The Perceptual Interaction of Simple and Complex Point Symbol Shapes and Background Textures in Visual Search on Tourist Maps

BY

Naeema Mohamed, AlHosani

Submitted to graduate degree program in Geography
and the Graduate Faculty of the University of Kansas
In partial fulfillment of the requirements for the degree of
Doctor of Philosophy.

George F. McCleary, Jr.
Chairperson

Karen S. Cook

Kevin P. Price

Stephen L. Egbert

Jay Childers

Date Defended: ____________________

The Dissertation Committee for Naeema Mohamed, AlHosani certifies
that this is the approved version of the following dissertation:

THE PERCEPTUAL INTERACTION OF SIMPLE AND COMPLEX POINT SYMBOL SHAPES AND BACKGROUND TEXTURES IN VISUAL SEARCH ON TOURIST MAPS

Committee:

George F. McCleary, Jr.
Chairperson

Karen S. Cook

Kevin P. Price

Stephen L. Egbert

Jay Childers

Date approved: ____________________

Abstract

This study investigated visual search for simple and complex geometric and pictorial point symbols displayed on light and dark smooth and textured map backgrounds. Group-administered tests asked subjects to count occurrences of target symbols. Efficiency of visual search was determined by analyzing subjects' self-recorded counts and times for accuracy and speed. Results for symbols indicate that simple geometric and pictorial symbols are easier to search, especially when their shapes differ considerably. In contrast, complex geometric and pictorial symbols differing only in minor details of shape or orientation are harder to search. Results for backgrounds show that high value contrast between symbol and background (e.g. black symbol on white ground) facilitates search, while low contrast (e.g. black symbol on dark gray ground) yields poorer results. Since subjects also found it harder to identify symbols displayed on textured backgrounds (e.g. aerial photograph, satellite image, or relief shading), visual noise is another background factor.

Acknowledgements

The following dissertation would not have been possible without the insights and direction of many people who supported me during my work on this dissertation. It is difficult to overstate my gratitude to my M.S. and Ph. D. supervisor, Dr. George F. McCleary, Jr. Geography Department, who was abundantly helpful. His experience and expertise in visualization were invaluable, and his encouragement, guidance and support allowed me to successfully complete this dissertation on schedule. I am also deeply grateful to Dr. Karen S. Cook, Spencer Research Library and Geography Department, whom I consider as my co-advisor, for her guidance, endless support and hard work with me on my journey from M.S. to Ph.D. I would like to thank her for her tireless work in compiling, editing, document management, and her teaching. She is also a friend of my family, and I would have been lost without her. My thanks also go to the other Geography Department members of my dissertation committee: Dr. Kevin Price (now at Kansas State University) and Dr. Stephen Egbert and to the outside member, Dr. Jay Childers, Communication Studies Department, who kindly read my dissertation, drew my attention to important points, and provided me with insights, wise advice, comments, and suggestions that guided my thinking

I would also like to thank Mr. Darin Grauberger, the Director of the Cartographic Services Laboratory, for his technical assistance and Mr. Mickey Waxman, Statistics Consultant, University of Kansas Libraries, for his statistics assistance. I would also like to thank Mrs. Rebecca Barrett-Fox for her editing work with me, her enjoyment of the topic and willingness to learn more about geography, besides to her encouragement of my dissertation writing. Special thanks also to graduate student friends for their help: Andy Hilburn, Lisa Rausch, and especially Lynnette Dornak for offering to have her class GEOG 104 participate in my visual search experiments. Dr. McCleary's GEOG 111 students also deserve thanks for participating in my visual search experiments.

I would like to thank my United Arab Emirates University for providing me with scholarship funding and for assisting me in every possible way to make my study successful. In particular, I would like to express my gratitude to His Highness Sheikh Nahyan bin Mubarak al Nahyan, the Minister of Higher Education and Scientific Research.

I am especially thankful to my family,including my grandmother, who has always prayed for me, my mother, who has always supported my dreams and aspirations, and my brothers, my sisters, and my nephews and nieces for their love and patience. I love all of them.

Thanks also for all those not specifically acknowledged here, but who have made an important difference in my life.

Dedication

I dedicate this dissertation to my father, who passed away May, 15, 2008, after suffering from cancer. He wished to see me holding the Ph.D. diploma. I love you so much, my father, and may God place you in heaven. I promise to be as you dreamed for me to be.

Lastly, and most important, I would also like to dedicate this dissertation to my beloved family, my husband, Jasem Mohamed Arab Allah Alqhatani, for his endless love, understanding, and supporting me socially and academically through the duration of my studies. He has given me the time finish this dissertation by taking care of our son, Abdul Aziz, who waits in front of the window for mommy to come home every day. Jasem has also joined me in the Geography Department computer laboratory, helping and encouraging me during long hours of statistical analysis and writing. My message to Jasem is, “ I love you so much; life without you is nothing, because you are my life in this life.”

Table of Contents

Chapter One

Introduction

Background to the Research

Human beings receive information daily from their surroundings through a variety of sense modalities. They smell scent, hear different sounds, feel the texture or the softness of objects, and see everything that is around them. And the most dominant of all senses is vision; more brain area is dedicated to vision than to any of the other senses. Humans by using vision can recognize the forms and objects around them (Reisberg, 2001).

Visual search is a cognitive task that plays an essential role in our everyday lives. Human beings start their day by trying to locate the weather report in the newspaper, medicine in the first aid cabinet, a milk bottle in the crowded refrigerator. Such visual search activities can be defined as locating and identifying a target item that is surrounded by distractor items. Moreover, visual search includes deployment of visual attention to different parts of the visual field and looking for the target at the location which is the focus of attention. Visual search is considered one of the most important research topics in cognitive psychology.

Many researchers studying visual search examine the process of looking for and identifying the presence or absence of a specific visual stimulus (a target) surrounded among other items (distractors). Up to now, most of the research questions that have been asked in this area have found that visual searches for some features are much easier and faster than searches for other features. Multiple questions are allied with these findings; for example, which visual features are found quickly and easily and which visual features are not? Why are some visual searches easier than others? Answering these kinds of questions and an understanding of the mechanisms involved in visual search will add to our understanding of the nature of visual information processing and the perceptual organization of our visual world. These questions apply equally to visual search for information using depictions of our visual world in the form of maps.

Graphic language, including map symbols and legends, is one of the earliest forms of communication in human history, though it is a form of communication acquired rather late in the individual human life cycle. First humans learn to communicate through touch, then through sight. In early childhood, most humans learn to communicate through a number of abstract sounds and symbols (articulacy) and eventually through written language (literacy). A form of communication developed later is abstract symbols, arranged two-dimensionally in order to show spatial phenomena and their relationships (graphicacy) (Robinson et al., 1995). Pictures, images, signs and symbols are part of our everyday graphic language. Graphic language is also important in different fields for professionals such as designers, engineers, artists and cartographers.

A map, the basic tool of geography, is a symbolic representation. It enables cartographers to depict spatial phenomena and the earth's surface on a sheet of paper or on a computer monitor. A map communicates information about objects in space and helps the reader to understand and form mental images of the spatial environment (Harley, 1987).

Cartography is the art and science of map-making. Many generations of cartographers in different places and cultures have contributed to the development of the graphic language of maps, point, line, and area symbols.

The cartographic communication process starts with real world data that is collected, analyzed, structured, and portrayed in the form of a map. Map symbols are the communication tool that the map maker uses for displaying the data (Müller & Zeshen, 1990). The perception of a map creates in the user's mind a view of reality, a cognitive map that usually diverges somewhat both from the map and from the real world that it represents, but it guides behavior, from understanding to action (McCleary, 1987).

