by a simple stimulus-response mechanism but rather the accumulation of connections in the nervous system. This information, however, was perceived as a cartographic representation and the information was stored in a specific spatial format that is similar or identical to that of a geographic map (Kuipers, 1982). Later research argued that environmental knowledge is not consistent or neatly organized but rather a patchwork or collage of information (Montello, 1992).

In the process of collecting environmental information, a distinct difference is noted between information gathered by navigation and information learned from reading a map. Navigation provides procedural type knowledge and map reading is more associated with survey knowledge (Llyod, 1989). Navigation is a sequential encoding of relationships between objects that relies on the perceptual information gathered about the different elements in the environment (Allen et al., 1979). Conversely, map learning is more centered on the overall knowledge of the relationships between objects in the environment, allowing for the simultaneous acquisition of distance and direction among objects and landmarks.

Landmarks play an important role in our navigation process. They provide a reference point that allows spaces to be divided in our cognitive maps and for references to be made from that information (Presson and Montello, 1988). Landmarks can be any number of objects; i.e. roads, intersections, buildings, trees, rivers, or signs. A visual landmark is an object that contains high informative value for navigation and orientation in an unfamiliar setting (Sorrow and Hirtle, 1999). Information about these landmarks is acquired initially without specific information about the spatial relationships between them (Siegel and White, 1975). Through experience, the sequential ordering of landmarks along a route occurs that leads to the understanding of the spatial relationship between them. The knowledge of the spatial relationship allows for an understanding of the layout of the route and initially consists of small “minimaps” that are connected by landmarks (Siegel and White, 1975).

Geographer Reginald Golledge applied landmarks as the foundation of his anchor point theory (Golledge, 1979). He theorized that anchor points gave structure to our mental representation and allowed for different segments, or minimaps, to be connected in to larger areas. Most commonly, locations associated with the home, work, or shopping become known and related to the various connections between them.

Cognitive mapping and map-reading studies have been conceptualized and approached from numerous different angles. Tobler (1976) focused on cognition of maps as a cartographic problem of data collection, projection and reception by the reader. Morrison (1976, 1996) concluded that a map-reader’s interpretation of map information is influenced by both the cognitive processes as well as information they previously acquired. This conclusion resulted in most cognitive map-reading experiments falling in to one of two broad categories: experiments that address strategies and experiments that focus on cognitive processes (Lobben, 2004). The tasks within each category varied greatly. Some reoccurring themes were “deciphering symbol meaning, route planning, self-locating, and text/image/geometry rotation” (Lobben, 2004 p. 272).

Researchers have further extended this research area through more recent foci on gender and age and their respective relationship to map use and navigation. With regards to gender differences, Choi and Silverman (1997) found that women are more likely to navigate with landmarks than their male counterparts. Liben (1995) found that men tend to have a greater knowledge of world geography. Studies have also found that males use more Euclidian strategies (distances and directions) while females use topographic strategies (landmarks) (Dabbs et al. 1998; Choi and Silverman 1997; Galea and Kimura 1993; Miller and Santoni 1982; Ward et al. 1986; Downs and Stea 1977). McGuiness and Sparks (1983) asked subjects to draw a map of their school campus and found that female subjects placed more buildings, while male subjects used more roads and connectors. The contribution of spatial abilities to navigation strategy and geographic knowledge has been found to influence these differences (Collins and Kimura 1997). For instance, men outperformed women on spatial tests that required manipulation of objects in space (Collins and Kimura 1997; Goldstein et al. 1990; Kimura 1983; Kolb and Whishaw 1990; Linn and Petersen 1985). Women, however, outperformed men on tasks such as keeping track of and locating objects (Eals and Silverman 1994; Silverman and Eals 1992). McBurney et al. (1997) found that women could remember the locations of previously viewed items better than men could, and James and Kimura (1997) found women superior in remembering specific objects located at specific places. Dabbs et al.

(1997) theorized that object location memory promotes the use of landmarks in navigation.

As humans age their ability to navigate in unfamiliar environments greatly diminishes (Burns 1999). Researchers have found topographical disorientation as one of the earliest symptoms displayed by patients with Alzheimer's disease (Pai and Jacobs 2004). Cushmen et al. (2008) found that younger participants acquired knowledge of presented environments faster and with more accuracy than their senior counterparts. Young adults have been found to use maps more effectively for spatial learning and recall more landmark locations after studying street maps than elderly adults (Meneghetti et al. 2011; De Beni et al. 2006; Thomas 1985). Researchers also found that older adults were slower and less accurate when tasked with learning specific routes on a map and then tracing them in the real-world environment (Carelli et al. 2011; Wilkniss et al. 1997). Having a map of the environment while they explored was found to not be beneficial to older adults' ability to learn locations of objects either, suggesting that the ability to translate from map-reading to spatial navigation deteriorates with age (Sjoliner et al. 2005).

Of particular interest for this thesis is the potential relationship between cognitive abilities and navigational map-reading ability. Several previous studies have indicated that higher scores on cognitive ability tests have correlated with higher scores on spatial cognition ability tests (Thorndyke and Stasz 1980; Sholl and Egeth 1982; Lloyd and Steinke 1984; Streeter and Vitello 1986; Kovach, Surrette, and Aamodt 1988).

The focus of current research efforts is shifting more toward the processes, and their role, and away from the strategies map-readers are using. Through fMRI researchers have found consistent patterns of activity in the brain for navigation tasks (Maguire et al. 1999). The medial and right inferior parietal cortex, the posterior cingulate cortex, parts of the basal ganglia, the left prefrontal cortex, the bilateral medial temporal region and the hippocampus proper all seem to be utilized in varying degrees during navigation tasks (Maguire et al. 1999). These studies present strong evidence that for humans to navigate successfully, use of the prefrontal circuits and associated cognitive systems is required (Moffat 2009).

2.3. Map Reading

Through the use of maps, the knowledge at an environmental scale can be obtained. Recently, geographers and cartographers are particularly interested in the process of map reading and spatial cognition (Lobben 2004). Using map-reading strategies to complete map-reading tasks, map-readers may use different strategies based on their individual abilities (Lobben 2004). From the cartographers, came the suggestion that research efforts should focus on both the map reader and the map-reading skills and abilities to gain a better understanding of how readers interpret the information on a map (Kolacny 1969; Ratajski 1973; Morrison 1976). This thesis uses the Navigational Map Reading Ability Test (NMRAT) for assessing spatial navigation ability that relies heavily on map-reading skills and decision making abilities of participants to understand the stimuli presented to them.

Spatial testing from psychologists has been primarily concerned with understanding spatial cognition as part of an overall cognitive process (Lobben, 2004). Psychologists have focused primarily on the human and less on the stimuli, often resulting in crude approximations of maps that are little more than a few lines and shapes. Different types of maps, map quality, and their possible interactions with a subject have had little consideration (Liben and Downs, 1989). Geographers use these methods from psychology and adapt them to better understand spatial behavior in the context of geographic specific theories of spatial abilities and cognition (Golledge, Dougherty, and Bell 1995; Golledge and Stimson 1997; Lobben 2007). In the context of cognitive map-design, the focus of research has been on improving maps as a means to communicate complex information or ideas (Montello 2002).

Lobben (2004) described self-location as “a person’s ability to effectively relate clues on the map to the represented real world.” Map readers achieve this task by using landmarks and relationship clues to formulate their position on a map. Self-location is an event, versus a continuous process, that occurs at the start of navigation when a map reader must locate themselves on a map in order to proceed with navigation, then occurs again “when ‘double-checking’ location or correcting erroneous decisions” (Lobben, 2004). This self-location process is one of the key pieces of the Navigational Map Reading Ability Test (NMRAT) developed by Lobben (2007).

2.3.1. Navigational Map Reading Ability Test (NMRAT)

The NMRAT was created to answer the question about what abilities influence map navigation (Lobben, 2007). The five abilities identified to test were: map rotation, place-recognition, self-location, route memory and environmental mapping. Lobben also created the Real World Map Navigation Exercise (RWMNE) to assess the construct and criterion validity of the NMRAT.

Lobben (2007) states “self-location alone is a strong predictor of the highly complex and dynamic task of navigational map reading”. Although there are more processes involved than the five included in the NMRAT, it is a strong start in narrowing down a process tree of navigational map reading. Self-location is also identified as a potential key to teaching better navigational map reading skills. There is a detailed description of the NMRAT in chapter three.

2.4. Cognitive Styles

In 1977 Witkin, Moore, Goodenough, and Cox defined cognitive style as being the way in which a person perceives, thinks, learns, problem solves, and relates to others. Alternatively, the research of Hunt, Krzystofiak, Meindl, and Yousry (1989) says cognitive style is the way people process and organize information and arrive at a conclusion based on their observations. Cools, Van Den Broeck, and Bouckenooghe (2007), the creators of the Cognitive Style Index used in this research paper, define cognitive style as “the way in which people perceive environmental stimuli, and how they organize and use this information for guiding their actions.”

The differences in cognitive styles have been found to be of great importance with regards to decision making (Leonard et al. 1999). Several studies have shown an innate preference in decision-making processes that are compatible with their cognitive style (Gardner and Martinko 1996; Hunt et al. 1989). As time went by and more studies were published, the number of definitions and overlapping cognitive styles grew rapidly. The increasing number of cognitive style dimensions and the measures that accompany them created a lack of unity and agreed upon definition despite having conceptually similar or identical definitions (Grigorenko and Sternberg 1995; Hayes and Allinson 1994; Rayner and Riding 1997). In the end it reduces the "usefulness and viability of the concepts" for most applications (Hodgkinson and Sadler-Smith 2003).

To create some semblance of order and uniformity within the field, many have tried to categorize the theories that are similar conceptually and design-wise (Cassidy 2004; Coffield, et al. 2004; Desmedt and Valcke 2004). It has also been suggested that some variations of cognitive styles are in fact the same underlying dimensions conceptualized with slight differences but referencing the same idea (Allinson and Hayes 1996; Riding 1997; Sadler-Smith and Badger 1998). Miller (1991) suggests that there exists a dichotomy in how we process information and that this has been repeated throughout Western thought. It is this duality in human thought that has been the focus of study for hundreds of years (Taggart and Robey, 1981). The appearance of two qualitatively different cognitive styles is a common theme amongst many studies. The commonly described analytical cognitive style has been labeled as many other things; deductive, rigorous, constrained, convergent, formal, and critical to name a few. The creative style has a similarly long list of aliases; synthetic, inductive, expansive, unconstrained, divergent, informal, and diffuse (Nickerson, et al. 1985). In 1996 a study by Allinson and Hayes labeled this the analysis-intuition dimension. They define analysis–intuition mainly as a difference between rational and intuitive reasoning, stemming from left brain/right brain theories. Again, however, numerous names have been coined to describe that same conceptual idea like analytic-non-analytic (Kemler-Nelson 1984), analytic–holistic (Beyler and Schmeck 1992), or logical–nonlogical (Barnard 1938). The underlying distinction is between a cognitive narrowness and broadness, or rational and intuitive thinking that continues to dominate current research on cognitive differences in behavioral and developmental psychology (Hodgkinson and Sadler-Smith 2003).

2.4.1. Cognitive Style Index

The Cognitive Style Index (COSI) (Cools et al., 2007) provides a participant's score on each of three distinct cognitive styles. Two of these styles, planning and knowing, are conceptually located in the classic analytical camp, while the creating style is firmly non-analytical. There is a detailed description of the COSI in chapter III.

The planning style is characterized by a need for structure. Planners control and organize the world around them and thrive in a well-structured working environment. They value preparation and planning in order to reach an objective. They very firmly want other people to respect rules and agreements. People with a planning style like rules and regulations, step-by-step explanations, and doing things the way they always have done. They do not like ambiguity and prefer clarity and order.

The knowing style is characterized by a need for facts and data. They want to know as many facts and details as possible and know exactly the way things are. They are detailed, task-oriented, and accurate. They like complex problems if they can find a clear and rational solution. They make decisions using a structured approach. People with a knowing style have an enormous capacity for details, make errors rarely, and are good at demanding tasks.

The creating style people like experimentation and creativity. They think more on a conceptual level and are less interested in the practical implementation of ideas. They like uncertainty and freedom and see a problem as an opportunity or challenge to be overcome. The creative style people prefer dynamic structures and are always looking for new opportunities and hidden possibilities. They value spontaneity and flexibility and tolerate ambiguity, especially if it creates new options.

People with a creating style lean more towards innovation and “restructuring the situation” to make decisions and solve problems. The knowing and planning style people have more of a tendency to think within the existing structure of the problem to solve it. The people with a creating style “do things differently” while people with a knowing and planning style try to “do things better” (Cools et al. 2007). From the descriptions of Gryskiewicz and Tullar (1995) the creating style are more likely to be innovators and the planning and knowing style are adaptors.

The link between cognitive style and ability has been a hotly contested subject among cognitive psychology researchers (Armstrong 2000; Furnham 1995). Some argue that cognitive style and intellectual abilities are vastly different in many key ways (Kirton 2003; Mudd 1996; Riding and Rayner 1998; Tullet 1997). Opposing research suggests that there is a relationship between them (Allinson and Hayes 1996; Federico and Landis 1984; Isaksen and Puccio 1988; Tiedemann 1989). Cools and colleagues tested this theory with the results of the COSI and various academic results, such as standardized aptitude test scores and school grades, and found that there was no significant correlation between cognitive style and intellectual ability or attainment. They suggested future research may investigate the influence of the type of task on the cognitive style-cognition relationship stating that “people have a preferred or dominant cognitive style, their actual behavior and performance is also influenced by the demands of the situation or task" (Cools et al. 2007).

CHAPTER III

METHODOLOGY

In behavioral research, the inherent nature of studying and theorizing the processes people follow that comprise actions and decisions are not tangible "things". As such, it presents a certain challenge to researchers to accurately and reliably generalize results about particular groups or individuals to say something about a general population. Categorizing and analyzing results from behavior studies becomes a careful exercise in not overstating the results of tests and drawing conclusions that can be tested for reliability and validity. Unlike the tests used in other fields, measuring soil particle size or soil profiles for example, the testing methods are often called in to question more than the results. As a result, researchers and their results may benefit from multiple measures and well-constructed participant pools. By including the NMRAT and COSI as instruments in this study, I have adopted "measures" of spatial cognition and cognitive styles that have been tested and validated in both laboratory and "real-world" settings. Because, when measuring the intangible cognitive processes, it is scientifically methodologically necessary to also assess the reliability and validity of the measurement instruments. In the sections below, I briefly discuss these critical steps in the methodology I have adopted for my thesis research.

3.1. Instruments

This study is comprised of four instruments: a demographic questionnaire; self-rated ability scale (Cornell 2003); the Cognitive Style Index (COSI); and Navigational

Map Reading Ability Test (NMRAT). All instruments were created and programmed in Adobe Flash using the ActionScrpit 3 language and then served via a secure website to participants. The participant responses were recorded to a database on a secure University of Oregon server.

Instrument one is a brief survey to attain basic biographical data. The purpose of this instrument is to obtain the independent variables for age, gender, and education. The questions and possible "multiple-choice" responses are:

1. How old are you?
    - 18-24
    - 25-34
    - 35-44
    - 45-54
    - 55-64
    - 65 and above
2. Are you male or female?
    - Male
    - Female
3. What is the highest level of education you have completed?
    - Primary School
    - High School
    - Some College
    - Associates or 2-year degree
    - Bachelor's Degree

- Graduate Degree (e.g. M.A., M.S., Ph.D., M.D., Law Degree)

Instrument two is a self-assessment of the participant's ability to think in a particular thinking style. How well do participants consider themselves able to think creatively, analytically, or spatially? Cornel et al. (2003) found self-assessment to have moderate correlations to actual abilities in spatial testing. It consists of a series of three questions, each on a 1-10 rating scale to estimate their thinking ability.

Instrument three is the establishment of the participant's primary cognitive style using the Cognitive Style Index (COSI) developed by Eva Cools and Herman Van den Broeck (2007). The questions categorize participants into "knowing", "planning", or "creating" cognitive styles with particular traits common among each group. The development of the Cognitive Style Index (COSI) in 2006, presented a multi-study research approach developed over a period of six years (Cools et al. 2007). Cools et al. began with 97 items, or questions, designed to evaluate how people perceive, process, and use information. Through a pilot study with 15,616 participants, 18 items were retained and found to be psychometrically sound and used in the resulting validation studies. The index was then tested for validity using 3 separate studies. The results of these studies were judged based on convergent and divergent validity, meaning it is related to conceptually similar constructs and unrelated to conceptually dissimilar measures (Campbell and Fiske, 1959). Cools et al. conducted a factor analysis and found three distinct cognitive styles.

In instrument four, the second part of the study, participants were tested on the dependent variable of spatial orientation ability. This instrument used the self-location section of the Navigational Map Reading Ability Test (NMRAT) (Figure 1). This task asks participants to pick locate and orient themselves on a map given a picture indicating their surroundings. The participants are shown a map with a red circle, indicating that they are located somewhere within that circle. Next to the map is a picture of the environment visible from somewhere within that circle. There are two possible orientation responses, in the form of red directional arrows, that the participant must choose from that best represents the probable view from the location.

The NMRAT was designed as a sit-down group administered test on the computer. The tasks asked participants to reach conclusions about the graphics displayed to them. During the self-location portion of the test, participants were shown a photograph of an environment then asked to determine their location and orientation, using the clues within the photo that would match that photograph. Participants were also informed that the purpose of the study was to assess map-reading ability.

Participants were later led through the RWMNE to separate the good and poor performers of map reading navigation. This was to see what correlation existed between the five ability measures that comprised the NMRAT and the real world navigation abilities the participants possessed. The RWMNE involved physically walking around and navigating from one point to another given the environment around. It took place inside a building with a street network that ran through the complex hallways. The hallways had street signs to help participants navigate. This indoor environment allowed for more experimental control than if it were conducted outdoors.

A total of forty-five participants were tested with forty-four results being used in the analysis. A multiple regression analysis was used to determine the relative influence of each factor in predicting the score on the RWMNE. The results showed that the NMRAT was overall a good predictor of real-world performance. Some sections of the test proved to be more significant than others. The results indicated that of the five constructs being tested, the self-location was the most influential. As a whole it also showed that certain cognitive processes should be investigated further to identify more clearly their role in navigational map use.