Numerous authors have reflected on the important role played by maps in contemporary society, not just in communication but also in analysis and discovery (Wook, 1992; Hall, 1993; Monkhouse and Wilkinson, 1978; Hopkin and Taylor, 1979; Monmonier, 1993). People use maps for many purposes, from locating known places to finding previously unknown places. Maps pass through human lives in many ways: on television, on the Internet and in books, magazines and newspapers. They guide human exploration and transportation by airplane, boat and car. They are found in a variety of places, including schools, universities, shopping malls, museums and other public buildings. In addition, maps are helpful in storing data, collecting information, making decisions, and performing tasks. A map is a way to organize, present and store spatial material of various sorts and for a variety of reasons.

Map reading is a form of communication involving a cartographer's representation of spatial information. The map encapsulates the cartographer's model of a geographical environment and makes it obtainable for the map reader's use. This communication includes two significant parts. The cartographer is responsible for selecting information and representing and displaying it on the map. The map reader's work is to search for information on the map and determine its meaning and importance. The interaction between the cartographer and the map reader is influenced by the extent to which each knows about the work of the other. For example, map readers who are conscious of the conventional methods that are used by cartographers to design their creations will find information and determine its meaning with less effort than those unfamiliar with standard cartographic practices. Cartographers who are conscious of the cognitive processes used by map readers to search for and interpret information will be able to produce more effective maps (MacEachren, 1995).

Every map includes specific marks that represent its purpose and its objectives. For example, a map of campus buildings will not portray highway routes but will instead display only the different buildings that are located on campus by using different kinds of symbols or marks to represent the buildings. In principle, the less unnecessary information that a map includes, the easier the map is to visually understand and the greater its usefulness to its user. Human ability to complete these tasks relies upon the quality of the map and its design. Poorly-designed maps can obstruct performance and guide users to make errors that are costly, inconvenient or even dangerous (Muehrcke, 1972).

The three basic elements of a map (points, lines and areas) can be varied by many visual variables (shape, size, orientation, value, texture/pattern and hue) (Bies and Long, 1983). These basic variables of map design play a significant role in representing data on the map. Consequently, they affect the map reading process, which includes tasks such as detection, discrimination, identification, recognition, understanding, locating, counting and visual search. Attention to the myriad factors that affect users' understandings of maps is an obligation of cartographers, and research in the area of visual search can assist cartographers to make the best choices and produce highly understandable maps. By studying map use in order to make maps that communicate better, cartographers may also gain insights into various perceptual and cognitive processes and contribute to the understanding of human psychology.

This study investigates visual search processes for point symbols on maps with various backgrounds. In a typical map use situation, the nature of the map use process will vary depending on symbol and map background design and content. The primary purpose of this research is to examine the cognitive processes used by map readers. Considering both pictorial symbols and geometric symbols in concert with tasks such as detection, discrimination and identification will make it possible to determine how accurately and how efficiently these symbols perform. Studying search for symbols displayed on different map backgrounds will reveal how different contexts (map backgrounds) affect search efficiency. Subject reaction times and errors can be used to evaluate the efficiency of the search process. It is expected that searching for pictorial point symbols will be faster and more accurate than searching for geometric point symbols on maps. Furthermore, the more contrast between the characteristics of the background and the point symbols, the more easily point symbols will be detected and discriminated. In addition, similarities or differences between the target symbol and the non-target distractors will affect both search time and accuracy.

Statement of the Research Problem

On maps cartographers often use a variety of symbols to represent different geographical features, but such symbols are often conventional, reflecting the preferences and traditions of generations of cartographers. Use of maps by different people from different cultures in both familiar and unfamiliar places often involves visual search for point symbols. The success of a particular human-map interaction may depend upon visual search, such as a tourist searching a map for that scenic picnic area recommended by a friend. Despite considerable psychology-based cartographic research into map perception from the mid-twentieth century onward, knowledge about point symbol design from the perspective of the map user is far from complete. How do graphic attributes of point symbols affect their detection and discrimination in visual search? Also, how does context, the map background from which the target symbols must be picked out by the searcher, affect visual search?

Purpose of the Study

The purpose of this study is to find out by means of map use experiments how graphic characteristics of point symbols and map backgrounds interact in map perception to help or hinder visual search by map users. The characteristics of point symbols tested are shape (geometric or pictorial) and complexity (simple or complex). The map background characteristics tested involve value (lightness or darkness) and texture (simple or complex). By conducting tests with map users of all of the point symbol types on all of the map background types, it should be possible to find out which point symbols work best and with which backgrounds.

Statement of Hypotheses

A number of hypotheses based upon relevant literature will be considered in this study:

1. Pictorial symbols are generally recognized faster and more accurately than geometric symbols.
2. Simple point symbols are easier to identify than complex point symbols.
3. Very different point symbol shapes are easier to discriminate than similar point symbol shapes.
4. Point symbols differing in only one graphic characteristic are easier to discriminate (by parallel search) than point symbols differing in two or more graphic characteristics (requiring serial search).
5. The more contrast in value (lightness and darkness) between point symbols and map background, the easier will be visual search for point symbols.

6. The less texture in the map background, the easier visual search for point symbols will be.

Organization of Chapters

This study, which focuses on the search processes used to find information in the form of pictorial and geometric symbols on maps with different backgrounds, draws upon the fields of environment symbolization, cartography, psychology and visual search and makes connections among them. Therefore, the review of literature in chapter two starts with a section on psychology and then considers symbols, visual search, and experiments. Chapter three describes the methodology of this study.

Chapter four deals with the two tests that were used to develop the first form of the experiment to be administered to a large group of subjects. Chapters five through nine explain the sequence of testing and the analysis of a program that yielded over 5000 responses. The analysis moves from general questions to specific --- from the overall analysis relating search time and accuracy to the consideration of the individual symbols in the background context. In chapter ten there is a small "extra" test ---looking at a number of "what if…" issues identified in the midst of the principal experiment. Chapter eleven provides general and specific conclusions, as well as more "what if…" questions.

Note to Readers

A sample of the test is available to readers in Appendix 1. Those interested in taking the test should have a timer (one is available at http://www.online-stopwatch.com/ full-screen-stopwatch/) or a proctor to monitor time. The test should be taken in a quiet place with normal lighting.   Instructions for using the test are included in Appendix 1. The correct answers appear at the end of the test..

Chapter Two

Literature Review

Psychology

Image Perception

Perception, one of the most significant mental processes, can be described as a window onto the world. The use of graphical languages is unlimited, and Bertin stated that there are kinds of perceptions associated with graphical signs that are used in these languages. He noted:

> The use of graphical language is limitless. Meaning attached to a sign is a function of perception and can be monosemic, with meaning preceding observation; polysemic, meaning deduced after observation; and pansemic, meaning is unrelated to the sign, and it can mean anything. In graphics the meaning of a sign is determined before hand. (Bertin, 1983, 2)

In fact, humans receive information from different sources, and sometimes these sources vary in their effectiveness in providing information. Kennedy held that the information provided from pictures is different from the information provided from languages (Kennedy, 1974). As mentioned by Vernon, for example, one factor affecting effectiveness could be the lack of descriptive names for intermediate or blended colors of objects represented. Another potential factor affecting the effectiveness of the representation in providing information is whether the objects' outlines are perceived as real objects. Additionally, colors may induce feelings of pleasure or displeasure that influence perception.

There have long been terms to describe image characteristics, such as the terms used by Gurak, which include length, direction, volume, area, curve, scale, shading, and color saturation (Gurak, 1992). Other related visual characteristics include line, tone, dot, contrast, grouping, and sharpening (after Dondis, 1973, in Horton, 1994). Vernon found that situations, appearance, behavior, characteristics, and uses affected the classification of perceived objects, and that led to the conclusion that human beings use perceptions, visual imagery, experience, and language to identify objects (1971). Perception-related theory offers a valuable vocabulary for evaluating graphic images and symbols and has been practiced by different authors (Vernon, 1971; Thorndyke, 1980; Mountford, 1990).

Understanding perception is important not only to cartographers, but also to designers, marketers, and others who communicate visually. Droste states that icons are used metaphorically at the human-machine interface, and icons help to represent actions or tasks in the easiest way (Droste, 1989). Icons, symbols, and graphical images are prominent in global marketing for example, of computers, appliances and other equipment (Gurak, 1992). The everyday activities of people deal with a variety of symbols, icons, and graphical images that they have to perceive in order to obtain information about the object represented.

Object Perception

These everyday objects have information-revealing characteristics that help in perception of these objects, for example, shape, color, texture, spatial position, and movement. As a rule, the simpler the actual shape that is seen, the more accurately it is perceived. The perception of form or of the object shape is the first stage in the development of perception, because the shape of the object is the essential factor that characterizes and differentiates objects from each other (Vernon, 1971). Other factors affecting the accuracy of perception include the background against which the shape is shown, the length of time available to the observer, the intensity of illumination, the orientation of a shape, and the shape's color.

Vernon pointed out that the simple shape is perceived most accurately. For example, geometrical shapes, such as circles, triangles, squares, and rectangles, are perceived very quickly, since they are simple and familiar. They can be seen in various situations, such as quite dim or very bright light, and can be recognized even if shown for a short time. Some experiments have shown that the most readily perceived are circles and squares, for the reason that their shapes are the simplest and the most regular of all. On the other hand, some experiments have found that triangles are the first shapes to be accurately perceived, since their angularity is quickly obvious. When other shapes are shown in very dim light, sometimes they appear circular before their actual shapes can be discriminated (Vernon, 1971).

The way to measure the degree of accuracy with which any given shape is perceived is to require the observer to match it against a number of shapes that are different from it by various degrees. Experiments using such methods have revealed a general tendency to perceive any shape with the maximum degree of simplicity, regularity, and symmetry. Therefore, if observers are shown a shape that is almost a square or is almost circular but faintly elliptical, they may think that the shape is square or circular. When they are shown asymmetrical shapes, they will overlook the lack of symmetry, as is presented in the reproduction of asymmetrical shapes that are shown in figure 1.

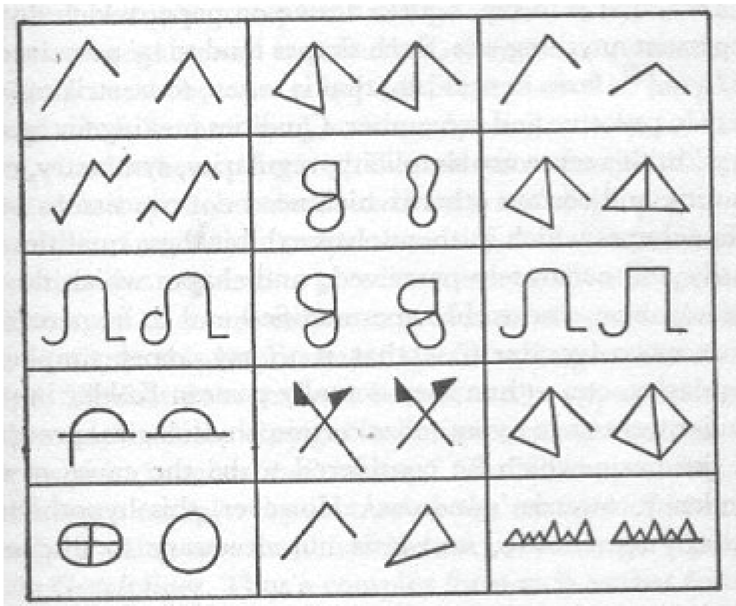


Figure 1. Reproductions shapes showing tendency towards symmetry and regularity. In each compartment is shown an original figure (left) and its reproduction (right). (Vernon,1971, 51).

Gestalt psychology, a German school of psychology, attached great importance to this tendency to perceive shapes not exactly as they are but in somewhat modified form and created theories to explain the phenomenon. Wertheimer, Köhler, and Koffka emphasized the fact that our perceptions always possess some kind of form or arrangement even if the formless fields look like a fog or mist, with no specific localization in space. Though the forms that we perceive are determined by the objective physical shapes of the objects in the field of view, this does not mean that we do not have the tendency to modify the formal qualities of what we perceive; for people, some shapes are meaningless and some are “good” in their shapes and are thus easier to perceive and remember.

The Gestalt psychologists suggest that humans do not exert sufficient effort to perceive every detail of the shape or the object in an accurate way. Furthermore, the visual mechanisms of the eyes and the brain are unable to provide enough information to identify everything people see. While the shapes that are regular and symmetrical are reasonably easy to perceive, the perception of more complex shapes requires the observation of more detail, so more time and greater strength of illumination are required to perceive the more complex shapes (Vernon, 1971).

Increasing the complexity of shapes involves incorporating more details. Attneave stated that silhouette shapes are increasingly complex when the changes in direction of the contour are increased in number and variety (Attneave, 1957). Additionally, Osterrieth pointed out that the outline of shapes could become more complex with an increase in the amount of interior detail along Gestalt lines. For example, the complex form that is shown in figure 2 could be perceived as a rectangle with other details inside and outside it (after Osterrieth, 1945, Vernon, 1971).

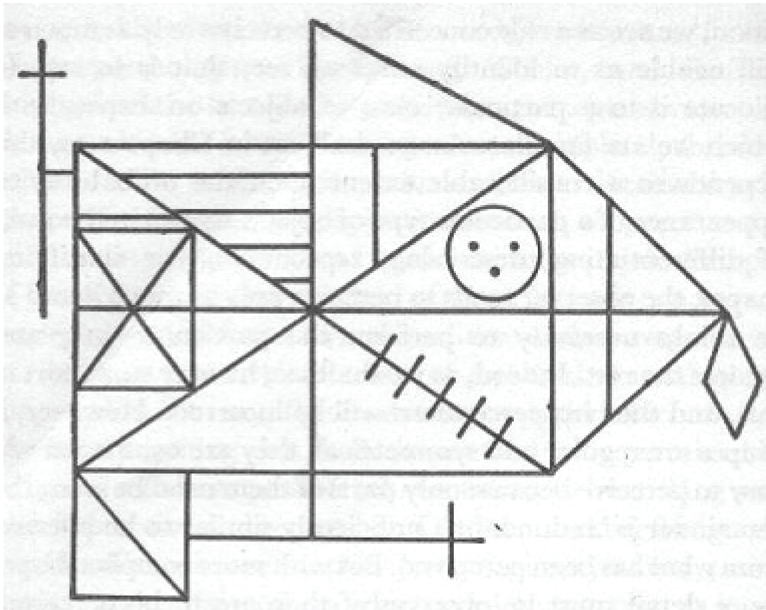


Figure 2. Complex figure with interior detail. (Vernon, 1971, 54).

Shapes with a broken, discontinuous, or dotted outline could be perceived as a whole continuous figure; the observer does not give attention to exact pieces of the outline but deals with the shape as a whole. For example, in figure 3, the dotted lines may be perceived as a triangle and a square. The difficulties in perceiving complex forms are caused by the incapability to perceive the parts of the shape independently of the whole, leading to a visual illusion.

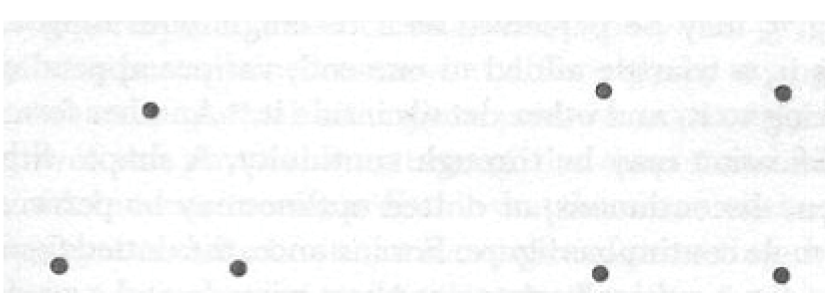


Figure 3. Discontinuous figures. (Vernon, 1971, 54).

.

For example, in figure 4a, the upper horizontal line appears to look shorter than the lower because it is difficult to approximate the lengths of the two lines separately of the arrowheads that form part of the same figure. Similarly, in Figure 4b, the horizontal lines in the four figures are straight and parallel, but since they are combined with the oblique lines, they look curved (Vernon, 1971).