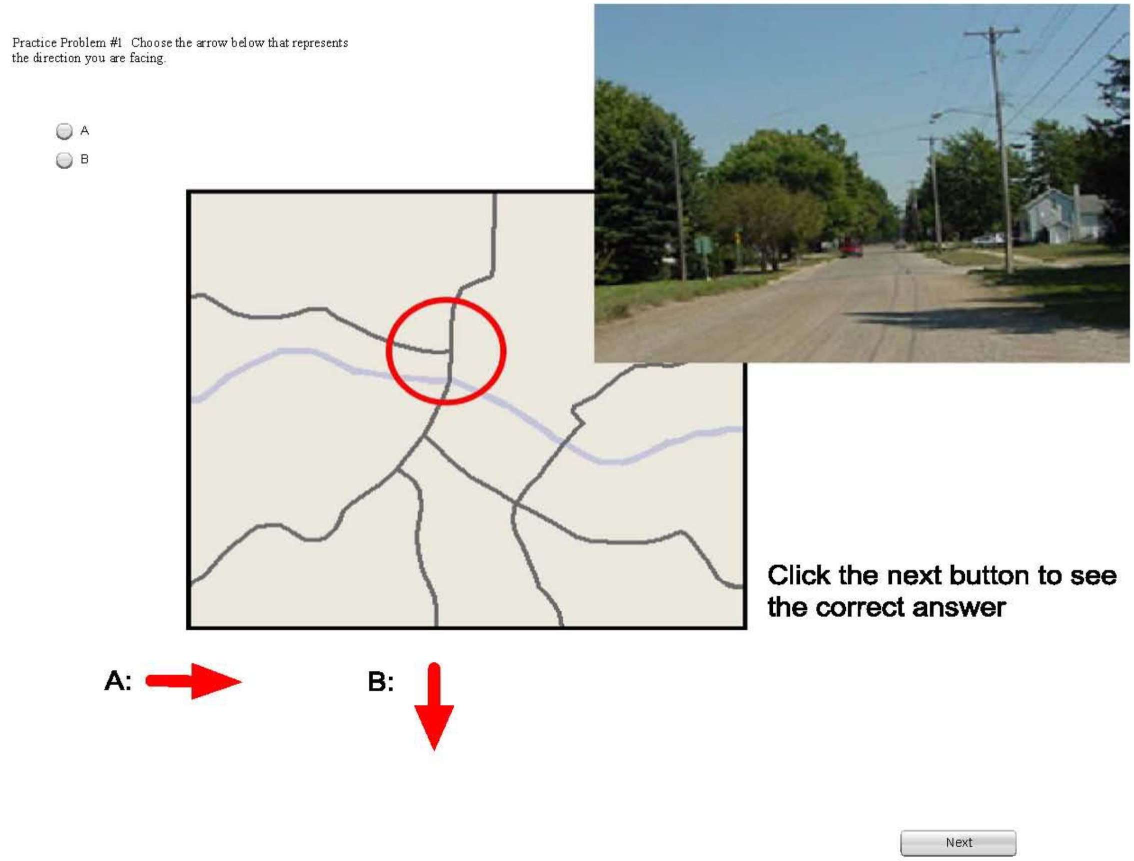


Figure 1: The self-location task of the NMRAT asks participants to choose an orientation arrow that would result in the view pictured if standing somewhere within the circle.

3.2. Instrument Analysis

The first and second instruments used in the study could be checked for reliability with a test-retest assessment to verify the consistency of participants' answers. However, given that no identifying information was collected about participants that may prove difficult. Instead a larger subject pool was constructed in an effort to average out erroneous responses. Instruments three (COSI) and four (NMRAT) of the research design are established testing methods that were tested for reliability and validity during their creation.

The instrument reliability of the NMRAT was tested using a split-half analysis, due to its construction as a speed test, which compares the consistency of two scores from equivalent halves of a test. The split-half correlation of the four sections was found to be highly reliable. The construct validity, or how well the test measure the theoretical construct, suggests how well the sections of test capture the map use constructs they were intended to measure. This was determined by analyzing the relationships between each of the parts of the NMRAT and the scores from each of the individual parts of the Real World Navigation Map Exercise (RWMNE). Results indicated that some of the sections of the NMRAT were more valid than others in predicting real-world performance, particularly the self-location portion being the most influential in predicting performance.

The convergent and discriminant validity of the COSI was supported by including several other cognitive style instruments as well as personality and academic performance measures. Criterion validity was established by the examination of the relationship between the cognitive styles and work-related characteristics. Cools et al.

(2007) also used a split-half reliability test to establish test reliability. All instruments were found to be reliable across the three studies used to develop the COSI.

In testing the construct validity, Cools et al. also found the knowing and planning style to be positively correlated with the Rationality scale (as described in Edwards, Lanning, and Hooker 2002; Epstein et al. 1996; and Pacini and Epstein 1999). This reinforces that both knowing and planning styles are located within the rational, analytic cognitive system. The creative style, however, had no significant correlation with Rationality indicating they are less likely to process information primarily in an analytical mode. Among the Rationality subscales, the knowing and planning styles diverge with significant differences. The knowing style favored Rational Ability and Rational Engagement. The planning style was positively correlated with Rational Ability but not Rational Engagement. This means that although a planning style person has the ability, they may not actually engage in the Rational Thinking process, where a knowing style is more likely to.

3.3. Participants and Testing Procedure

In constructing a participant pool you want a research pool that is large enough so you can identify groups based on performance. In this research, I have attempted to be intentional in my participant pool characteristics and construction. Steps for recruiting: recruit as many people from as many different backgrounds as possible. Realistically, most of the recruiting will be done on campus, limiting the age and education level spectrum. However, because I am testing more innate abilities, rather than learned skills, I feel that I can adequately identify performance groups recruited from campus, primarily. This recruiting and selection method has been used successfully by Lobben & Lawrence (in progress a,b) and Lobben et al. (2005).

Again, because one of my objectives is to generalize my results so I may make statements about spatial abilities and cognitive styles of the general public, I will, as much as possible, recruit participants from a wide array of age and gender groups as well as education levels.

Additionally, because individual differences in navigation and spatial abilities have been identified (Lobben and Lawrence, in progress), I will also develop participant groups based on their recorded self-assessed ability levels in analytical, creative, and spatial thinking abilities. Since it is difficult to test for that beforehand, a large enough sample will be used to find an adequate sample of people that excel in each category. Although this is not a representation of the general public, the participant group should represent a large spectrum of values for the independent variables.

The participant's information was kept confidential with no identifying information being taken. The study received the approval of the Institutional Review Board (Protocol 05232011.034) for the involvement of human participants. Since the test is administered online, the risk to participants is deemed to be minimal. The survey includes a clause that by taking the survey, participants are consenting to submitting the information to the study.

The pilot-test participant group, consisting of thirty-two participants, was recruited initially by the use of advertisements, listservs, and a website. Several listservs were identified that contain sufficient populations that might be interested in participating in the study. The participants were directed to a website that loads and proctors the test. The testing ran for two weeks until a sufficient number of participants to be confident that the results are not being skewed by individual results.

After analysis of the pilot-test responses a larger testing pool was recruited using various internet forums and email “listservs” that are believed to contain populations that would help “round out” the subject pool. Additionally, participants were recruited during several days at the Holiday Market hosted at the Lane County Fair Grounds. Subjects from the market received $20 in compensation for their participation. To avoid potential abuse, such as taking the test multiple times, the days and times of testing were not distributed. Participants recruited from the market were also required to complete a paper version of the participation waiver for records (See Appendix A). 54 participants were recruited from the Holiday Market with 77 responses coming from online recruitment sources.

Since no identifying information was recorded during the test taking process, the individual records are impossible to match to a specific user. This does open up the remote possibility of the results being skewed by multiple responses by the same person. This seems highly unlikely due to the time required and static and repetitive nature of the test, but a possibility that must be acknowledged.

3.4. Data Recording and Database Construction

The testing was done at the participant’s selected pace with no imposed time restrictions. The testing process took no more than 15 minutes with most participants completing the test in less than 10 minutes. Variables for question response and response time were recorded in to an array via ActionScript 3 and sent through an .ASP script that wrote to a secure Microsoft Access Database. The information gathered was written to a secure server at the University of Oregon. All the information is stored electronically and backed up with an external data storage medium in a securely locked location.

CHAPTER IV

RESULTS AND ANALYSIS

The primary analysis of the data collected from the four test instruments consisted of a multiple linear regression model to ascertain if any of the independent variables (age, gender, education level, analytical thinking ability, creative thinking ability, spatial thinking ability, and Cognitive Style) can significantly explain the variation in the dependent variable of NMRAT self-location score. Since several variables are being analyzed a multiple linear regression approach is used instead of a series of simple, or single, linear regressions. The multiple regression analysis tells how well all the independent variables collectively predict the dependent variable. The multiple regression analysis also tells how well each independent variable predicts the dependent viable, controlling for the other independent variables. The analysis tells you if a model or variable can predict the output, given the input, at a rate better than chance with the p-statistic. For this thesis, statistical significance is defined as a p-value of less than .05.

This chapter will look at the range and distribution of responses for each of the independent variables. Following the independent variable review will be a description of the results of the NMRAT self-location test, again showing range and distribution. The chapter will conclude with a section explaining the results on the multiple linear regression models.

4.1. Number of Observations

A total of 163 subjects participated in the experiment. The subjects that participated represent the total number "n" for the experiment. Initially the results were surveyed to ensure that each of the participants completed the entire test. The experiment also recorded a variable for the amount of time each participant took to answer each question as well as the cumulative time to complete the test. Upon analysis of this variable, a high likelihood existed that six of the respondents simply clicked through the test as quickly as possible. The mean response time and cumulative response time of each of these six was more than two standard deviations lower than the average response time. Most importantly, response times were relatively uniform across the test despite the change in tasks or the amount of text the participants were required to read. As such, these results were omitted from further analysis. This resulted in 157 results used in the following analysis (n=157). This method is described by Whelan (2010) as a means to control for "fast guesses" that do not actually consider the stimuli being presented in reaction time based psychological testing.

4.2. Independent Variables

The test presented in this thesis gathered information on six independent variables. As described in Chapter III, the survey gathered information about the age category and gender of participants. The next question asked participants to indicate the highest level of education they had completed. For the next independent variables, participants indicated their ability to think analytically, creatively, and spatially, on a scale ranging from 1-10. The final independent variable is the score on the three

Cognitive Styles tested by the COSI. A further discussion of the results is located in Chapter 5.

4.2.1. Age

The participants represented a wide range of age values, populating all of the age category options (Figure 2). Twenty-six respondents (16.5 percent) reported being 18-24 years old and four participants (2.5 percent) indicating they were 65 years of age or older. The most common age categories were 25-34 (32 percent) and 35-44 (34 percent).

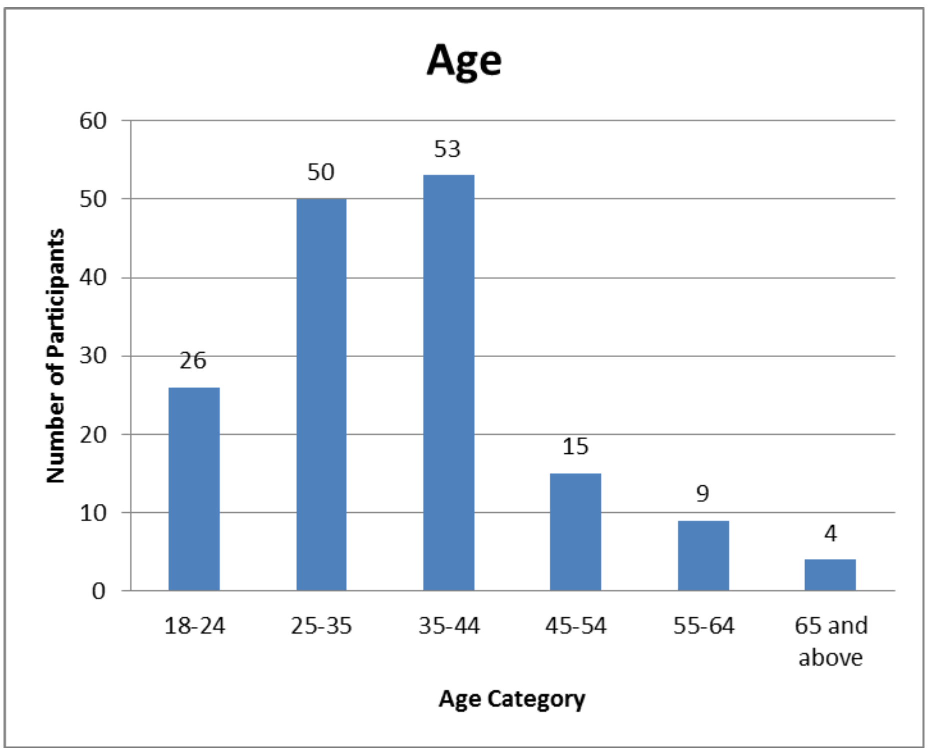


Figure 2: Reported age category of experiment participants.

The results from the Age variable are shown in Table 1 and Figure 3. The 45-54 age category had the highest average score (12.86). It is in the 55 and older categories that the decline a performance seems to appear with those groups scoring an average of 10.77 (55-64) and 10.5 (65 and older) on the NMRAT test.

Table 1: Shows the calculated average scores by reported age category.

Age Category	Average Score
1. 18-24	12.38461538
2. 25-34	12.42
3. 35-44	12.49056604
4. 45-54	12.86666667
5. 55-64	10.77777778
6. 65+	10.5

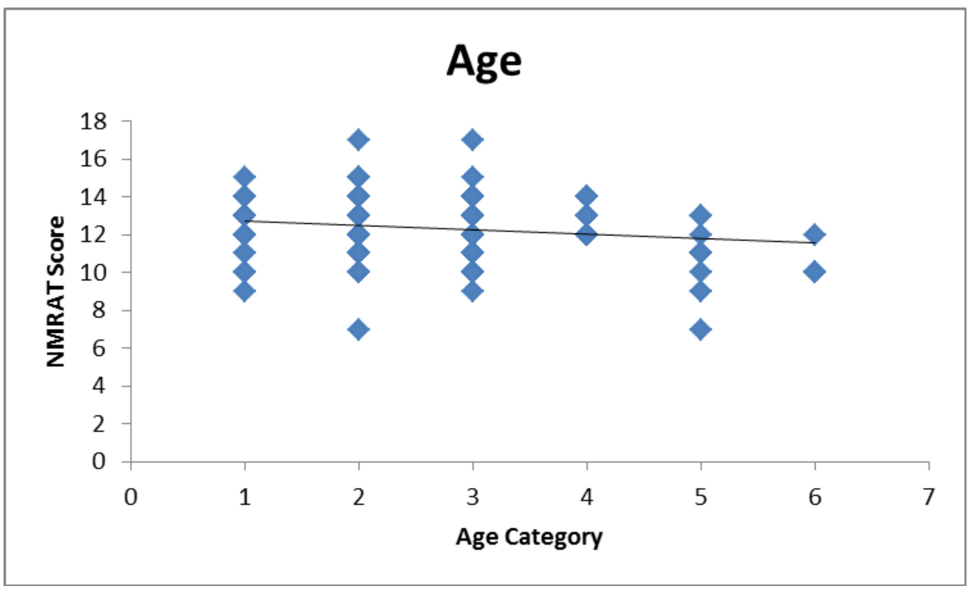


Figure 3: Shows the NMRAT score by self-reported age category and the trend line from the linear regression analysis.

4.2.2. Gender

The second variable, gender, shows the sample population comprised a fairly even amount of participants that were male and female at 87 (55 percent) and 70 (45 percent), respectively (Figure 4). Results from this study (Table 2 and figure 5) indicated only a slightly higher average score for men (12.48 for the men and 12.15 for the women). In this subject pool the NMRAT Self-location test performance is similar between genders.

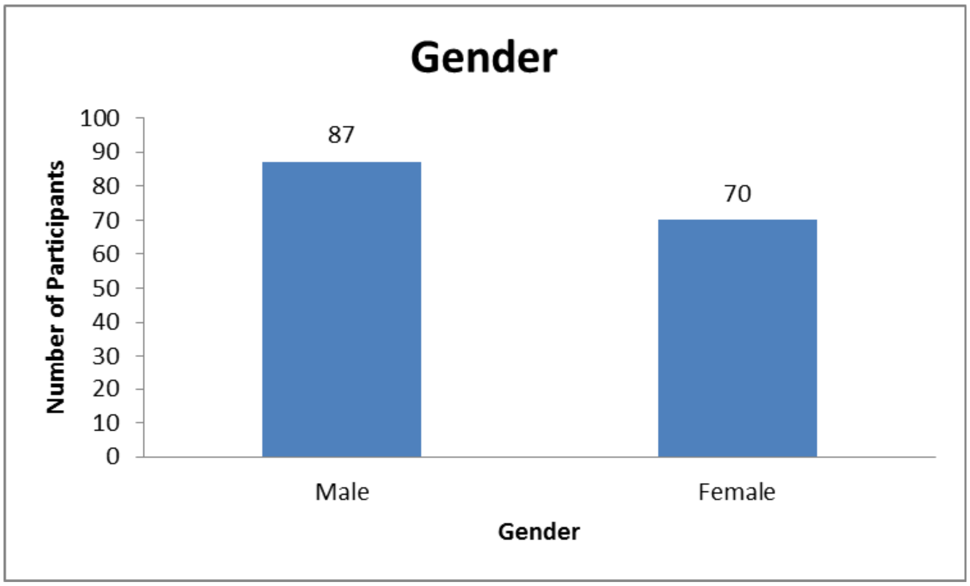


Figure 4: Shows the gender reported by participants.

Table 2: Shows the calculated average score by reported gender.

Gender	Average Score
Male	12.48275862
Female	12.15714286

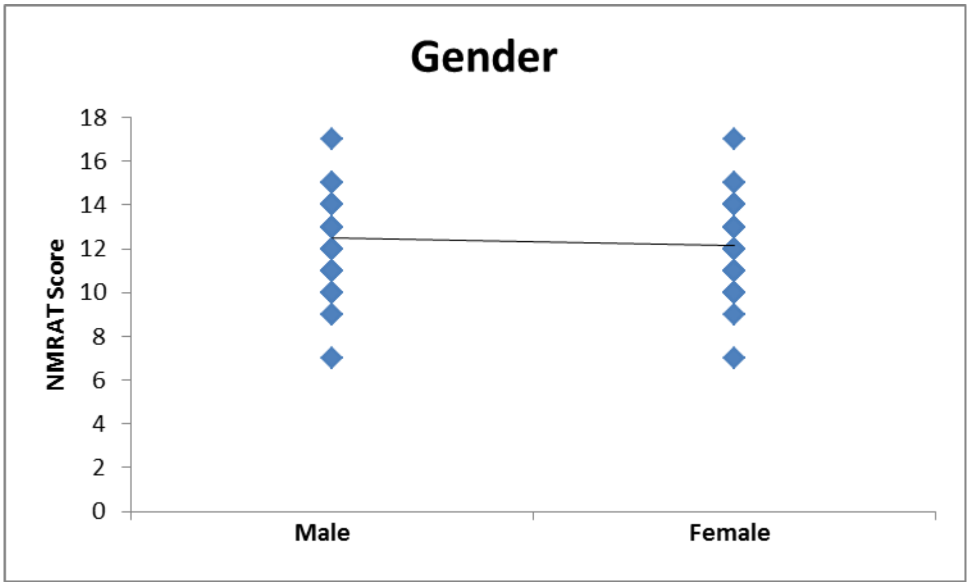


Figure 5: Shows the NMRAT score by self-reported gender and the trend line from the linear regression analysis.