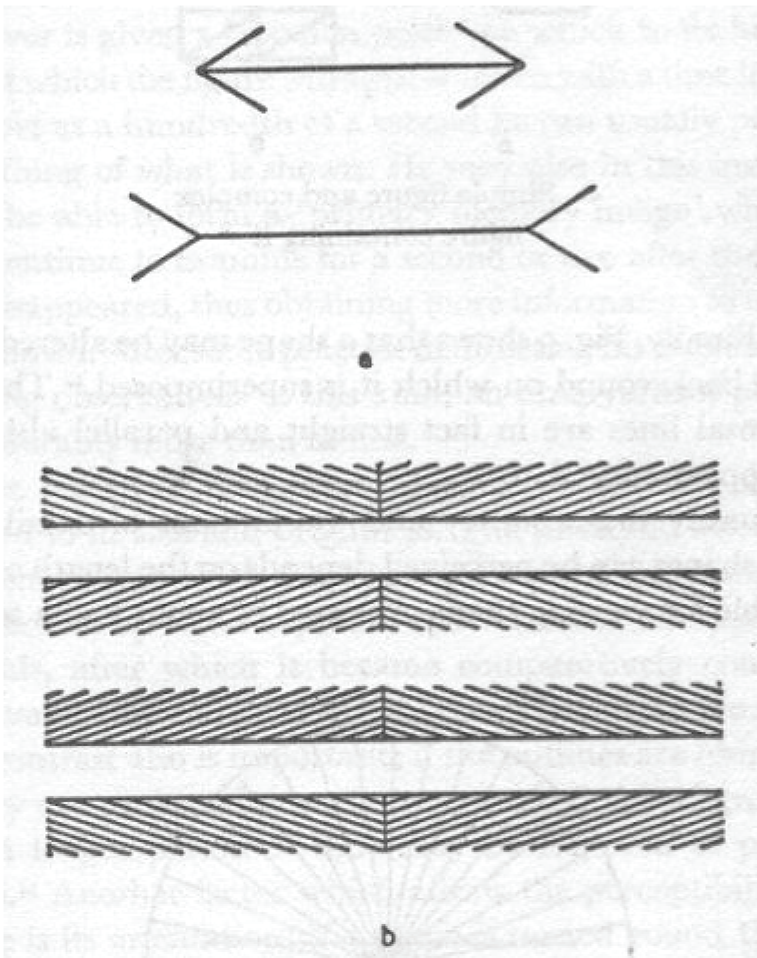


Figure 4. Visual illusions. (Vernon, 1971, 55).

Gottschaldt performed an experiment in which the simple figures shown in figure 5a were shown a number of times, followed by a set of complex figures, such as figure 5b, each of which contained within it one of the simple figures shown earlier. However, the observers rarely noticed the presence of the simple figure within the complex figure, and they also had difficulty doing so even when asked to search for the simple figure. A shape's design plays an important role in perceiving the real picture of the shape. Also, it creates simplicity or complexity for the shape.

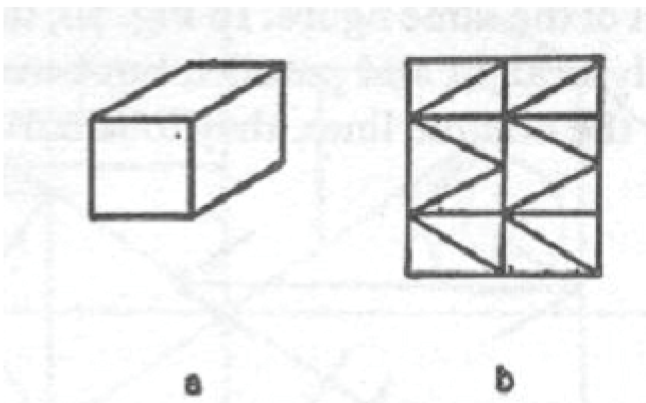


Figure 5. Simple figure and complex figure containing it. (Vernon, 1971, 56).

Moreover, sometimes a shape may be distorted by the background; for example, figure 6 shows a shape that has two horizontal lines that are straight and parallel although they look curved because of the background's effect (Orbison, 1939).

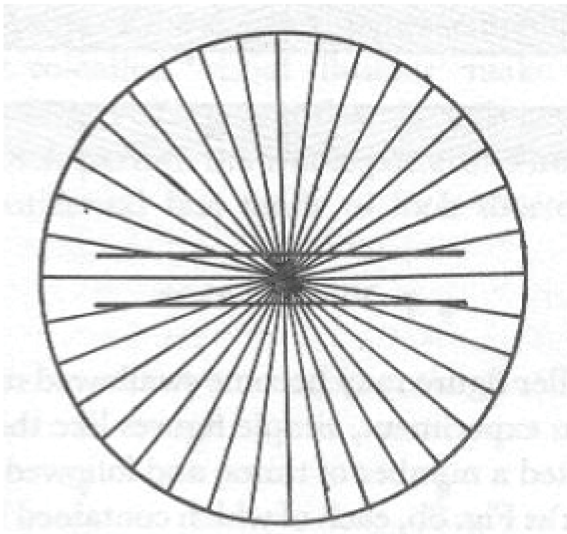


Figure 6. Effect of background on figure. (Vernon, 1971, 56).

The accuracy of perceiving shapes depends on the length of time available to the observer, the intensity of illumination, and the orientation of a shape. Many experiments have determined the amount of perceiving in shorter intervals of time (as cited by Vernon, 1971). The instrument that is used to determine the time to perceive, the tachistoscope, exposes figures on a screen for a constant interval of time, a fraction of a second. Also, the observer is given a “fixation point” to fix his eyes on the figure when it appears. Size and brightness play a role in the length of time necessary to perceive a simple shape (Vernon, 1971). Krauskopf found that the threshold intensity of illumination of perceiving shapes decreased up to an exposure time of about one and a half seconds, after which it became comparatively constant (Krauskopf, 1954). Similarly, Crook found that contrast also plays an important role in the length of time required to perceive the shape. For example, when the outlines are blurred or are projected onto a gray or mottled background, objects require a

Human cognition and encoding

Geographers, cartographers, and psychologists have a common interest in cognitive mapping (Robinson and Petchenik 1976; Cohen 1985; Golledge and Stimson 1987). Psychologists are always concerned with improving theories to clarify the cognitive processes that encode and store spatial information in memory, as well as those that decode the stored information in order to make decisions and solve problems. Moreover, cartographers have an interest in understanding precise processes during map reading that transfer spatial information from cartographic maps to cognitive maps (Peterson 1985). Cognitive processes used during the interaction between the map and the map reader performing a task are important, as MacEachren mentions (1995, 8).

Rheingold recognized that communication involves both cognitive and emotional aspects of language (Rheingold, 1990). The terms “linguistic” and “nonlinguistic” describe two classes of language or sign systems. The users of the linguistic language, also known as “verbal language”, are able to identify objects and interpret the environment by using descriptive words (Vernon, 1971; Droste, 1989). The nonlinguistic system, which is also identified as “semiotics,” is a system of symbols and signs (Luskin, 1996). Moreover, two classes of mental representations are used in cognitive processing. The first class is analogical, and the second is linear-temporal (Droste, 1989).Droste noted:

> Analogical representations are imagelike and are found in the sensory code, the code of the sculptor, the painter, the architect, etc. Linear-temporal representations are languagelike, abstract, and nonstatic and are characteristic of codes such as natural language, logic, algebra, musical composition, and the like …Analogical or imaginal codes are characteristically used to make picturelike representations –their signs are iconic. Linear-temporal codes operate with symbolic representations, at least in principle, in which the relation of expression and denotation is conventional and nonmotivated. (Droste, 1989, 927-928)

Droste also noted that natural signs are iconic; they enclose universal meaning and are directly understood. As a result of being directly perceived, the icons do not have to be learned. Arnheim says that humans use language to “name what we have seen or heard or thought” (Arnheim, 1971, vi). Since many objects surrounding people need to be known and understood, Arnheim used the term “visual judgment” to explain this judging-perceiving of an object. Visual judgment includes an evaluation of size, color, pattern, balance, location, and over-all relationship (Arnheim, 1971).

Similarly, Kennedy described the concept of perception as being constructed from sensory information and being built from visual cues (Kennedy, 1974). Gibson observed that both the real object and an image are present in the same optic information. For example, pictures are immediately recognizable by adults as depictions of real and imaginary things, theories and concepts (Gibson, 1950).

Cartographic Communication Theory

Cartographic communication theory is the basis for most research being conducted in cartography. Morrison defined contemporary cartography as a science of cartographic communication, declaring, "A cartographer who still believes that cartography is the making of maps cannot find any true area of research except perhaps historical cartography" (Morrison, 1972, 8).

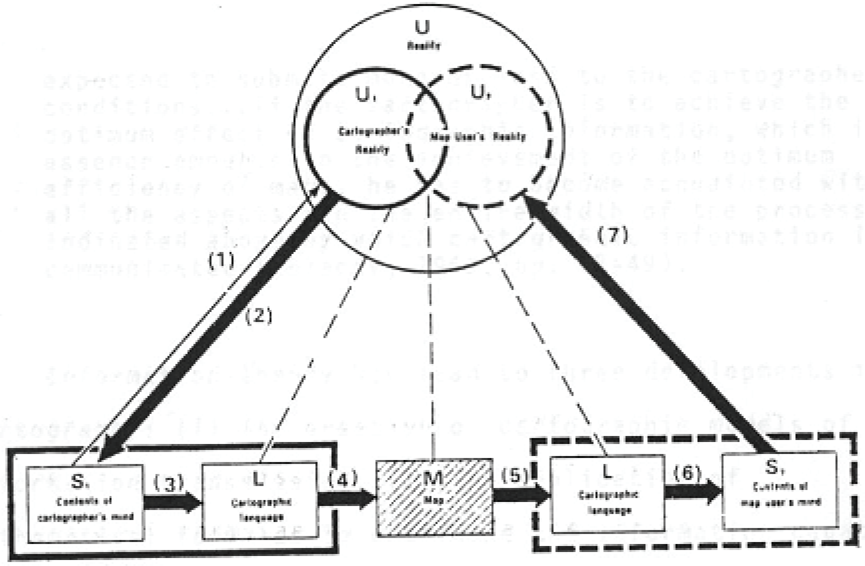
Cartographic communication theory includes information theory, psychophysical theory, semiology, modeling, and cognitive theory. Different research approaches based on cartographic communication theory are derived from diverging interpretations of graphic, mathematical, and descriptive research models (Ratajski, 1978).

Information Theory

Cartographic communication developed out of information theory. It became defined as "cartographic communication" or a form of "information transmission," or "transmission theory" by different researchers like Moles, 1964, Bocharov, 1966, and Kolāčný, 1969 (Ratajski, 1978).

Robinson and Petchenik pointed out that information theory began in 1928 at Bell Laboratories. It was rooted in a mathematical formula designed for evaluating the capacity of a telecommunication system for transmitting electronic signals that represent verbal language (Robinson and Petchenik, 1975). Antonin Kolāčný, in 1969 developed a model of cartographic communication founded on information theory (figure 7). That model became a prototype and catalyst for research into a previously unexplored area. The model could be described as a diagram that shows the intersection of two circles with in a larger circle, which represents the universe. The two smaller circles exemplify the intersection of the universe as seen by a cartographer with the environment as seen by a map user. The connection between the circles and a flow diagram shows the flow of information from a cartographer's mind through the language of a map to a map user's mind.

Though information theory has inspired many developments in cartography, the theory does have some weaknesses. Robinson and Petchenik state that because information theory's assumption of linearity in the transmission of information does not necessarily apply to maps, information theory has come under attack for being too narrow to cover the complexity of cartographic communication (Robinson and Petchenik, 1975). Additionally, Lawrence Frank says, "We need a larger conception of communication than that provided by the formula of stimulus and response… or Information Theory" (Frank, 1966, 6).



Factors of Communication

U_1 - reality as seen by the cartographer

S_1 - the cartographer

L - cartographic language of symbols

M - the map

S_2 - the map user

U_2 - reality as seen by the map user

I_c - cartographic communication

Processes of Communication

1. - observation of reality
2. - effect of selected information
3. - cartographer transforms selected information into a two-dimensional intellectual model
4. - cartographer expresses the intellectual model by producing a map
5. - map produces an informative effect upon the user
6. - map user creates in his mind a multi-dimensional model of reality
7. - map user acts on the strength of cartographic information

Figure 7. Kolāčný's (1969) model of cartographic communication based on Information Theory. (Kolāčný, 1969, 48)

Moreover, the concept of noise is problematic in information theory. Noise, a factor inherent to the communication system or external to the system, as in the conditions of poor vision, poor lighting, or even intervening cultural filters, extends reception time in a map context. The selection by a cartographer of graphic representations not accepted by map users is a common source of system noise. The feedback of the users is a prerequisite for reducing that noise (Robinson and Petchenik, 1975). In addition to Kolāčný's model, models have been proposed by Board, Lech Ratajski, Muehrche, and Robinson and Petchenik (1975). Figure 8 explains a communication model developed by Robinson and Petchenik (1975) that shows the relationship of cognitive elements within a communication channel.

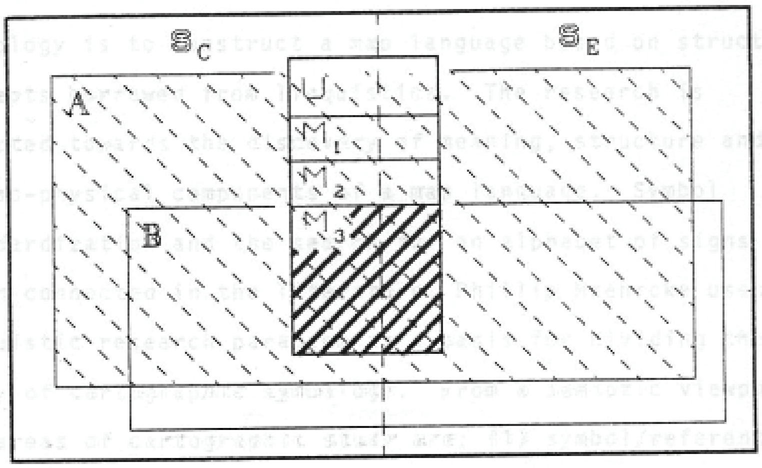


Diagram Elements

S_c - correct conception of the milieu

S_e - erroneous conception of the milieu

A - conception held by the cartographer

B - conception held by the map percipient

M - map prepared by the cartographer and viewed by the map percipient

M_1 - part of map previously conceived by the map percipient

M_2 - part of map newly comprehended by the map percipient

M_3 - part of map not comprehended by the map percipient

U - increase in conception of the milieu by the map percipient not directly portrayed by the map

Figure 8. A Venn diagram showing the cognitive elements in cartographic communication. (Robinson and Petchenik, 1975, 34).

Psychophysical Theory

Psychophysical theory is closely related to information theory. It concerns how an organism responds to the environment via its sensory receptors. While in information theory the transmission of information is by electronic signals between a source and a recipient, in psychophysical theory the transmission of information is via neural impulses from sensory receptors to the brain. Gilmartin states that the sensory experience's measurement in cartography is shown in the perceptual studies of graduated symbology. Some studies have paid attention to finding psychophysical power functions or the quantitative relations between the magnitude of a physical stimulus and the magnitude of a corresponding perceptual experience (Gilmartin, 1981a).

Theories of psychophysics have developed into theories of cognition, and since the basic cognitive activity is the perception of information, no clear-cut edge between the perception of information and the mental processing of information into meaning has been noted. As a result, cartographic investigations should use combined approaches and not depend completely on psychophysical data in order to understand a cartographic process of communication (Gilmartin, 1981b).