4.2.3. Education

The number of respondents within each education category was not as evenly distributed as initially intended. 54 (31 percent) of the 157 respondents indicated have completed a graduate level degree (Figure 6,7 and Table 3). Recruiting from technical and specialty internet forums and academic listservs could have biased this result due to a higher level of education required in academia or GISciences.

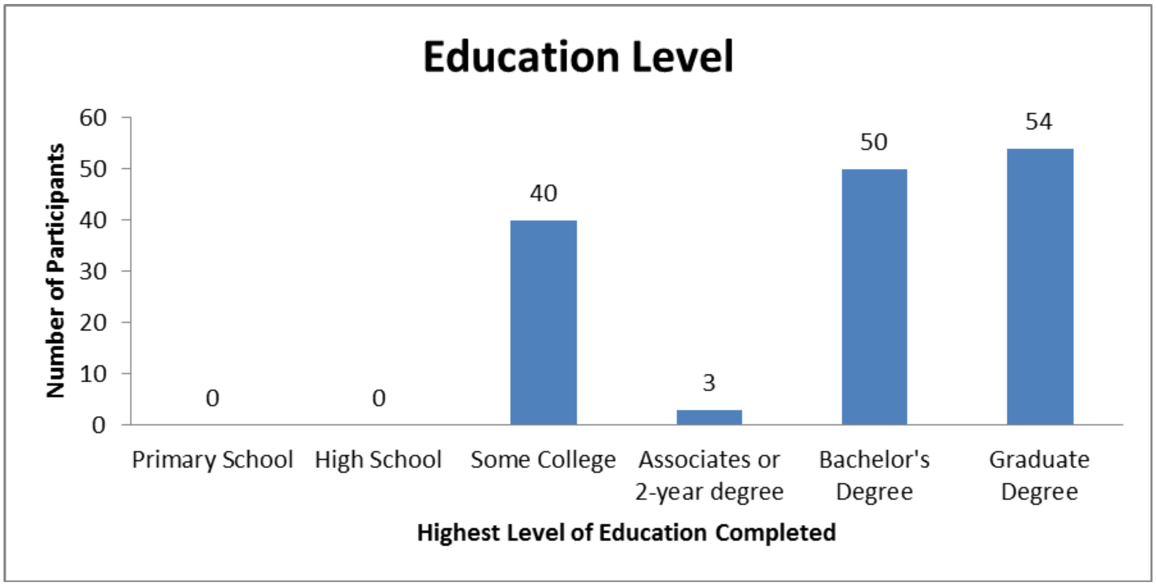


Figure 6: Shows the number of participants for each level of education.

Table 3: Shows the calculated average score by education level.

Education	Average Score
2. High School	N/A
3. Some College	12.4
4. Associate's Degree	11.66666667
5. Bachelor's Degree	12.72857143
6. Advanced Degree	11.98648649

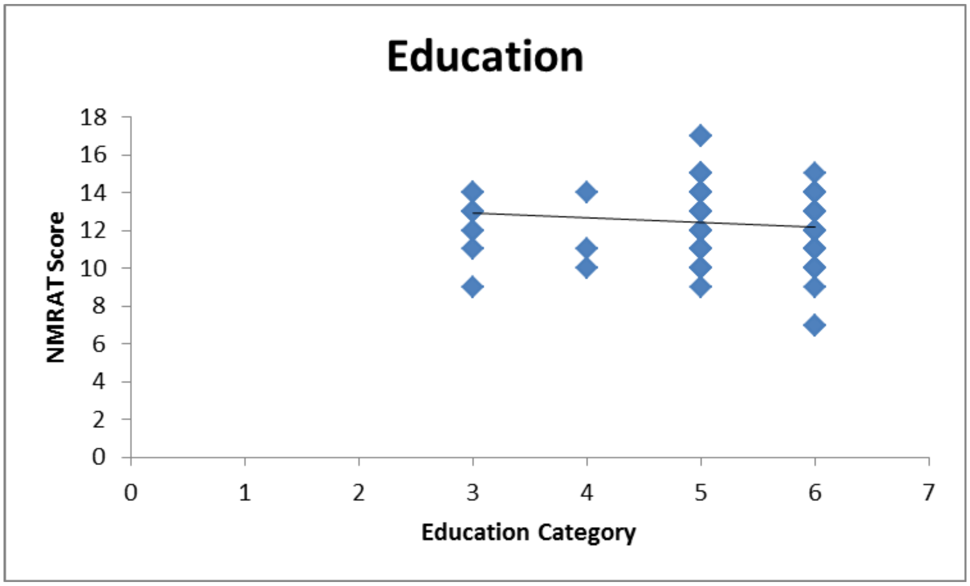


Figure 7: Shows the NMRAT score by self-reported education level and the trend line from the linear regression analysis.

4.2.4. Analytical Thinking Ability

The self-reported analytical thinking ability shows a negatively skewed distribution with a mode response value of “10” on the 1-10 scale (Figure 8). The distribution has a skewness of -0.8889 and an excess kurtosis value of .451 giving the data a larger than standard peak. The median value of the responses was 8. There were no “1’ responses given and only sixteen of the 157 total participants indicated having an analytical thinking ability of five or less.

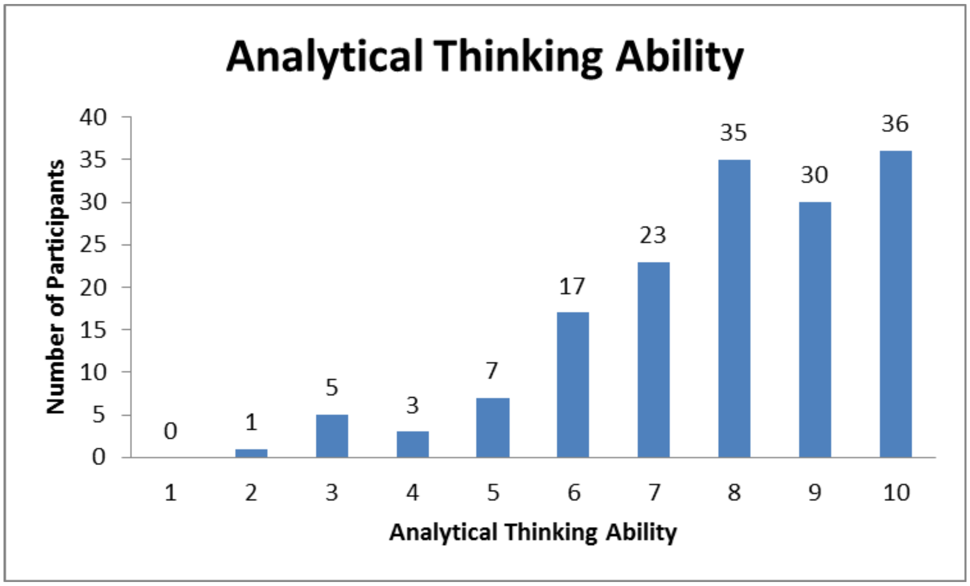


Figure 8: Histogram showing the participants response to the self-reported analytical thinking ability question on a 1-10 scale with a “1” indicating a low ability.

The average scores and analytical thinking ability value (Table 4) shows a large average value for both “2” and “5”. In looking at the individual responses there is only a single response in the “2” category, due to this it could be an anomaly associated with too small of a sample size. The “5” value had seven responses, again representing a relatively small portion of responses compared to the other larger values (6=17, 7=23, 8=35, 9=30, 10=36). The higher values with larger populations do show a positively sloped trend line of increasing score (Figure 9).

Table 4: Shows the calculated average score by self-reported analytical thinking ability.

Analytical Thinking Ability	Average Score
1	N/A
2	14
3	10.2

4	11
5	14.42857143
6	12.52941176
7	11.7826087
8	12.25714286
9	12.46666667
10	12.52777778

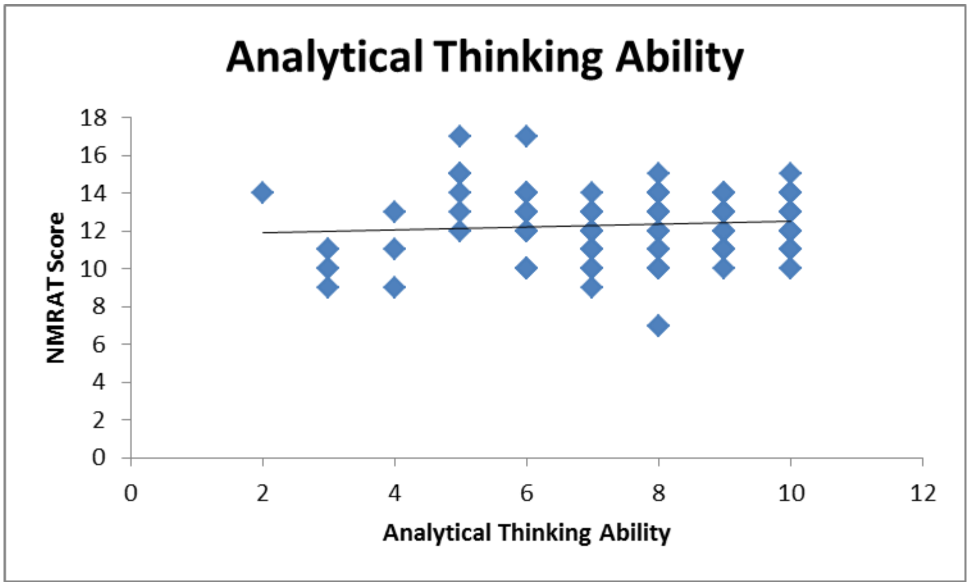


Figure 9: Shows the NMRAT score versus self-reported analytical thinking ability and the trend line from the linear regression analysis.

4.2.5. Creative Thinking Ability

The median value of respondent's creative thinking ability was 7 with a mode value of 7. There was a single response for the value of "1" and twenty six of the 157 total responses indicating a creative thinking ability of five or less. The values are more normally distributed than the results of the analytical thinking ability question, but still skewed negatively to the left with a skewness value of -0.5689 and a slightly larger peak than a standard normal distribution with an excess kurtosis value of 0.6188 (Figure 10, 11 and Table 5).

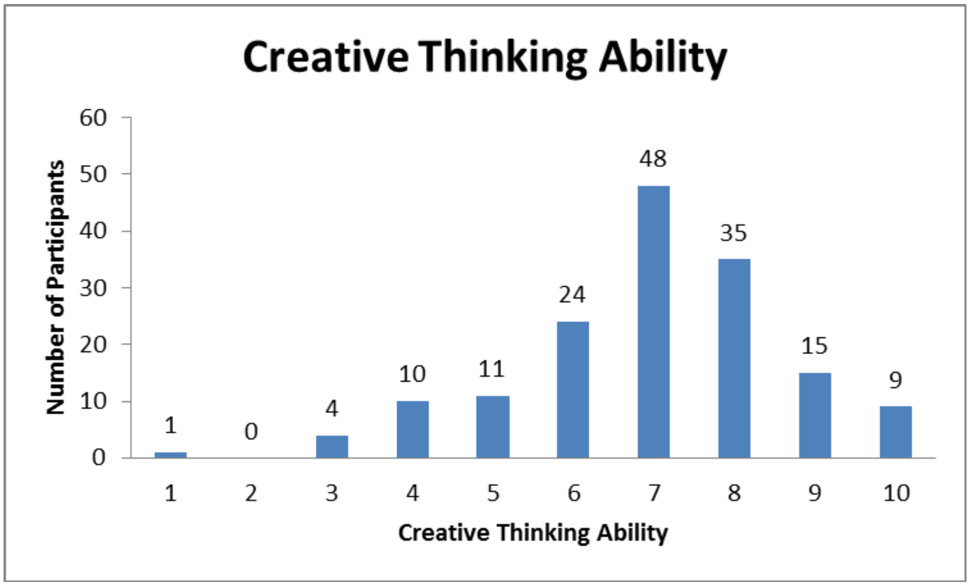


Figure 10: Histogram showing the participants response to the self-reported creative thinking ability question on a 1-10 scale with “1” indicating a low ability.

Table 5: Shows the calculated average score by self-reported creative thinking ability.

Creative Thinking Ability	Average Score
1	11
2	N/A
3	11.5
4	12.3
5	12.81818182
6	12.25
7	12.3125
8	12.14285714
9	13.2
10	11.77777778

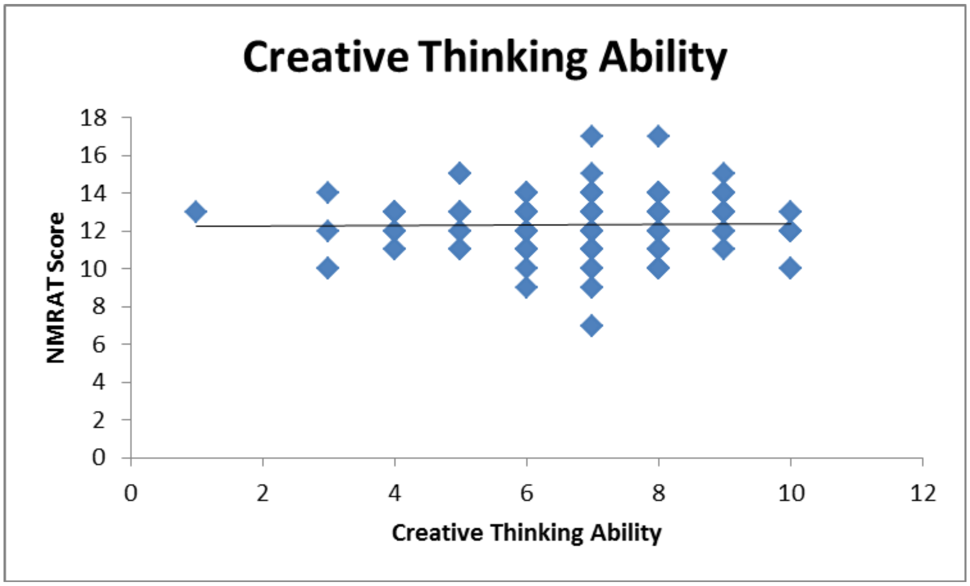


Figure 11: Shows the NMRAT score versus self-reported creative thinking ability and the trend line from the linear regression analysis.

4.2.6. Spatial Thinking Ability

The median value of the spatial thinking ability question was 7 and a mode of 8. Of note is the larger spread of the values for spatial thinking with forty two (26.8 percent) of the 157 responses indicating they are on the lower side (a value of five or lower) of the spatial ability thinking scale, but no responses of "1". With a skewness value of -0.5050, the data is slightly negatively distributed and a kurtosis value of -0.5105 showing it has a relatively flat peak compared to a standard distribution.

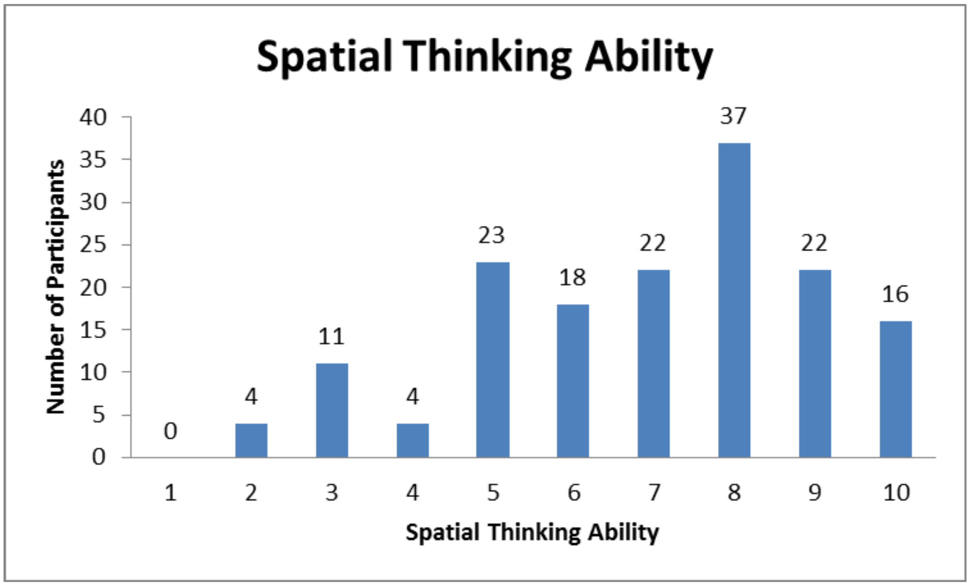


Figure 12: Histogram showing the participants response to the self-reported spatial thinking ability question on a 1-10 scale with “1” indicating a low ability.

Table 6: Shows the calculated average score by self-reported spatial thinking ability.