Semiology

Semiology is a wide area of study utilized in the field of cartography to construct a general theory for cartographic symbology. Jacques Bertin's *Semiologie Graphique* (1967) is the primary cartographic work drawing on the concept of semiology, the language of graphic symbols. Semiology's goal is to build a map language based on structural concepts borrowed from linguistics. It aims to discover the meaning, structure, and psychophysical components of a map language. Muehrcke uses a linguistic research paradigm as a foundation for separating the areas of the cartographic study of symbology: symbol/ referent relationships or semantics, symbol/symbol structural relationships or syntactics, and symbol/user relationships or pragmatics. Figure 9 shows how the divisions of semiotic research are difficult to isolate in the context of a map (Muehrcke, 1972).

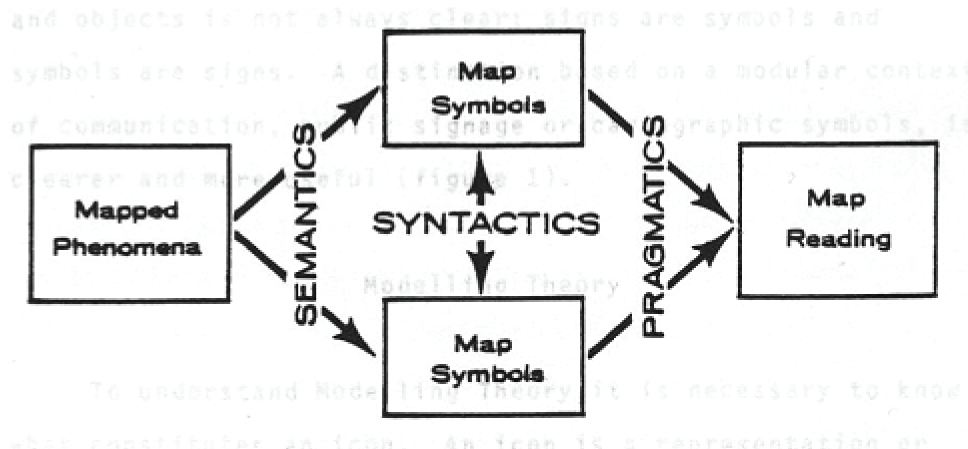


Figure 9. A cartographic interpretation of the theory of signs. (Muehrcke, 1972,19).

Much literature concerning semiology fails to make a significant distinction between signs and symbols. More particular definitions are given by Modley (1966). While signs refer to objects and percepts and attempt to change actions, symbols refer to concepts and ideas and serve to start and facilitate mental computations. As designators, symbols are considered to be part of the human world of meaning; also, they are used to pass knowledge across generations (Frank, 1966).

Modeling Theory

An icon is a symbol or representation that portrays the characteristics of the object. A map in cartographic terms can be seen as an iconic model of reality. Across various cultures, people accept the idea of a map as an icon. For example, in the East, the iconic pictures of Christian personages play fundamental roles in the Russian Orthodox Church, while in the West, an iconic map corresponds to the qualities of a geographical reality in three kinds: it could be a control model of space and knowledge (distance and location), logic and graphics, and images and ideas (rivers and mountains), as first noted by Board (Ratajski, 1978).

In considering the map as an iconic image, Arnheim (1966, 1976) suggests that the pictorial image is a creation of the mind rather than a deposit of the physical object. Also, Arnheim advances the problem of meaning in perception by separating it into intellectual meaning and meaning that is drawn from past and present images. Arnheim states that a person's mental legend can only be modified by the image of an object and not by the object (Arnheim, 1966, 1976). Ratajski notes that the iconic map emphasizes the map as a tool in research and cognition and stands counter to the formal approach of information theory and the structural comparative approach of semiology (Ratajski, 1978). Kretschmer points out that in the former Soviet Union, where cartography was defined as a means of acquiring knowledge from spatial images, scholars considered the iconic map an essential part of cognitive research (Kretschmer, 1980).

Cognitive theory

While cognitive cartography encompasses the application of cognitive theories and methods in order to understand maps and mapping, the application of maps can also help in understanding cognition. As commonly understood, cognition includes perception, memory, learning, thinking, communication, reasoning, and problem-solving. Cognitive cartography includes three areas of research. The first area, as outlined by Olson, is map-design research. It is principally conducted by academic cartographers, and its aim is to understand maps, mapping, and map use so as to improve them (Olson, 1979). The second area, as denoted by Lloyd and Steinke and Tversky, is map psychology research. It is performed primarily but not entirely by academic psychologists, and its purpose is to understand human perception and cognition (Lloyd and Steinke 1984; Tversky 1981). Finally, the third area, as stated by Rushdoony, is map-education research. It is conducted by researchers in the fields of cartography, geography, psychology, and education who are attempting to improve education with maps and about maps (Rushdoony, 1968).

Cognitive theory, as it is applied is in the cartography field, spotlights the mental phenomena used in order to process map elements. Ratajski held that cognitive theory had developed from two different foundations: the former U.S.S.R and the West. While cognitive theory was based largely on philosophical speculations in the former U.S.S.R , it was developed from experimental testing associated with psychological concepts in the West (Ratajski, 1987).

As cartography has developed in the U.S, a concern about the cognitive element in maps has grown (Ratajski, 1987). Pechenik and Olson explain that cognitive theory in the U. S. has appeared with broader concerns and holistic assumptions concerning the mental processing of map elements (Pechenik, 1975; Olson, 1979). Pechenik arguea a straight connection between cognitive theory and a concern with the cartographic transmission of meaning, positing, “We must be concerned with meaning in cartography to an extent far greater than that to which we have been in the past. If the function of a map is to trigger meaning, then meaning becomes all important” (Petchenik, 1975, 185).

Cartography (Symbols)

Introduction to symbols

A symbol is a graphic image that stands for an object, action, or attribute. Symbols convey information with a picture or image. Different classes of symbols range from totally geometric to images that are very representational and, in some cases, almost pictures. The great advantage of pictorial symbols over more geometric symbols is that they can more easily be understood by most people, whatever their age, language or reading ability. They provide information in a simple and direct way that can often be universally understood. This is why symbols have become very important in the design of signage for the Olympics, roadways, and airports, where many different people from all over the world may pass them.

Horton states that the use of icons or symbols dates back to the days of cave dwellers and is among the oldest forms of communication. Long ago, people began to use pictures to record history and tell stories (Horton, 1994). In addition, Giedion mentions that the earliest written languages of China, Egypt, and Mesopotamia used pictures in order to represent their ideas (Giedion, 1996). Later on, with the creation of the alphabet, the visual symbols came to represent sounds rather than ideas. The invention of the alphabet developed, changed, and replaced iconic languages in many cultures. That does not mean that the ancient graphic symbols no longer exert influence, for the ancient graphic symbols influence art, traveler information signs, and even computer programs (Horton, 1994).

Definitions of terms:

Even though graphic representations have ancient origins and appear in all cultures today, terms to discuss them are inconsistent. The following terms, which are used in this study, have specific meaning; because their usage in the literature is often ambiguous, they are explained below.

1. Icon: this term means a small symbol that represents an object or activity. It may be a pictorial representation of an image or object. In computer science, it also means a graphic symbol (usually a simple picture) that stands for a program, a command, a data file, or a concept in a graphical user interface.
2. Semiotics: this is the science of signs as well as the study of semiotic sign systems. It frequently uses linguistic terms to describe the functions of a sign system. Semiotics, semiotic studies, or semiology is the study of sign processes (semiotics), or signification and communication, signs and symbols, both individually and grouped into sign systems. It includes the study of how meaning is constructed and understood (Chandler, 1994).
3. Symbol: "An abstract and often simplified pictorial representation which is not necessarily realistic … [it] often requires a learning process" (Bocker, 1996, 107). It also refers to a "universally recognized metaphor" (McNair, 1996, 82). A symbol is something that represents something else by association, resemblance, or convention, especially a material object used to represent something invisible.

4. Sign: A sign is a conventional figure or device that stands for a word, phrase, or activity. A symbol is a type of sign, but sign is a broader term. It can also mean any nonverbal action or gesture that encodes a message (Jung, 1946).

Symbol design

Importance of well-designed symbols versus text

Symbols serve as signs to indicate and represent concepts, ideas, or abstractions. For example, in the United States, Canada, Australia, and Great Britain, a red octagon is the symbol that means "STOP." Common examples of symbols used on maps include a picnic table to indicate a picnic area or a question mark to represent an information center. Symbols and signs are not limited to one type of environment; instead, they occur in many environments and contexts. They appear in airports, commercial advertisements, and public places, and on highways, electric equipment, maps, etc.

The viewer’s understanding of a symbol’s meaning depends on its design. The better the design of a symbol, the more it communicates a comprehensible idea. In many cases, the symbol must convey ideas rather than physical objects. Symbol design requires an understanding of graphic design in order to accomplish this.

Many studies discuss how well-designed symbols can send their messages more accurately and quickly than words on signs (Edworthy and Adams, 1996). Several reasons encourage graphic designers to use icons to present information. For example, Horton states that a well-designed icon can help people to work more quickly since it will eliminate the need for them to read, analyze, or translate it. Also, Horton suggests that different professionals, such as designers, engineers, and scientists, are familiar with visual images in their work; thus, such visual images make completing their work easier. Research to investigate the human visual and perceptual systems that have a powerful ability to identify and recognize icons was done by Standing (1973). His study showed subjects 2,500 slides for 10 seconds. Then the subjects were shown pairs of slides and asked which of the two they had already seen. Standing found that subjects were able to recognize 85 to 95 percent of the slides correctly. The research of Horton and Standing reveals that visual icons are a powerful and valuable part of the process of human cognition.

Edworthy and Adams state that well-designed symbols are recognized more quickly and accurately than similarly worded signs (Edworthy and Adams, 1996). Walker, Nicolay, and Stearns (1965) examined in their research the ability of subjects to identify word and symbol signs and found that subjects were able to identify the symbol signs more correctly (Walker, Nicolay, and Stearns, 1965). King (1971) completed a study that compared the ability of subjects to interpret the meaning of symbol and word highway signs. He asked the subjects to match a test sign to one of nine they were shown on a following film segment. The study's results showed that 65 percent of subjects reported that the symbol signs were easier to match. King's research affirmed the findings in a similar experiment performed earlier by Walker, Nicolay, and Stearns, 1965. His study indicated that people were able match symbol signs more precisely than they were word signs (King, 1971). Horton provided three reasons for this: (1) icons are more visually different from each other than words; (2)

visual symbols have names humans remember with them; therefore they are stored as both visual and verbal memories, while text labels are stored only verbally, and (3) visual images are stored in different forms and link strongly to one another (Horton, 1994). These results indicate that graphic designers are more likely to increase the comprehension of their information when they use well-designed graphics rather than words.

Rogers attributes the success of icons to another reason: the increase in the number of commercial products that are used by people from different languages and cultures. The global market needs more universal, well-designed icons and symbols for conveying messages across different cultures and for assisting consumers in the comprehension of the meaning of these icons and symbols (Rogers, 1989).

Hemenway and others give another reason to use icons; icons can present information in a more spatially condensed form than can most text-based messages (figure 10). This is especially important in designing road signs that have a limited amount of space to represent information (Hemenway, 1982; Zwaga and Boersema, 1983; Rohr and Keppel, 1984). Research by Walker et al. and others showed that symbols can be recognized more rapidly and are legible at greater distances and at smaller sizes than information presented in other formats (Walker et al., 1965; Jacobs, Johnston, and Cole, 1975; Ells and Dewar, 1979). The condensation of information that is expressed via icons, combined with the ease of recognition, make icons an efficient choice for expressing information that must be quickly understood.

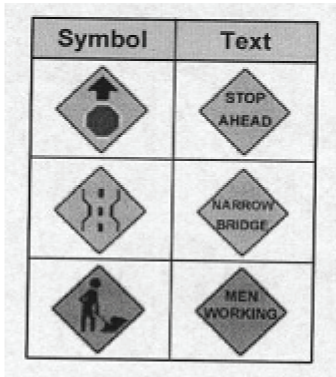


Figure 10. Examples of symbolic vs. textual road signs. (U.S. Department of Transportation, 1998, 11)

Dimensions of visual communication (symbol)

The words "legibility," "readability," and "clarity" commonly appear in discussions about symbols. Though these words reflect realistic concerns, they are too inaccurate to be useful in evaluating symbols. To create consistent judgments, a more objective basis is needed. All visual communication, including symbols, has three distinct dimensions that were used as the basis for the American Institute of Graphic Arts (AIGA) committee's evaluations: semantic, syntactic, and pragmatic. The strengths and weakness of every symbol can be evaluated in relation to these basic dimensions of communication.

The semantic dimension refers to the relationship of a visual image to its meaning. The visual image must convey a message. Understandability, cultural biases, age demographics, existing standards, learnability, and inadvertent interpretations all must be considered when assessing a symbol's semantics.

The syntactic dimension refers to the relationship of one visual image to another. The symbol should have good visual properties. Elements of the symbol should relate to each other, and the symbol should also fit into its intended environment. The symbol construction should be consistent in its use of figure/ground, solid/outline, color, etc. The most important elements of a symbol should be recognized first.

The pragmatic dimension refers to the relationship of a visual image to a user. The symbol must be operable. Can the user see the sign under anticipated conditions, including variations in lighting, distance, viewing angle, or other visual noise? (AIGA, 1981, 20).

An example of such principles in action is in the collaboration of the AIGA and the U.S. Department of Transportation, which worked together to create symbols to guide passengers and pedestrians through transportation facilities. They collected a list of symbol systems that had been used in different locations worldwide, ranging from airport signs and train station signs to the signs used at the Olympic Games. AIGA chose a committee of five leading designers of environmental graphics to evaluate the symbols and make recommendations for adapting or redesigning them. Employing their conclusions, a team of AIGA member designers produced the symbols.

The AIGA designers created a system of fifty symbol signs for use at crossroads, in airports and other transportation hubs, and at international events. The system of symbols signs that was produced through this collaboration aimed to address a universal communication need. The first set of thirty-four symbols was published in 1974 and received one of the first Presidential Design Awards. Sixteen more symbols were added in 1979 (AIGA, 2008). To meet their semantic, syntactic, and pragmatic goals in the design of icons related to transportation, the AIGA developed the following rules to guide them:

1. Simplification of the images is one feature that makes the set of symbols a logical group. The amount of detail that is used should be reduced to a practical minimum and unimportant features should be eliminated. As a result, a set of bold and direct symbols will be designed.
2. The symbols should all be drawn to function as dark figures on a light background. Whenever possible, the forms should be symmetrical shapes with a vertical center axis. Seeing the symbol as dark figures centered on a light background helps to avoid confusion between the figure and its background.
3. The symbols should all be drawn within a uniform format, a square with rounded corners; this type of frame helps the users find the figure very quickly.

These rules for creating well-designed symbols have the ability to communicate large amounts of information at a glance. They can also be useful in conveying information to persons who cannot read a printed verbal message, either because they have vision problems (e.g., older adults), lower-level verbal skills, or inadequate knowledge of the language used (AIGA, 1981, 129).

The process that the AIGA undertook reveals the care that designers give to designing the perfect icons for a product, including passing icons through multiple iterations and adjusting colors and fine details. The work of design-conscious groups such as AIGA enables viewer to understand complex information quickly and helps scholars to place icons on a continuum from completely incomprehensible to readily comprehensible (Haramundanis, 1996).

People resist reading words; they find looking at pictures that substitute for verbal descriptions much easier. Moreover, looking at images is faster than reading words once the user knows what the image represents or means (White, 1982). The familiarity of icons across languages and cultures reveals their power as a communication device.