Spatial Thinking Ability	Average Score
1	N/A
2	10.25
3	12.45454545
4	12.5
5	12.39130435
6	12.33333333
7	12.27272727
8	12.86486486
9	11.77272727
10	12.3125

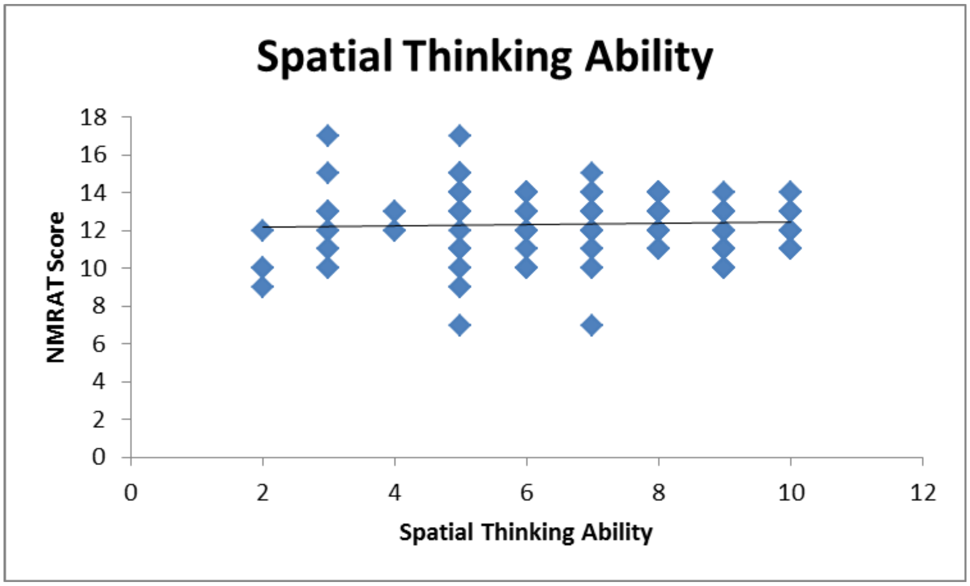


Figure 13: Shows the NMRAT score versus self-reported spatial thinking ability and the trend line from the linear regression analysis.

4.2.7. Cognitive Style Index

The values for the Cognitive Style questions in instrument three were calculated using the scoring guide and methodology prescribed by Cools et al. (2007). An equation was created in Microsoft Excel that automated the score calculation and scored each respondent on each of the three Cognitive Styles; Planning, Knowing, and Creating. Automating the tabulation of values was done to speed the scoring process and reduce the possibility of human error in transcribing the data from the database to a results spreadsheet.

On the Knowing Cognitive Style, values ranged from six to twenty with a median value of 15 and a standard deviation of 2.33. The responses show a moderate left skewed unimodal distribution pattern with a skewness of -0.9661. The excess kurtosis value of 2.7416 means it has a peak that is larger than that of a standard normal distribution.

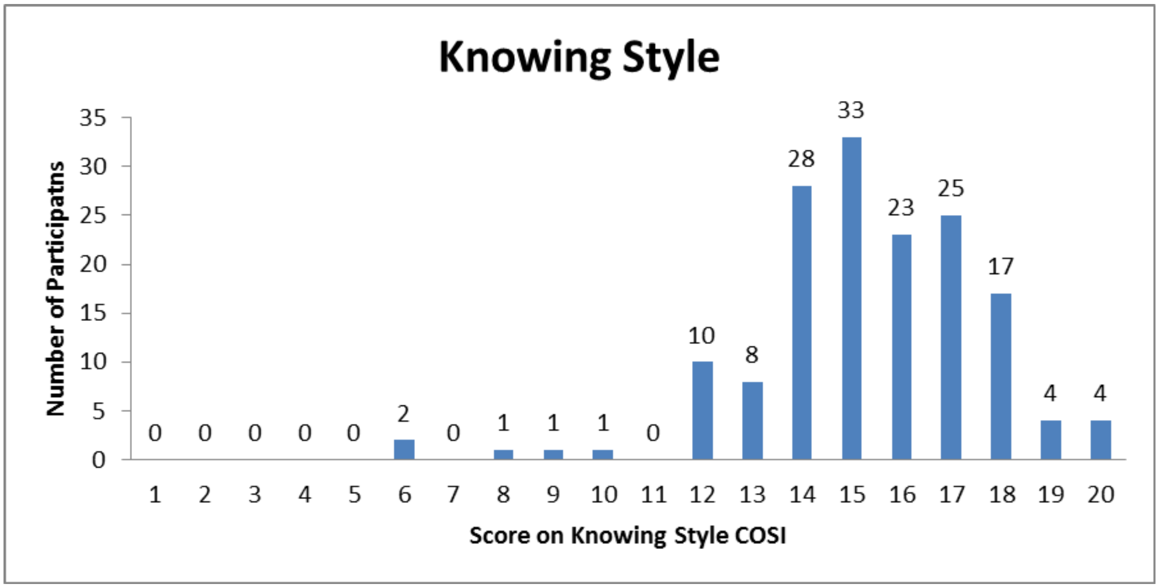


Figure 14: Histogram showing the distribution of "Knowing Style" scores on the COSI.

When looking at the table of average NMRAT scores for the knowing style value, the score of 6 is from only two responses and values of 8, 9, and 10 represent a single response each. The linear regression model resulted in a near horizontal trend line. The p-value from the analysis is also too high to be considered statistically significant at 0.91258.

Table 7: Shows the calculated average score by knowing cognitive style value.

Knowing Style	Average Score
6	11
7	N/A
8	9
9	17
10	9
11	N/A
12	13.3
13	12

14	12.28571429
15	12.24242424
16	12.60869565
17	12.44
18	12.35294118
19	12
20	11

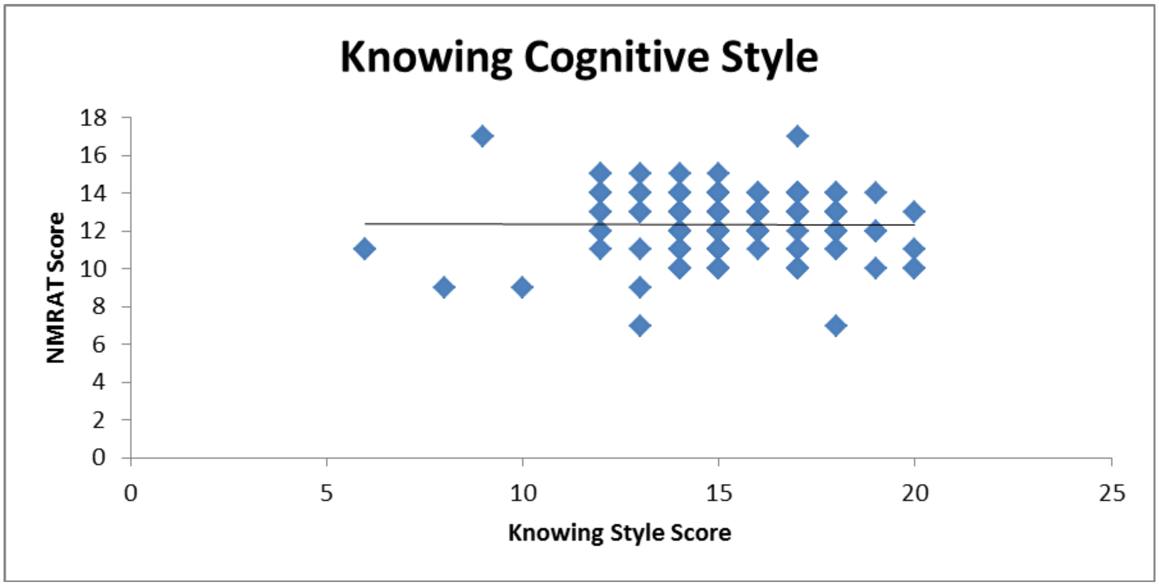


Figure 15: Shows the NMRAT score by the knowing cognitive style value and the trend line from the linear regression analysis.

The Planning Style values ranged from twelve to thirty with a median of 21, mode of 23, and a standard deviation of 3.90. Like the Knowing Cognitive Style, results of the Planning Cognitive Style show a very slight unimodal left skewed distribution with a skewness value of -0.1434. The excess kurtosis value of -0.0619 gives the peak a very similar shape to that of a standard normal distribution. The planning cognitive style was the only value that reached the statistical significance p-value threshold ($p < .05$) with a value of 0.00282 in the initial multiple linear regression analysis.

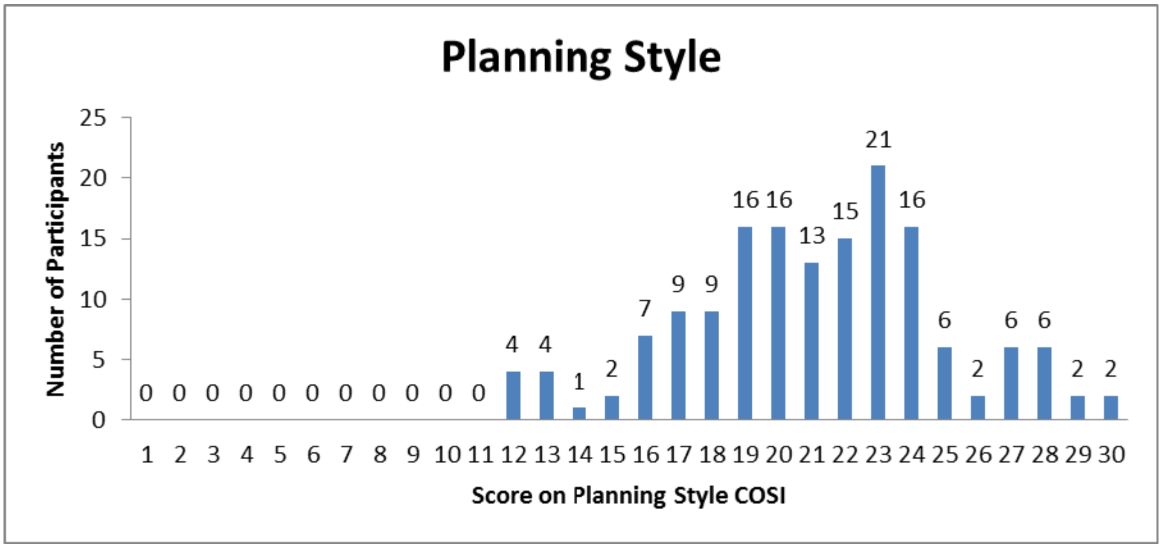


Figure 16: Histogram showing the distribution of "Planning Style" scores on the COSI.

Table 8: Shows the calculated average score by planning cognitive style value.

Planning Style Value	Average Score
12	12.25
13	13
14	13
15	11
16	12.42857143
17	12.33333333
18	13.44444444
19	12.6875
20	12.9375
21	12.76923077
22	12.06666667
23	11.76190476
24	12.5625
25	13
26	11
27	11
28	12.16666667
29	9
30	10

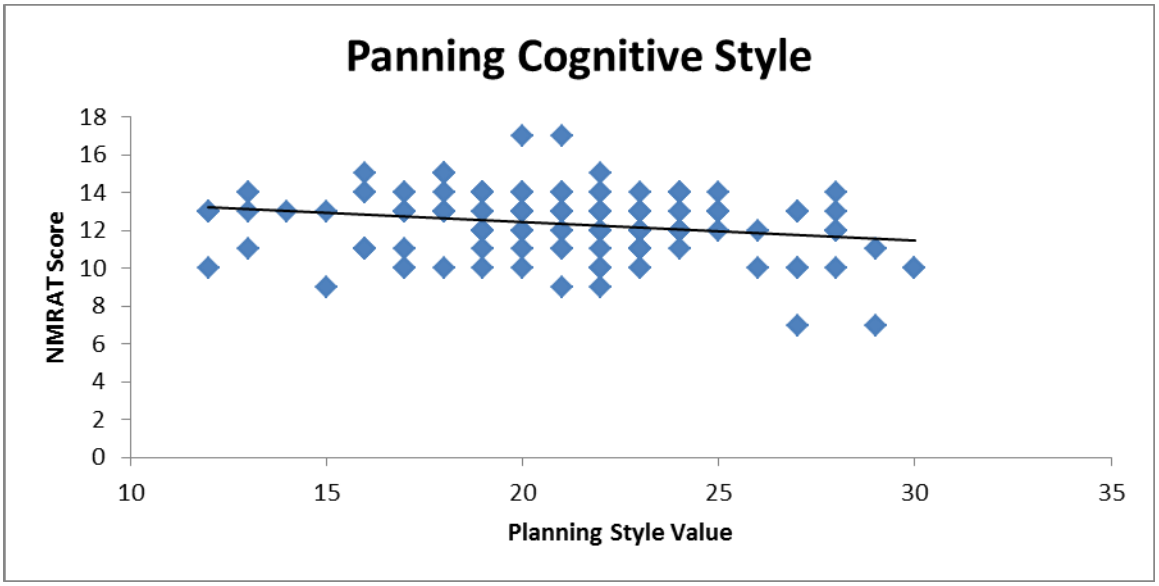


Figure 17: Shows the NMRAT score by the planning cognitive style value and the trend line from the linear regression analysis.

The Creating Style had values from eleven to thirty-five with a median value of 25, a mode of 26, and a standard deviation of 4.16. The Creating Style also has a unimodal slight left skewed distribution with a skewness value of -0.3550. The excess kurtosis value of 0.6529 means the data has a slightly sharper peak than the standard normal distribution peak. Similar to the knowing style, the number of responses comprising the creating cognitive style is more populated toward the higher values. The linear regression analysis also produced a similarly horizontal trend line, although this one very slightly indicates a negative relationship. The Creating Cognitive Style was not found to be statistically relevant with a p-value of 0.27529 in the initial multiple linear regression analysis.

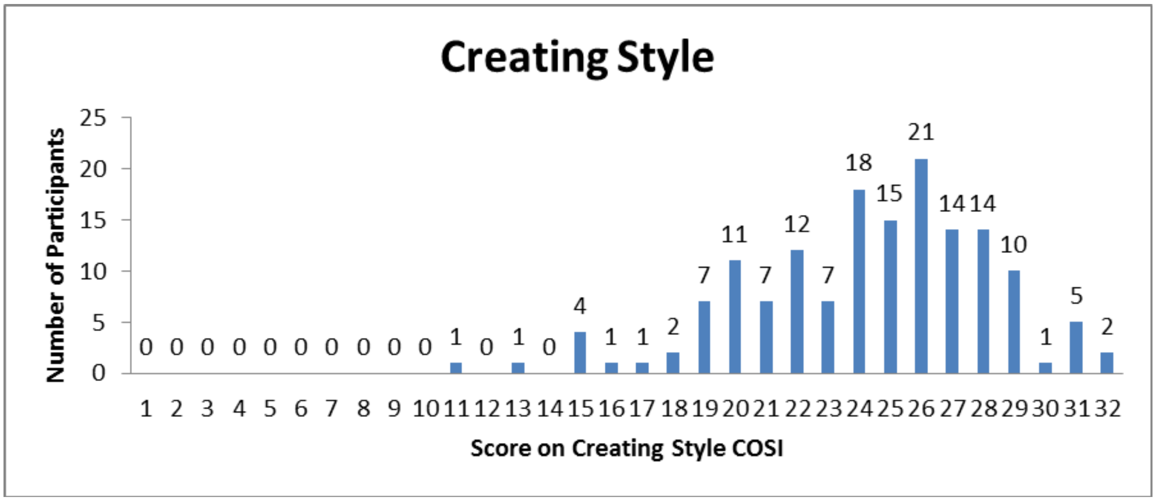


Figure 18: Histogram showing the distribution of “Creating Cognitive Style” scores on the COSI.

Table 9: Shows the calculated average score by creating cognitive style value.

Creating Style Value	Average Score
11	13
12	N/A
13	14
14	N/A
15	11.75
16	12
17	9
18	13.5
19	12.14285714
20	11.36363636
21	13.71428571
22	12.33333333
23	13.57142857
24	12.05555556
25	13
26	12.42857143
27	12.07142857
28	11.78571429
29	12.7
30	14

31	12.6
32	11.5
33	N/A
34	N/A
35	10.66666667

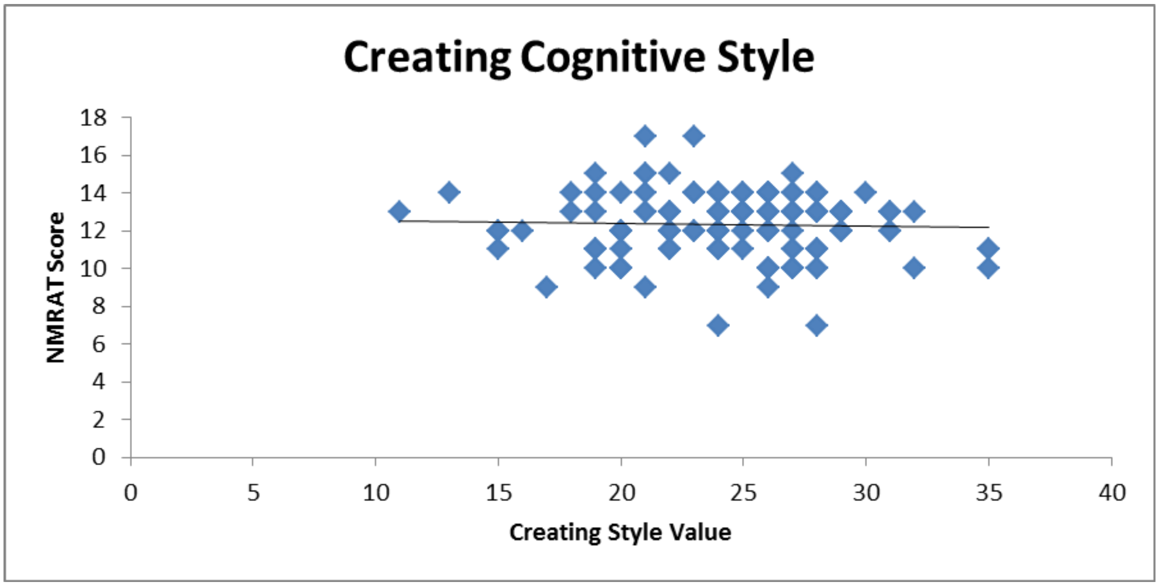


Figure 19: Shows the NMRAT score by the Creating Cognitive Style value and the trend line from the linear regression analysis.

4.3. Navigational Map Reading Ability - Dependent Variable

For instrument four, the self-location task of the NMRAT, scores ranged from seven to seventeen correct answers out of a possible twenty questions. Correct answers were coded in to the ActionScript in the testing procedure and recorded an incorrect ("0") or correct ("1") response in the database. These values were then totaled to determine the participant's NMRAT score. The median and mode score was 13 with a standard deviation of 1.60. The highest score was 17 and the lowest was 7. The results show a unimodal distribution skewed slightly to the left with a skewness value of -0.3862. The excess kurtosis value of 0.9617 means the data has a higher or sharper than standard peak.

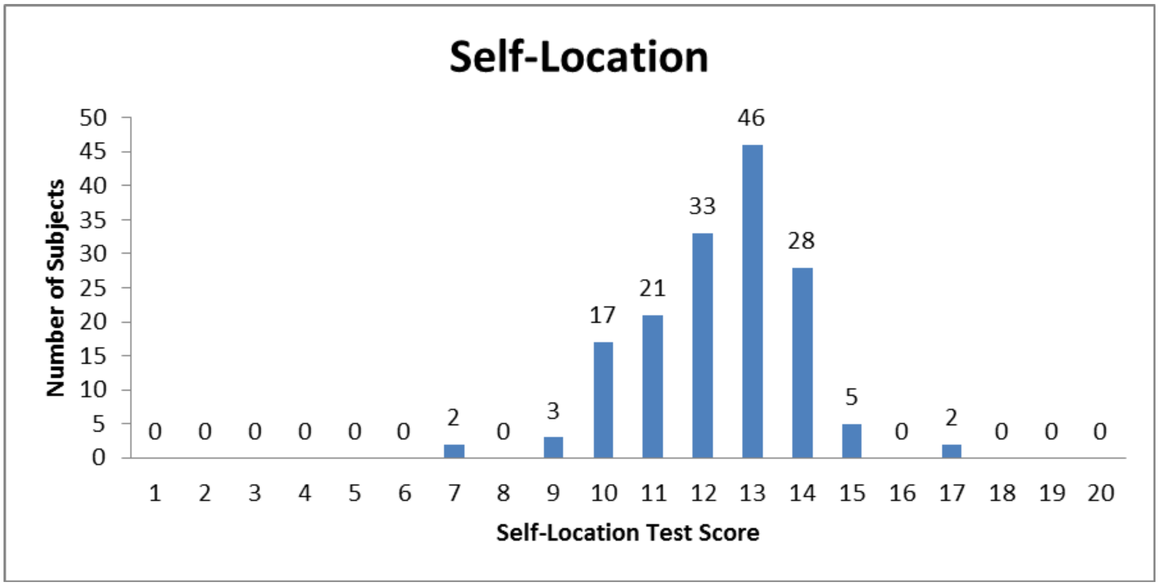


Figure 20: Score of participants on the NMRAT Self-Location Test.

4.4. Regression Analysis

The next task was to create a multiple linear regression model from the data collected to see how each independent variable influenced the dependent variable of self-location ability. All of the independent variables were included in the initial multiple regression model, the goal being to see if any one variable, or all of the independent variables collectively, could reliably predict the dependent value at a rate better than chance. The results of the model showed an r-squared value of 0.1061, indicating that it could only account for about ten percent of the variability in the dependent variable given the data input by the independent variables. The model had a p-value of 0.03552 which does make it statistically significant. The model also indicated the planning cognitive style as the only statistically significant variable within the model (defined as a p-value of less than or equal to 0.05). The beta coefficient (Estimate column from Table 10) from the model indicated that for every point on the planning scale a participant increased their score on the self-location test decreased by .11 and can be seen in Figure 21. The results of the regression are discussed individually and in more detail in the following chapter, Chapter V. In looking at the correlation matrix (Table 11), there is no variable that appears to be highly correlated with any other variable. Many of the variables show values very close to “0” indicating no correlation at all. To be sure, an analysis of the variance inflation factor (VIF) was performed (Table 12). The results of the VIF do not show any signs of multicollinearity that is normally associated with values at or above “4” (Farrar and Gluaber, 1967).

Table 10: Results from the linear regression model of independent variables versus the dependent variable of self-location. $*p<0.05$

Independent Variable	Estimate	Standard Error	t-value	Significance (p-value)
Creating	-0.041106	0.037539	-1.095	0.27529
Planning	-0.110266	0.036302	-3.037	0.00282*
Knowing	0.007803	0.070951	0.11	0.91258
Spatially	0.055445	0.069212	0.801	0.42437
Analytically	0.058978	0.090823	0.649	0.51711
Creatively	-0.05283	0.09397	-0.562	0.57484
Education	-0.170544	0.167716	-1.017	0.31089

Age	-0.153847	0.116475	-1.321	0.18860
Gender	-0.266021	0.257156	-1.034	0.30261

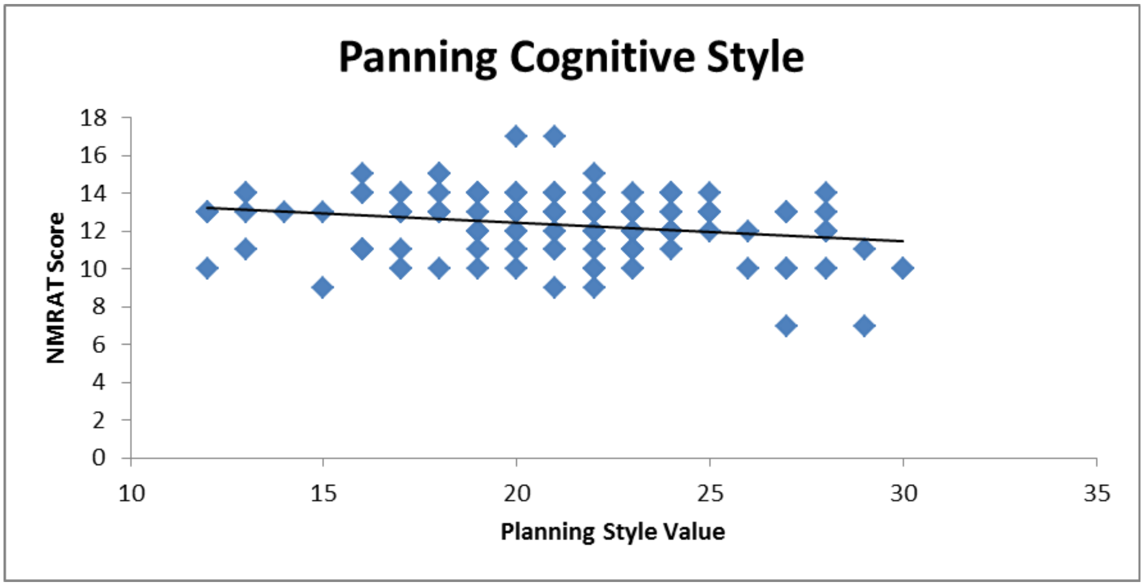


Figure 21: Plot of Panning Cognitive Style values versus NMRAT Self-Location Score with the linear regression line.

Table 11: Correlation matrix shows none of the variables are highly correlated with any other variable. The Knowing Cognitive Style with the Analytical thinking ability value is the highest correlation at .57.

	Age	*Gender*	*Education*	*Creatively*	*Analytically*	*Spatially*	*Knowing*	*Planning*	*Creating*	*Score*
Age	1									
Gender	-0.07124	1								
Education	0.232043	0.0522484	1							
Creatively	-0.06204	-0.010214	-0.13439375	1						
Analytically	-0.15704	-0.114769	0.065470895	0.210286801	1					
Spatially	-0.03845	-0.055587	0.135110266	0.335503967	0.401095565	1				
Knowing	-0.20579	0.0646223	0.091793039	0.087339289	0.57099026	0.16946459	1			
Planning	0.01874	0.0758058	0.168460945	-0.23810252	0.076587481	0.06669134	0.2630058	1		
Creating	0.174943	-0.081345	-0.12097862	0.501582798	0.078480211	0.13357795	0.07175538	-0.3055742	1	
Score	-0.16402	-0.101259	-0.12563671	0.014445433	0.085106844	0.04886879	-0.0100917	-0.2319741	-0.0393826	1

Table 12: The Variance Inflation Factor table indicates that none of the variables raise a red flag for multicollinearity.

	Age	*Gender*	*Education*	*Creatively*	*Analytically*	*Spatially*	*Knowing*	*Planning*	*Creating*	*Score*
Age	1.248967	0.084228	-0.31903	0.15668	0.039949	0.02943	0.297306	-0.11004	-0.3858	0.128483
Gender	0.084228	1.067069	-0.0626	-0.08727	0.239515	0.01782	-0.18099	-0.01247	0.099935	0.093223
Education	-0.31903	-0.0626	1.174902	0.136338	-0.01674	-0.21388	-0.1374	-0.03244	0.158092	0.096166
Creatively	0.15668	-0.08727	0.136338	1.585271	-0.14994	-0.42022	0.043641	0.190395	-0.68777	0.061909
Analytical	0.039949	0.239515	-0.01674	-0.14994	1.826738	-0.51753	-0.9888	0.1206	0.116229	-0.07673
Spatially	0.02943	0.01782	-0.21388	-0.42022	-0.51753	1.371435	0.177345	-0.19466	-0.03681	-0.08196
Knowing	0.297306	-0.18099	-0.1374	0.043641	-0.9888	0.177345	1.759122	-0.45713	-0.31775	-0.01277
Planning	-0.11004	-0.01247	-0.03244	0.190395	0.1206	-0.19466	-0.45713	1.369602	0.398557	0.301906
Creating	-0.3858	0.099935	0.158092	-0.68777	0.116229	-0.03681	-0.31775	0.398557	1.584841	0.120208
Score	0.128483	0.093223	0.096166	0.061909	-0.07673	-0.08196	-0.01277	0.301906	0.120208	1.126877

To further explore the results, a multiple linear regression was performed on the three variables from the COSI and resulted in an r-squared value of 0.07255, meaning the model is only able to predict about 7% of the variance seen in the dependent variable. This model was also statistically significant with a p-value of 0.009052. The analysis also indicated that of the three independent variables, the Planning style was still the only value to reach the statistical significance threshold of a p-value below 0.05 (as seen in Table 13).

Table 13: Linear regression results from just the three COSI variables. (*) indicates a p-value < 0.05 that is statistically significant.

	Estimate	Std. Error	t value	Pr(>|t|)
Knowing	0.0528	0.05634	0.937	0.3502
Planning	-0.12069	0.03528	-3.421	0.0008*
Creating	-0.05183	0.03195	-1.622	0.1068

A median split was performed on the scores from the NMRAT, categorizing the “good performers” and “bad performers” by dividing them along the median value of 13. Another multiple linear regression model was run on all of the independent variables (Table 14 for the good performers and 15 for the bad performers).

The multiple linear regression model of the good performers resulted in an r-squared value of 0.2817, indicating that the model with those variables as an input likely accounted for about twenty eight percent of the variance in the dependent variable of the NMRAT score. This model was also statistically significant with a p-value of 0.001697. The model also found different significant variables than the previous model. When just looking at the good performers, the Creating Cognitive Style, spatial thinking ability, and creative thinking ability emerged as being statistically significant (p-value < 0.05).

The multiple linear regression model for the bad performers resulted in an r-squared value of 0.1406, meaning the model can likely account for about fourteen percent of the variation in the dependent variable. The model was also not found to be statistically significant with a p-value of 0.2256. The regression analysis showed that none of the independent variables were statistically significant (See table 16).

Table 14: Linear regression results from all variables from participants that scored 13 or higher on the NMRAT. (*) Indicates a statistically significant finding with a p-value <.05

	Estimate	Std. Error	t value	Pr(>|t|)
Creating	-0.06574	0.028785	-2.284	0.02534*
Planning	-0.00825	0.024966	-0.33	0.74199
Knowing	-0.04267	0.051346	-0.831	0.40872
Spatially	-0.16356	0.052681	-3.105	0.00272*
Analytically	-0.0453	0.059263	-0.764	0.44714
Creatively	0.175993	0.064145	2.744	0.00766*
Education	0.173775	0.121395	1.431	0.15662
Gender	0.168441	0.107662	0.964	0.7639
Age	0.007107	0.094246	0.075	0.9401

Table 15: Linear regression results from all variables from participants that scored below 13 on the NMRAT. (*) Indicates a statistically significant finding with a p-value <.05

	Estimate	Std. Error	t value	Pr(>|t|)
Creating	-0.01946	0.037643	-0.517	0.607

Planning	-0.04363	0.038215	-1.142	0.258
Knowing	-0.00185	0.069066	-0.027	0.979
Spatially	0.100102	0.065742	1.523	0.133
Analytically	0.124257	0.096038	1.294	0.2
Creatively	-0.09718	0.099522	-0.976	0.332
Education	-0.07326	0.16435	-0.446	0.658
Gender	-0.06425	0.143991	-0.318	0.71
Age	-0.03095	0.112415	-0.275	0.784

With respect to just the Cognitive Style Index results, a multiple linear regression analysis of the median split results of the good performers and bad performers was also conducted on just those three variables of Creating, Planning, and Knowing Cognitive Styles. The model from the good performer group resulted in an r-squared value of 0.1349, accounting for about 13.5% of the variation in the NMRAT score. The model was statistically significant with a p-value of 0.01054. That model also produced results similar to the previous model of good performers, that the Creating Cognitive Style was a statistically significant variable within the model (See Table 16). The model from the results of the bad performers resulted in an r-squared value of 0.04516, meaning the model could only predict about 4.5% of the variation in the dependent variable and a p-value of 0.3408 making the model not statistically significant. As with the previous model of bad performers, which included all the variables, there were no individual variables that were found to be statistically significant in this model (see Table 17).

Table 16: Linear regression results from the COSI variables from participants that scored 13 or higher on the NMRAT. (*) Indicates a statistically significant finding with a p-value <.05

	Estimate	Std. Error	t value	Pr(>|t|)
Creating	-0.0575	0.02574	-2.235	0.0283*
Planning	-0.0276	0.02577	-1.069	0.2882
Knowing	-0.08309	0.04588	-1.811	0.074

Table 17: Linear regression results from the COSI variables from participants that scored below 13 on the NMRAT. (*) Indicates a statistically significant finding with a p-value <.05

	Estimate	Std. Error	t value	Pr(>|t|)
Creating	-0.04188	0.02938	-1.425	0.158
Planning	-0.04444	0.03718	-1.195	0.236
Knowing	0.06081	0.05238	1.161	0.249

CHAPTER V

DISCUSSION AND CONCLUSION

5.1. Discussion

The results of the analysis provide mixed results. One statistically significant finding of this research being that the Planning Cognitive Style is negatively related to the performance on the NMRAT self-location test with a beta value of -.11 (Table 10). The research question posed in Chapter I- “What is the relationship between age, gender, education level, spatial thinking ability, analytical thinking ability, creative thinking ability, cognitive style and navigational map reading ability?”- has a mixed answer. As with many types of research involving behavior or cognitive processes, having a mixed answer is not a bad thing. It is a very complicated task to attempt to predict a person’s ability on one task given the results from another task.

In the initial regression analysis results that included all of the independent variables, only the planning cognitive style was found to have a statistically significant relationship with NMRAT score in this research. In subsequent regression models that divided the sample population the Creating Cognitive Style, the ability to think creatively, and ability to think spatially emerged as significant variables within the populations that scored higher than the median on the NMRAT task. The models of the bad performers, however, found no significant findings and had lower r-squared values than the models of good performers.

This chapter will discuss the results of the analysis and show the relationship between each of the independent variables and the dependent variable. Also, the relationship of the findings of this thesis will be discussed in the framework of previous published works. The chapter will finish with concluding remarks about the findings of this thesis and possible avenues for further research to explore.

5.1.1. Age

The results for the age variable (see Table 1 and Figure 2) show performance on the NMRAT had a negative trend as participant age increased with a beta coefficient of -.15 from the initial regression model (see Table 10). The initial all-inclusive multiple linear regression analysis failed to report a statistically significant result using multiple linear regression modeling to corroborate the findings of previous research conducted on the influence of age on navigation ability that were outlined in Chapter II. The p-value of the age variable in the linear regression model (see Table 10) for spatial thinking ability was 0.18860, needing $p<.05$ as the threshold for statistical significance. The results from the additional median split performance based analysis of good and bad performers showed similar beta coefficients at 0.007 and -0.030 respectively. Both of these additional models did not find age to be a significant predictor of performance.

One potential drawback of this study with respect to the age variable was that a categorical age answer was used. This made it impossible to break down the data in to smaller units for further analysis. The category method was the result of a programming obstacle in the testing design and a timely solution could not be found.

5.1.2. Gender

Results also do not offer concrete support for some of the previous research on gender and navigation. Earlier studies had found that men used more Euclidian strategies (distance and direction) for navigation where women used landmarks (Dabbs et al. 1998; Choi and Silverman 1997; Galea and Kimura 1993; Miller and Santoni 1982; Ward et al. 1986; Downs and Stea 1977). Recall from Chapter IV that the results from this thesis reported a very similar average score for men and women (12.48 for the men and 12.15 for the women) this would suggest that the NMRAT Self-location test performance is not significantly related to gender and information about participants using the Euclidian-type solution or a landmark-type approach was not gathered. The first multiple linear regression model did not sufficiently predict the data with a p-value of 0.30261 making the findings not statistically significant. Subsequent models also found that gender was not a significant predictor of performance.

5.1.3. Education

In looking at the education level of participants (Table 3) the data shows a decline in average score for the group that indicated having completed a graduate level degree (eg MS, MA, PhD, MD, or Law). Like previous variables, analysis of the education variable in the multiple linear regression models failed to meet the p-value threshold for statistical significance with a value of 0.31089 in the first model. This also held true when the sample population was divided based on performance with p values of 0.156 for good performers and 0.658 for bad performers. This means that within this sample, education level is not a reliable predictor of performance.

The large population in the "some college" (forty responses) category and zero responses on the "high school" category would seem to indicate that participants attended a college at some point, although it does not distinguish between those currently in school and those that have dropped out without completing a degree. This problem in this categorization could likely be solved by modifying future studies to distinguish between participants that are currently enrolled and those that are not by renaming the "some college" category as "currently attending college". This would likely create a distinction between current students and those that failed to obtain a degree and only have a high school education.

5.1.4. Creative Thinking Ability

Values for the self-reported creative thinking abilities do not show a strong pattern for higher scores being related to higher ability levels (see Table 5 and Figure 10). The low end of the scale does contain an average score that is lower than the upper end of the scale. The peak average (13.2) in the "9" score could show an increase. Also of note is the apparent increase at the "5" value, which occurs in the creative thinking ability table. The first multiple linear regression model for creative thinking ability resulted in a p-value of 0.57484. When looking at just the good performers, those that scored above average, creative thinking ability was indicated as being one of three significant variables in the regression analysis with a p-value of 0.00766. The beta coefficient value of 0.175 would indicate that among the good performers their self-reported assessment of their creative thinking ability is positively related to their performance on the NMRAT.

5.1.5. Analytical Thinking Ability

The analytical thinking ability variable did not yield any statistically significant results. Similar to the creative thinking ability the first all-inclusive multiple linear regression model, the analytical thinking ability resulted in a p-value of 0.51711. In the regression model created from the good performers' data, analytical thinking ability was also not found to be statistically significant with a p-value of 0.44714. The results from the multiple linear regression model of the bad performers further supported the other models and found analytical thinking ability to not be significant with a p-value of 0.2.

5.1.6. Spatial Thinking Ability

Recall the research cited in Chapter II that found that a self-reported value of spatial ability was previously found to be a reliable predictor of ability on spatial ability tasks (Cornell et al., 2003). My study found mixed results with regards. The p-value of the spatial thinking ability variable in the first linear regression model (see Table 10) was 0.42437, well above the $p<.05$ threshold for statistical significance. When just looking at the results from the good performers, however, the spatial thinking ability variable became a significant variable in the multiple linear regression analysis with a p-value of 0.00272 (see Table 15).

The average NMRAT score appears relatively uniform across the range of spatial ability values reported by participants. Contributing to this may be the small sample populations for the lower values with only nineteen of the one hundred and fifty seven participants reporting a value of four or lower. Also of interest is the most frequently reported value, “8”, also had the highest average score and was 1.09 and .55 higher than the average scores for the “9” and “10” categories, respectively.

The results of the three self-reported ability metrics show a slight positive trend in ability level and navigational map reading ability as seen in the positive beta coefficients reported in the first linear regression model (Table 10). The results from previous studies on ability tests have indicated that higher scores on general abilities tests show a positive correlation on a spatial cognition test (Thorndyke and Stasz 1980; Sholl and Egeth 1982; Lloyd and Steinke 1984; Streeter and Vitello 1986; Kovach, Surrette, and Aamodt 1988). The results from this thesis do not uniformly support those previous findings due to two of the ability values having opposing slope values positive on the linear regression models and being considered statistically significant in the linear regression model for good performers (Table 13). Spatial thinking ability has a negative slope while creative thinking ability is has a positive slope. The lack of significance in the bad performers is interesting though and would be an interesting avenue for another study on performance differences.

5.1.7. Knowing Cognitive Style

People with a Knowing Cognitive Style rely heavily on having all the facts and data in their efforts to solve problems. Recall back to Chapter IV(figure 14) that the values of Knowing Cognitive Style were skewed with the values between fourteen and eighteen comprising 128 of the 157 responses received. Conclusions from the data are hard to come to as there is not a clear relationship present in the data. The initial all-inclusive multiple linear regression model did not report a statistically significant relationship between the Knowing Cognitive Style value and score on the NMRAT, indicating that NMRAT score is not significantly influenced by the knowing cognitive style value. The p-value from the analysis is also too high to obtain statistical significance at 0.91258, the highest among all the independent variables. The second multiple linear regression analysis that just included the Cognitive Style Index variables still did not find the Knowing Cognitive Style to be significant with a p-value of 0.3502. All four of the performance-based multiple linear regression models had similar results, indicating that the Knowing Cognitive Style was not found to be statistically significant variable in predicting NMRAT score.

5.1.8. Creating Cognitive Style

Creating Style people like creativity and exploration and are less interested in practical applications. Similar to the Knowing Style, the number of responses comprising the Creating Cognitive style is skewed with more responses found in the higher values. The first multiple linear regression analysis also produced a p-value too large to be statistically relevant though with a p-value of 0.27529. The second multiple linear regression model that just included the Cognitive Style Index variables (Table 14) also found the Creating Cognitive Style to not be statistically significant with a p-value of .1068, which is close to being considered marginally significant. When looking at just the results of the good performers, those with a NMRAT score of 13 or above, the Creating Cognitive Style was found to be a statistically significant variable in that model with a p-value of 0.02534. The model that only included the values from the good performers on the three Cognitive Style variables also found the Creating Cognitive Style to be statistically significant with a p-value of 0.0283. The two models that used the results of the bad performers, those scoring less than 13 on the NMRAT did not return a statistically significant finding for the Creating Cognitive Style.

5.1.9. Planning Cognitive Style

One of the main attributes of the Planning Cognitive Style is the need for structure. They also are averse to ambiguity and prefer clarity and order. As stated in the beginning of this chapter, the planning cognitive style was initially the only value that reached the statistical significance p-value threshold ($p < .05$) with a value of 0.00282. The beta coefficient from that analysis was -.11 (Table 10). The second multiple linear regression analysis that only looked at the three COSI independent variables also found the Planning Cognitive Style to be a statistically significant variable in the model with a p-value of 0.0008. The second model found Planning Cognitive Style to be more significant among just the three COSI variables. The beta coefficient from that analysis was similar at a value of -.12 indicating that there is a very slight negative relationship between Planning Cognitive Style score and score on the NMRAT task. In the initial all-inclusive multiple linear regression analysis the results suggest that the traits specific to the Planning Cognitive Style negatively influence a person's ability on navigational map reading tasks. Further analysis did not find Planning Cognitive Style to be a significant variable within subsequent models that divided the sample population based on NMRAT performance. When looking at the different performance groups, the Planning Cognitive Style was not found to be statistically significant in any of the four models.

5.2. Conclusion

Studying cognitive processes can be a difficult task with results not presenting a clear indication of what is happening or how to interpret them. Navigation and spatial cognition are very complex tasks that researchers are just beginning to explore and understand. This thesis included a new way to compare Cognitive Style and ability to navigation ability by including a Cognitive Style measure. With the mixed results discussed here there is potential that with further exploration and refinement of the methods, Cognitive Style research may prove useful to understanding more about navigation and spatial cognition processes.

The research presented in this thesis failed to offer any statistically significant results that support previous research conclusions about the effect of age on navigation ability. This thesis also does not show a significant gender related performance difference on the self-location task of the NMRAT with enough difference to be significant. The results from the self-reported thinking ability portion found that within the good performers, creative and spatial thinking abilities were found to be significant variables in the multiple linear regression models. The results of the regression analysis performed on the COSI variables did indicate that the Planning Cognitive Style score was statistically significant within the all-inclusive regression model and the COSI variable model that included both good and bad performers. This finding was not supported by subsequent analysis of the good and bad performance groups. Instead, the good performance group analysis found the Creating Cognitive Style, creative thinking ability, and spatial thinking ability to be statistically significant.

The multiple linear regression model in this analysis that could best model that data was the model created from the good performers that included all the variables which had an r-squared value of 0.2817, meaning the variables that were included account for about 28% of the variation in the dependent variable. The model that used data from the bad performance group and only the three COSI variables had the lowest r-squared value at 0.04516, accounting for a mere 4.5% of the variation seen in the NMRAT score. Four of the six regression models were found to be statistically significant. The two models that only included the results from the low performance group did not result in a statistically significant finding.

Further study is needed that includes different cognitive styles to see if there is one that can more reliably predict NMRAT scores. Future studies could also address using a Cognitive Style test to identify navigation performance groups. I would make the suggestion to expand the self-reported thinking value questions to include actual aptitude tests such as the Santa Barbara Sense of Direction Scale for spatial ability. Also I would suggest changing the education classifications as well as recording a numerical value for age rather that a categorical value to re-evaluate their importance in the event a potential bias was introduced by my methods.

APPENDIX

TEST FRAMES

You must agree to continue.

◯ Agree

You are invited to participate in a research study conducted by Amy Lobben from the University of Oregon Department of Geography. The study purpose is to learn about how spatial thinking skills enhance learning and is funded by the National Institutes of Health.

If you decide to participate, you will view several graphics that represent spatial concepts, including maps. You will be asked to study those graphics and make decisions about them. Your participation in this project will help us better understand spatial thinking, map use, and geographic education. However, we cannot guarantee that you personally will receive any benefits from this research.

Any information that is obtained in connection with this study and that can be identified with you will remain confidential and will be disclosed only with your permission. To keep subject identities confidential, we will use a numeric code to associate subject responses with identities. No information will be released to any other party outside of the research group for any reason.

If you choose to participate, the entire session will take less than one hour. Your participation is voluntary. Your decision whether or not to participate will not affect your relationship with the University of Oregon. If you decide to participate, you are free to withdraw your consent and discontinue participation at any time without penalty.

If you have any questions, please feel free to contact Amy Lobben, Department of Geography – University of Oregon, 541-346-4566. If you have questions regarding your rights as a research subject, contact the Office for Protection of Human Subjects. This Office oversees the review of research to protect your rights and is not involved with the study. Office of Human Subjects Compliance, University of Oregon, Eugene, OR, 97403, 541-346-2510. For a copy of this form contact Amy Lobben.

Checking the "AGREE" box constitutes your consent to participate, that you willingly agree to participate, that you may withdraw your consent at any time and discontinue participation without penalty, that you have reviewed this form, and that you are not waiving any legal claims, rights, or remedies.

Next

How old are you?

- 18-24
- 25-34
- 35-44
- 45-54
- 55-64
- 65 and above

Next

Are you male or female?

- Male
- Female

Next

What is the highest level of education you have completed?

- Primary School
- High School
- Some College
- Associates or 2-year degree
- Bachelor's Degree
- Graduate Degree (e.g. M.A., M.S., Ph.D., M.D., Law Degree)

Next

Rate your ability to think CREATIVELY

- 1 - Not a Creative Thinker
- 2
- 3
- 4
- 5 - Neutral
- 6
- 7
- 8
- 9
- 10 - Very Creative Thinker

Next

Rate your ability to think ANALYTICALLY

- 1 - Not Analytical Thinker
- 2
- 3
- 4
- 5 - Neutral
- 6
- 7
- 8
- 9
- 10 - Very Analytical Thinker

Next

Rate your ability to think SPATIALLY

- 1 - Not Spatial Thinker
- 2
- 3
- 4
- 5 - Neutral
- 6
- 7
- 8
- 9
- 10 - Very Spatial Thinker

Next

I like much variety in my life.

- ◯ typifies me totally not
- ◯ typifies me rather not
- ◯ neutral
- ◯ typifies me rather well
- ◯ typifies me totally

Next

I study each problem until I have understood the underlying logic.

- typifies me totally not
- typifies me rather not
- neutral
- typifies me rather well
- typifies me totally

Next

I prefer well-prepared meetings with a clear agenda and strict time management.

- ○ typifies me totally not
- ○ typifies me rather not
- ○ neutral
- ○ typifies me rather well
- ○ typifies me totally

Next

I like to contribute to innovative solutions.

- typifies me totally not
- typifies me rather not
- neutral
- typifies me rather well
- typifies me totally

Next

New ideas attract me more than existing solutions.

- typifies me totally not
- typifies me rather not
- neutral
- typifies me rather well
- typifies me totally

Next

I make definite engagements which I follow-up meticulously.

- typifies me totally not
- typifies me rather not
- neutral
- typifies me rather well
- typifies me totally

Next

I try to avoid routine.

- typifies me totally not
- typifies me rather not
- neutral
- typifies me rather well
- typifies me totally

Next

I want to have a full understanding of all problems.

- typifies me totally not
- typifies me rather not
- neutral
- typifies me rather well
- typifies me totally

Next

Developing a clear plan is very important to me.

- ◯ typifies me totally not
- ◯ typifies me rather not
- ◯ neutral
- ◯ typifies me rather well
- ◯ typifies me totally

Next

A good task is a well-prepared task.

- typifies me totally not
- typifies me rather not
- neutral
- typifies me rather well
- typifies me totally

Next

I prefer to look for creative solutions.

- typifies me totally not
- typifies me rather not
- neutral
- typifies me rather well
- typifies me totally

Next

I like to analyze problems.

- typifies me totally not
- typifies me rather not
- neutral
- typifies me rather well
- typifies me totally

Next

I like to extend the boundaries.

- typifies me totally not
- typifies me rather not
- neutral
- typifies me rather well
- typifies me totally

Next

I make detailed analyses.

- typifies me totally not
- typifies me rather not
- neutral
- typifies me rather well
- typifies me totally

Next

I prefer clear structures to do my job.

- typifies me totally not
- typifies me rather not
- neutral
- typifies me rather well
- typifies me totally

Next

I am motivated by ongoing innovation.

- ○ typifies me totally not
- ○ typifies me rather not
- ○ neutral
- ○ typifies me rather well
- ○ typifies me totally

Next

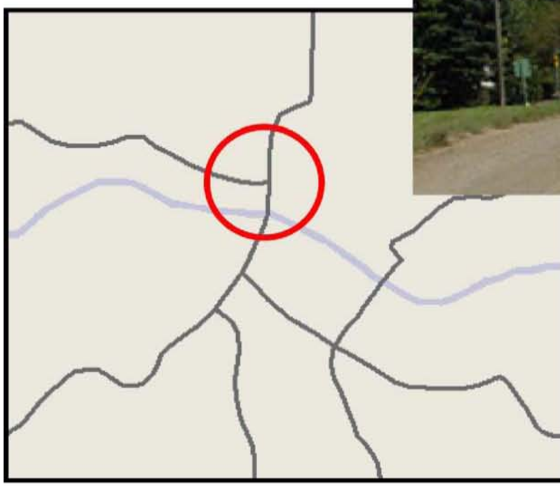
I like detailed action plans.

- ◯ typifies me totally not
- ◯ typifies me rather not
- ◯ neutral
- ◯ typifies me rather well
- ◯ typifies me totally

Next

In this next section, you will see both a map and a photograph of a real-world location. Your location is indicated on the map by the red circle. Look at the photo and determine which direction you are facing on the map.

Continue

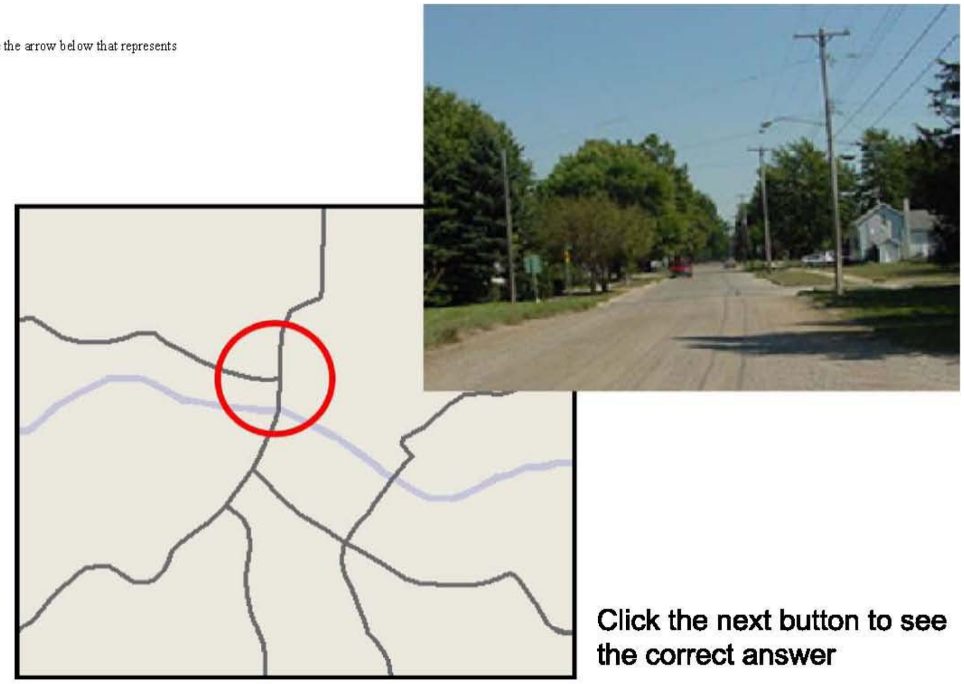


You will choose the button that matches one of the red arrows below as your answer. The following screens provide two practice problems to familiarize you with the test protocol.

Next

Practice Problem #1 Choose the arrow below that represents the direction you are facing.

- A
- B

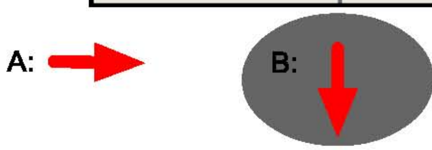


Click the next button to see the correct answer

Next

Practice Problem #1

Continue

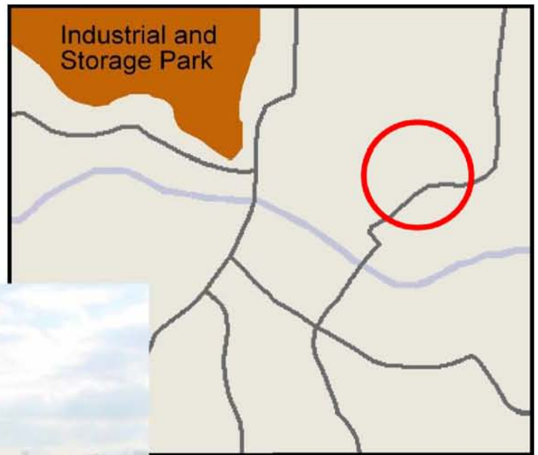


The arrow on the right is the correct answer.

Next

Practice Problem #2 Choose the arrow below that represents the direction you are facing.

- A
- B



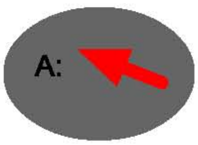
Click the next button to see the correct answer

Next

Practice Problem #2 Choose the arrow below that represents the direction you are facing.

Continue

Click the next button to see the correct answer



B:

The arrow on the left is the correct answer.

Next

Next is the real questions. Select continue and press next to proceed.

○ Continue

Next

#1) Choose the arrow below that represents the direction you are facing.

- A
- B

Next

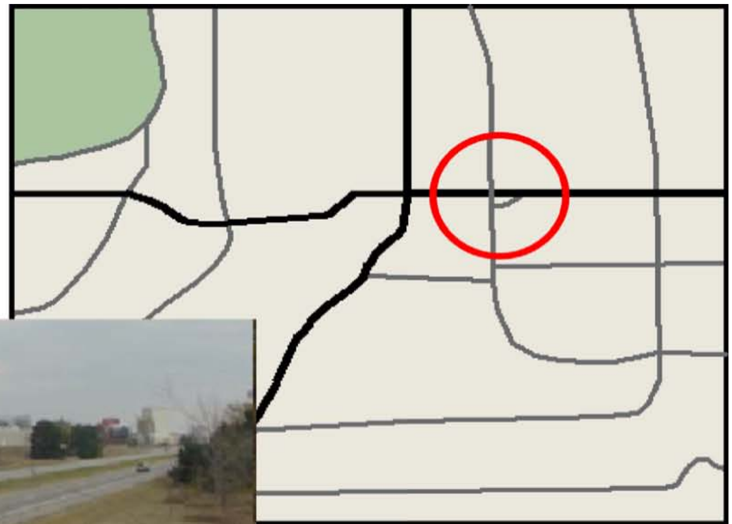
#2) Choose the arrow below that represents the direction you are facing.

- ◯ A
- ◯ B

Next

#3) Choose the arrow below that represents the direction you are facing.

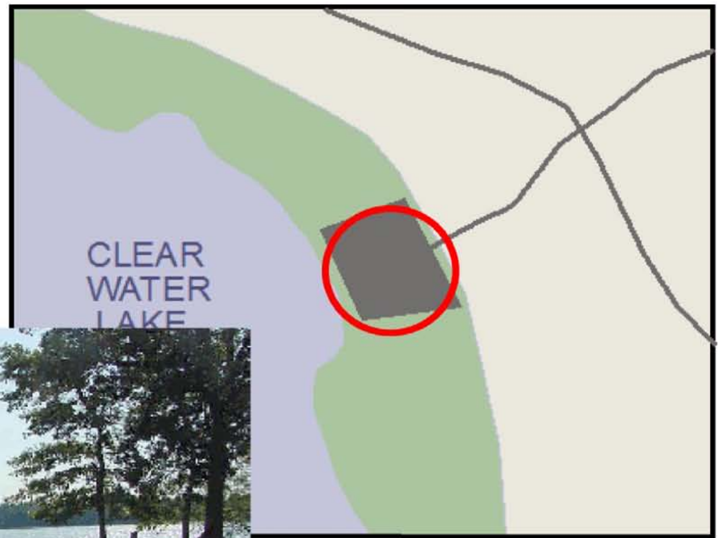
- A
- B



A: B:

#4) Choose the arrow below that represents the direction you are facing.

- ( ) A
- ( ) B

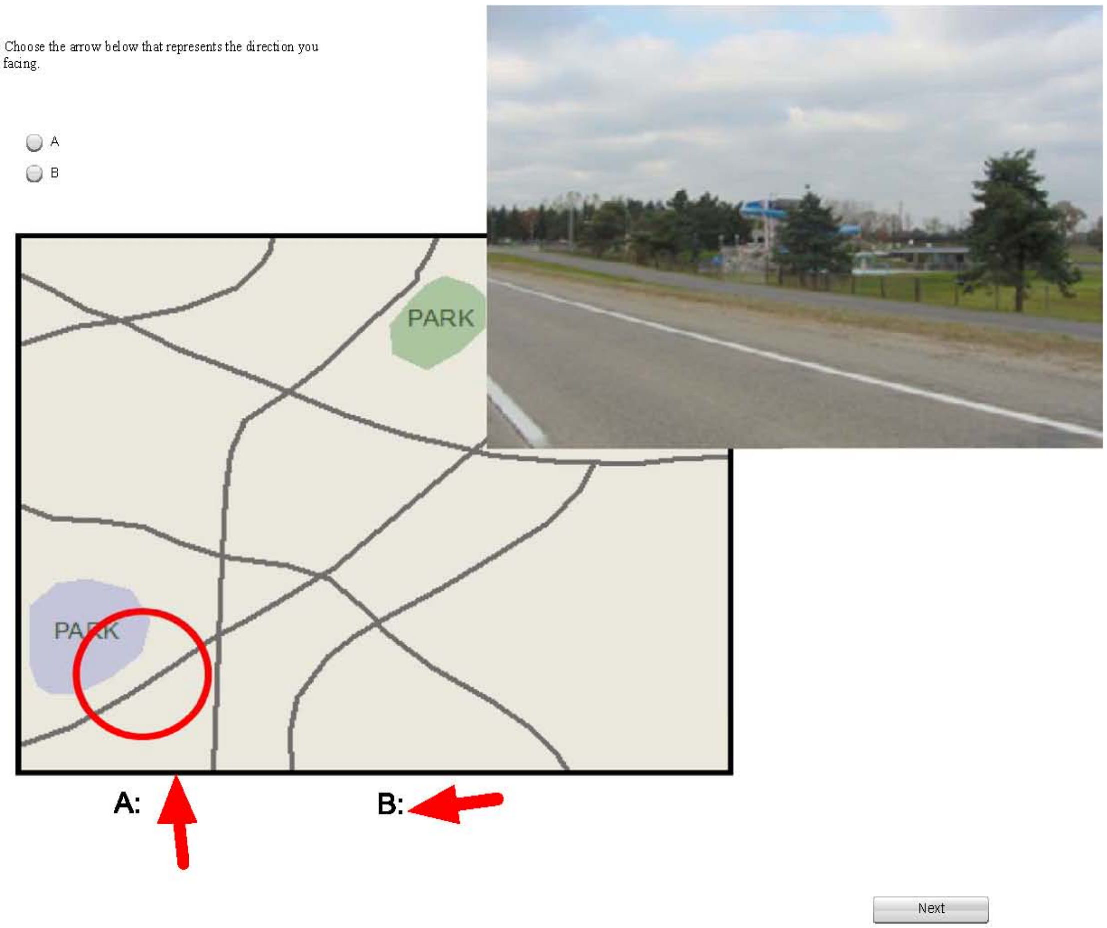


A: ↗ B: ↙

Next

#5) Choose the arrow below that represents the direction you are facing.

- A
- B



#6) Choose the arrow below that represents the direction you are facing.

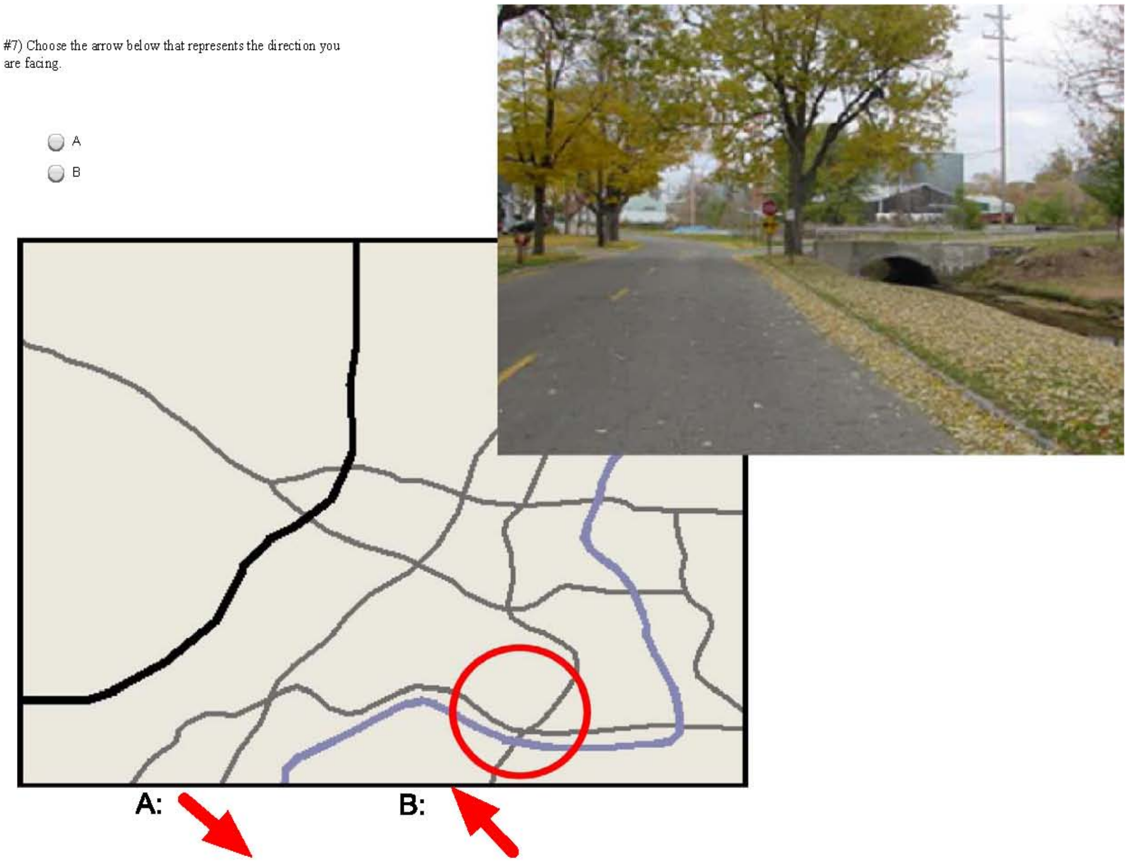
○ A

○ B

Next

#7) Choose the arrow below that represents the direction you are facing.

- A
- B



Next

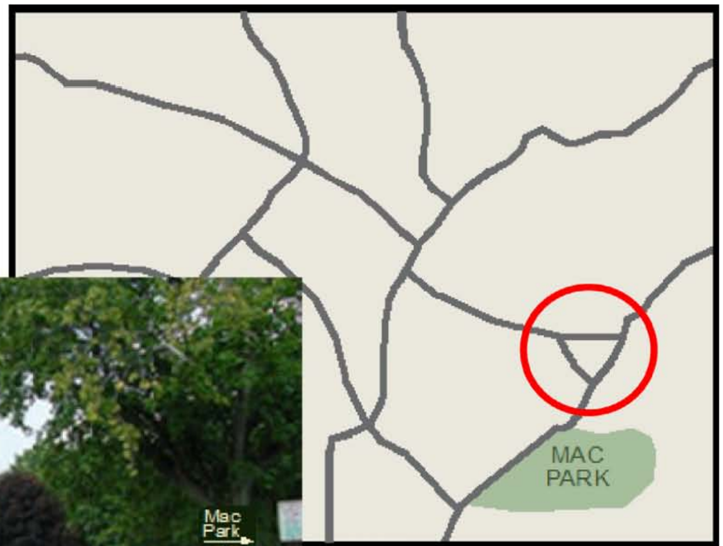
#8) Choose the arrow below that represents the direction you are facing.

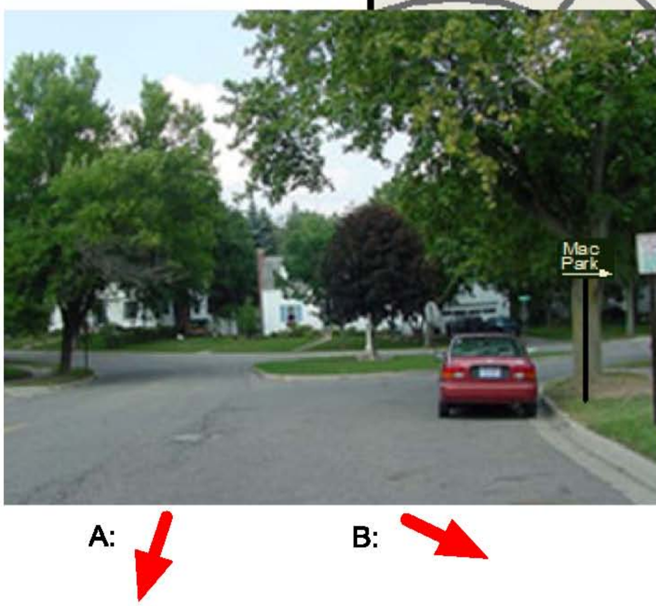
- A
- B

Next

#9) Choose the arrow below that represents the direction you are facing.

- A
- B

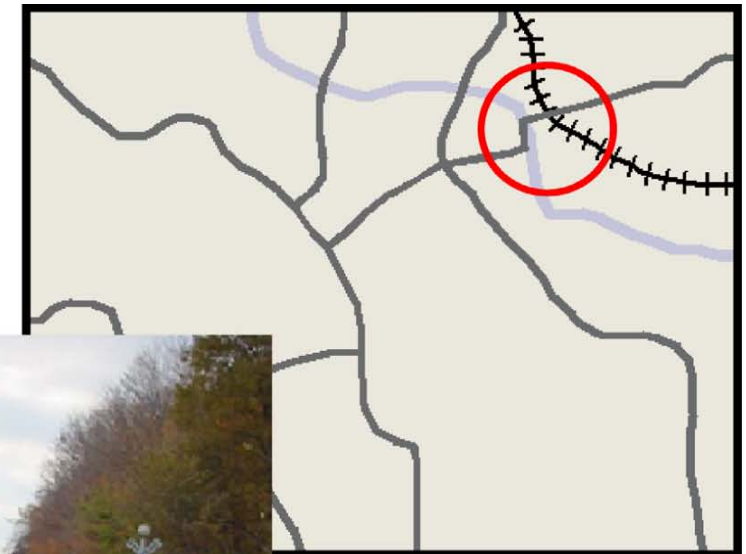


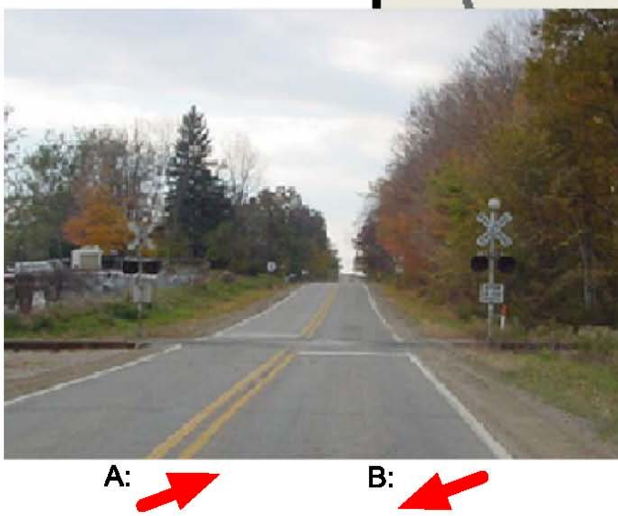


Next

#10) Choose the arrow below that represents the direction you are facing.

- A
- B

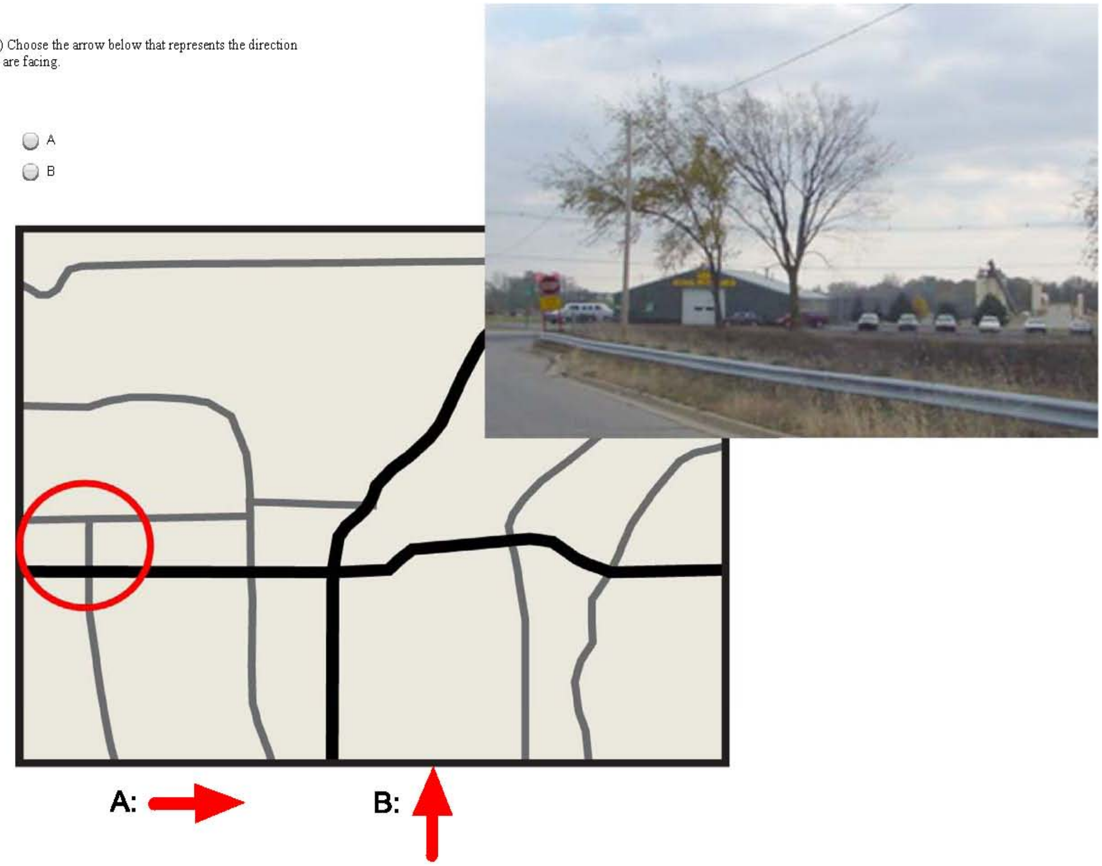




Next

#11) Choose the arrow below that represents the direction you are facing.

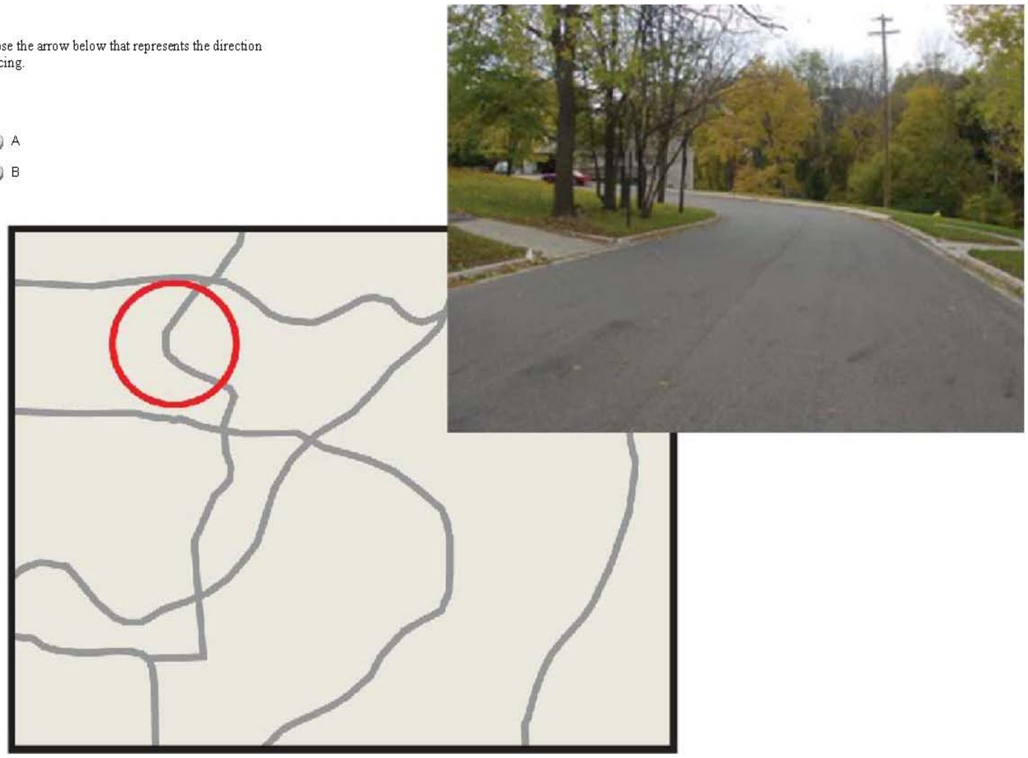
- A
- B



Next

#12) Choose the arrow below that represents the direction you are facing.

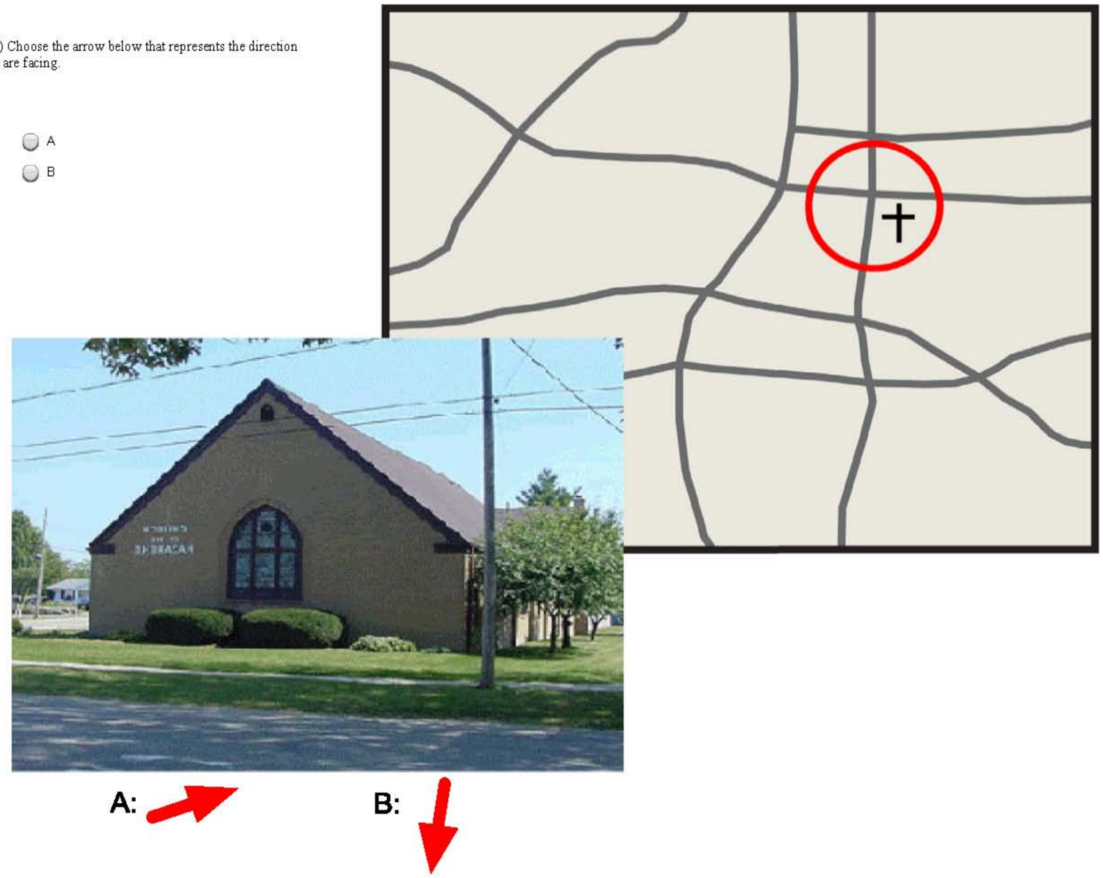
- A
- B



Next

#13) Choose the arrow below that represents the direction you are facing.

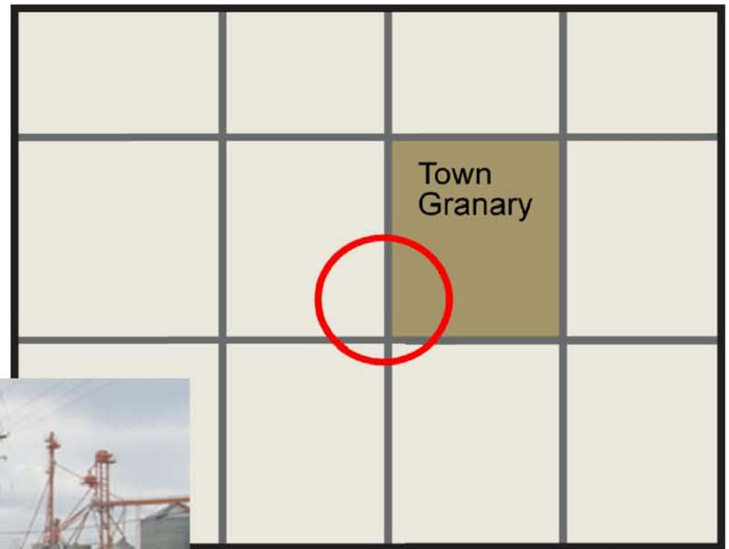
- ◯ A
- ◯ B

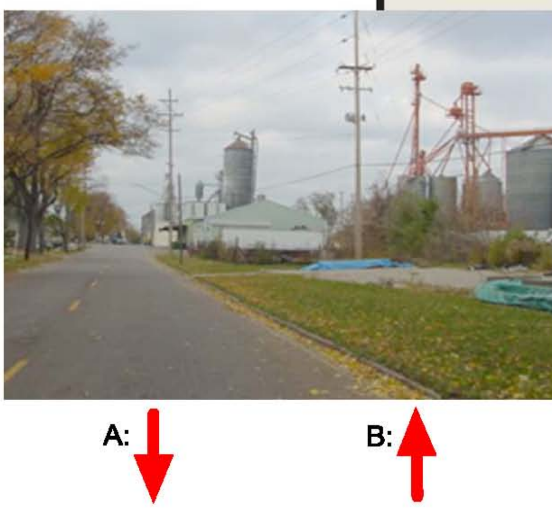


Next

#14) Choose the arrow below that represents the direction you are facing.

- A
- B

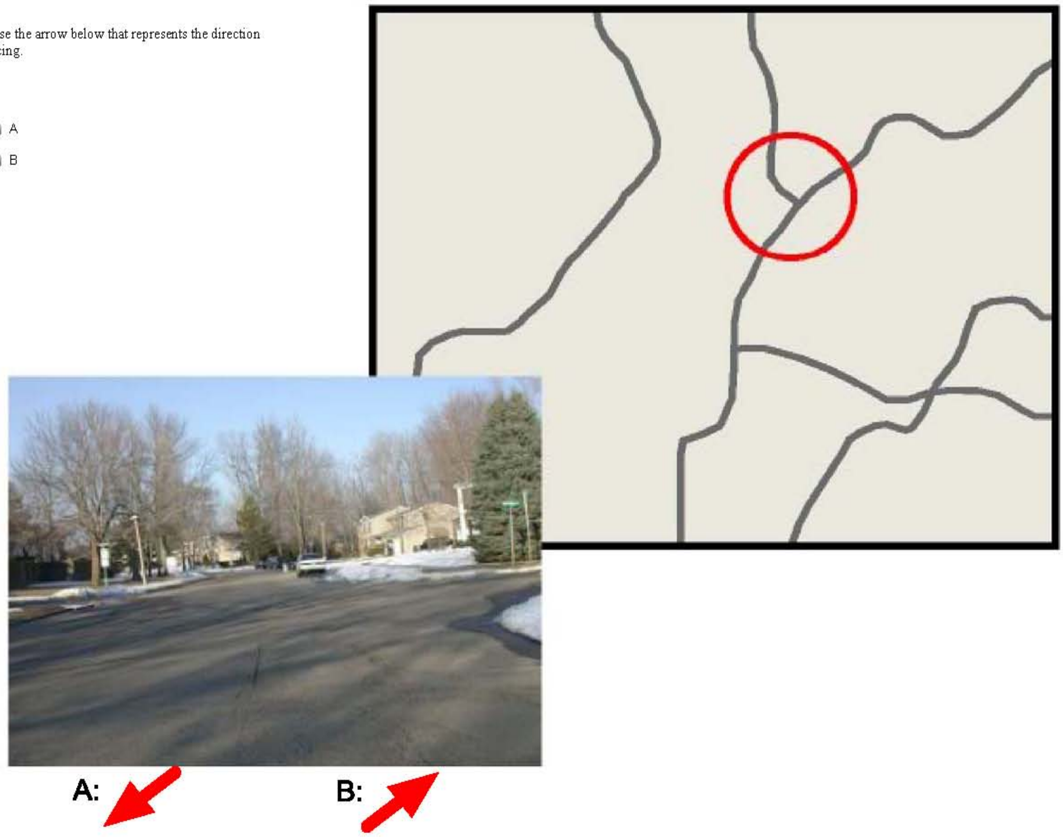




Next

#15) Choose the arrow below that represents the direction you are facing.

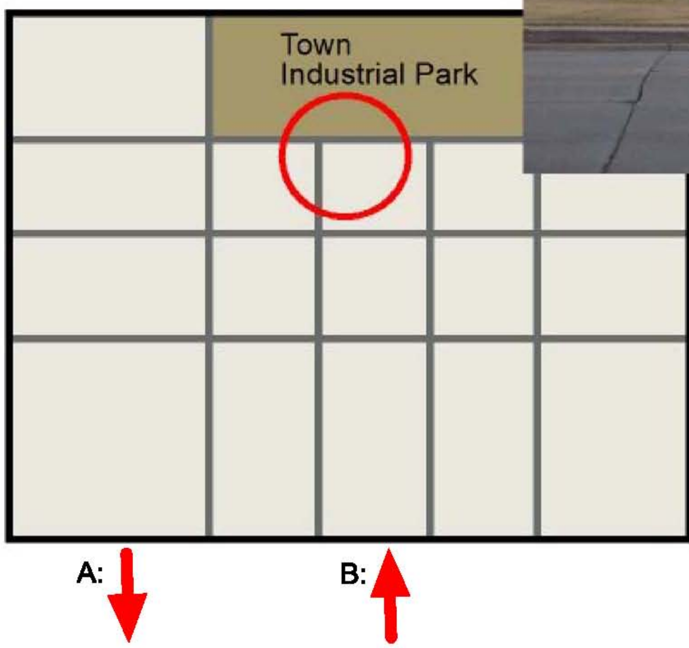
- A
- B



Next

#16) Choose the arrow below that represents the direction you are facing.

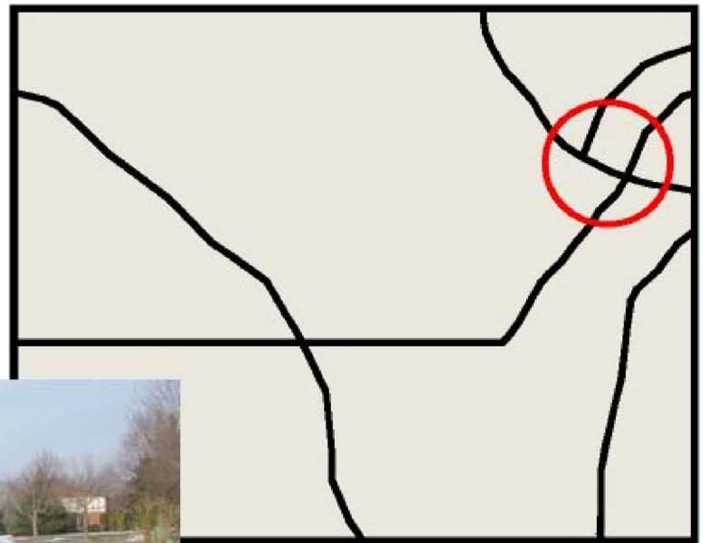
- ○ A
- ○ B

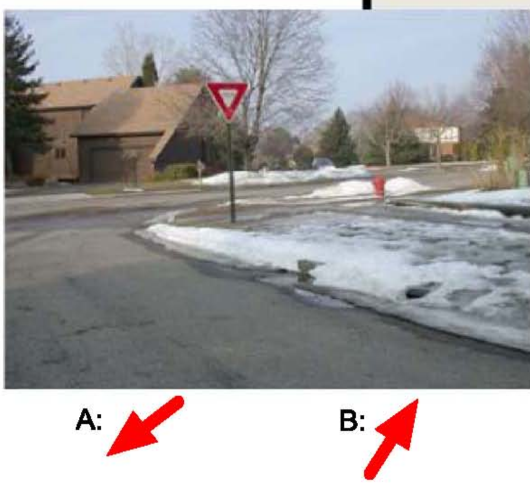


Next

#17) Choose the arrow below that represents the direction you are facing.

- A
- B

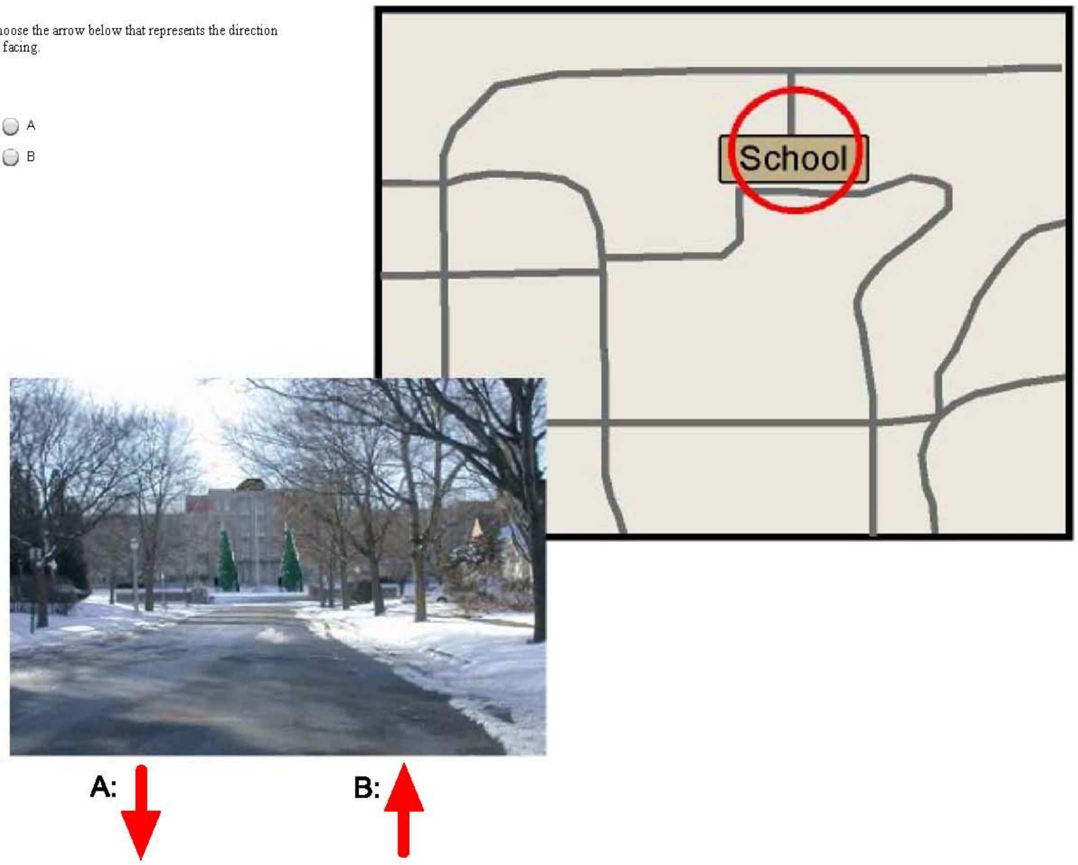




Next

#18) Choose the arrow below that represents the direction you are facing.

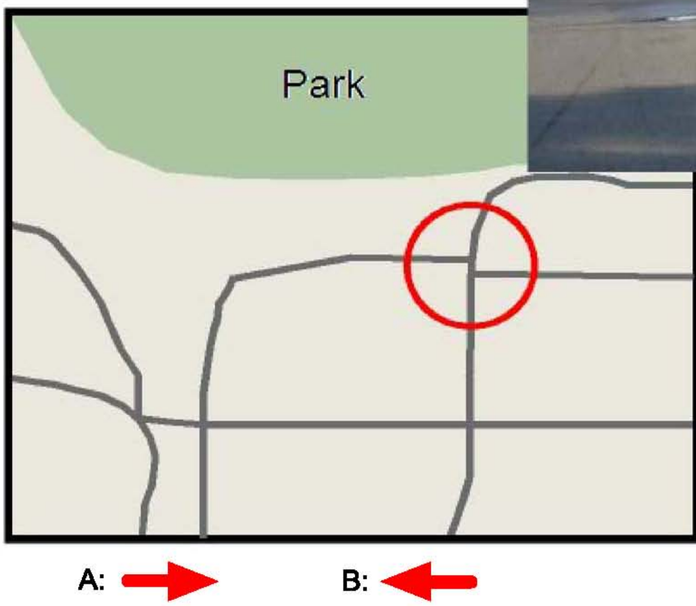
- A
- B



Next

#19) Choose the arrow below that represents the direction you are facing.

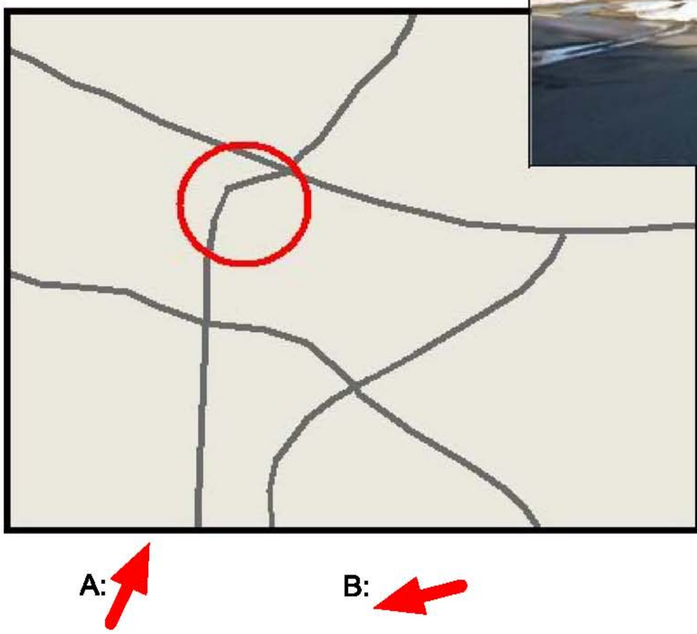
- ○ A
- ○ B



Next

#20) Choose the arrow below that represents the direction you are facing.

- A
- B



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