Icon structure

An icon can include several parts: a border, a background, a text label, and a symbol that is made up of elements (figure 11). While the most important element of an icon is the symbol, the other elements listed above are necessary. Each of these elements has its function.

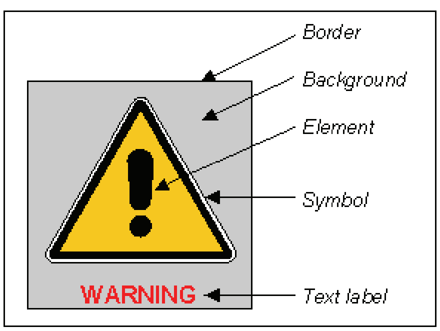


Figure 11. Icon structures. (U.S. DepaRtment of Transportation, 1998, 12)

Border

The border shows the extent of an icon and can make the icon emerge as more consistent, constant, orderly, and uniform. Also, it clarifies the icon’s meaning.

However, at the same time, some drawbacks related to border use can make icons less distinguishable, compete with the image, and limit its size.

Background

The background can help to group icons or can help in emphasizing the image, or can show the state of an icon (figure 12), as with the border, the background could compete with the overall symbol or other elements. Thus, it has to be used in a manner that complements the image and increases icon or symbol comprehension (Horton, 1994).

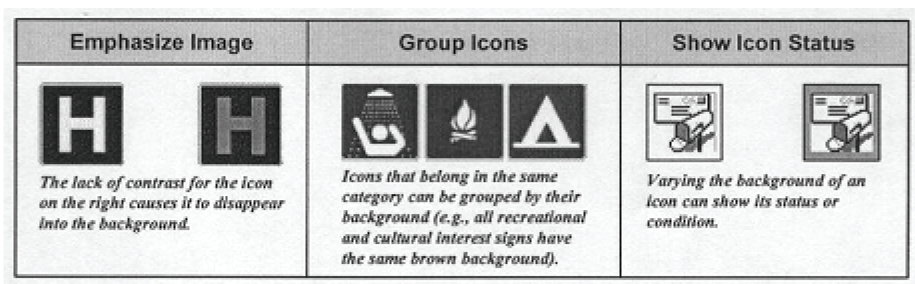


Figure 12. The use of background in icon design. (U.S. DepaRtment of Transportation, 1998, 25)

Horton proposes many suggestions for successfully using backgrounds to enhance an icon:

1. Do not cover up more than half of the available area with objects.
2. Keep the background static because if anything moves, the viewer observes or perceives it as a foreground image.
3. Make the background image a simple version of a recognizable, concrete object.
4. Place objects in the center with the background around the periphery.

5. Put the image visibly in front of the background.
6. Use unsaturated, cool colors for the background, whereas saturated, warm colors should be used for the foreground image.

When the background of the icon is designed following these suggestions, it helps the icon to be recognized very quickly and to stand out.

Text Labels

Text labels can also aid image identification. Edigo and Patterson (1988) state that designers should label the icon with text, especially if the icon is not obvious or if it is appearing for the first time. They examined the ability of subjects to navigate through a database using either pictorial icons, text labels, or a combination of the two. The results found that presenting the combination of the two together increased comprehension of the icons, and the subjects were able to attain the target object much quicker. Though text labels have advantages, they can lead to other problems. For example, if the text label is not chosen carefully, it might mislead the user and decrease comprehension, so it must be brief, no more than one or two words. It also reduces the universal nature of icons, because it must reflect a specific language or culture. Moreover, it could take up space that might be better used to increase the size of an icon.

Symbol shape

The shape of the symbol is an important factor in icon design, because it can help people distinguish between icons in a set. For example, a study by Arend, Muthing, and Wandmacher (1987) compared the selection and response times for three different sets of icons: a set of icons that differed in global features (i.e., color, shape, size), a set of icons that differed in local features (i.e., lines and structures within an icon), and a word set. The results showed that viewers respond faster to the global features of an icon than to the local features.

Symbol Design: Models of symbol recognition and understanding

Knowledge of the basics of visual processing helps significantly in recognizing and understanding symbols. Lodding (1983) states that the ability to perceive the symbol and process it is the first step in comprehending it. Humans process language and visual information in different hemispheres of the brain. While the left hemisphere of the brain processes language, the right hemisphere processes visual/spatial information. In addition, these two types of information are processed in different ways. Although the left hemisphere processes information serially, the right hemisphere functions in a parallel mode. Consequently, once humans first perceive an image, it is captured as a whole and processed in a parallel manner, and its meaning goes through into long-term memory. Moreover, this transfer of visual information to long-term memory may happen straight from sensory memory, or it may occur via a short-term visual memory similar to that of verbal memory. This process works very well. Studies by Paivio and Haber have proved that most people can recognize previously viewed images with almost perfect accuracy (Haber, 1970; Paivio, 1971). Fleming and Levie (1977) found that people given a certain number of items, are capable of recognizing pictorial material faster than textual material; as the saying goes, a picture is worth a thousand words.

Differences between geometric and pictorial symbols

There is an important distinction between abstract images (symbols, signs, icons, etc.) and pictorial images (photos, realistic paintings, etc.). Abstract images play a role very similar to words. Their meanings are fixed by conventions. In contrast, pictorial images, due to their concreteness, directly represent objects or activities. They do not label what they mean; instead, they stand directly for their meanings. Therefore, no problem of meaning occurs when viewers process information from a pictorial image.

Even though people understand the information in a pictorial representation directly, they still use abstraction, a method of disregarding some particularities to grasp the essence. Pictures, even photographs, are at a certain level of abstraction, since a photographer focuses on one certain segment of reality, cut out of the milieu that contextualizes the picture. Decontextualization introduces some element of interpretation. When a small segment is cut out of reality, a high level of interpretation is especially needed. Icons are more concrete than words, photos are more concrete than icons, and the most concrete bearers of meaning are probably movies. The more abstract a symbol is, the more interpretation is needed to understand its meaning. Though, in reality, movies produce more context than photographs and icons and photographs produce more context than icons, they are all abstractions; however, the greater context of movies and photographs makes them more immune than icons are to different interpretations (Danka, 2008).

Classification of Symbols

In order to produce a good symbol, designers must understand the classes of symbols. Though authors divide and define the classes of symbols using different language, their definitions are not significantly different. For further explanation, Table 1 shows for a selected group of authors and the terms that they use for the different classes of symbols. The authors include cartographers and others who have contributed to the literature used in this study.

Table 1. Different definitions of the classes of symbols

Author's Name	Pictorial Symbols	Geometric Symbols
MacEachren	Pictorial	Geometric
Muehrcke		
Robinson, Sale, et al		
Zwaga		
Glendenning	Pictorial	Abstract
Harvey		
Robinson and Petchenik		
Dent	Replicative	Abstract
Williams	Replicative or Pictographic	Abstract or conventional
Thralls	Semi pictorial	Non pictorial
Forrest and Castner	Pictographic	Geometric and Abstract
Beardon	Image-related	Arbitrary
Bliss	Image-related	Arbitrary
Lodding	Image-related	Arbitrary
Modley	Image-related	Arbitrary
Rogers	Image-related	Arbitrary
Campbell	Realistic pictorial	Abstract geometric
Nyíri in István	Living	Abstract

Some authors employ only two categories. Thralls (1958) points out that there are two types of symbols (semi pictorial and non pictorial), stating:

> There are two kinds of map symbols—the semi pictorial and the non pictorial. The simplest type is the semi pictorial, those symbols which somewhat resemble the landscape item for which they stand, for example, the wavy line for a river, the curved and irregular lines for coast lines.
> The non pictorial symbols are those which have no resemblance to the landscape features for which they stand (Thralls, 1958, 28-29).

Only one major textbook divides point symbols into three categories. Robinson et al. (1984) state that there are three categories of point map symbols: pictorial, associative, and geometric (figure 13.)

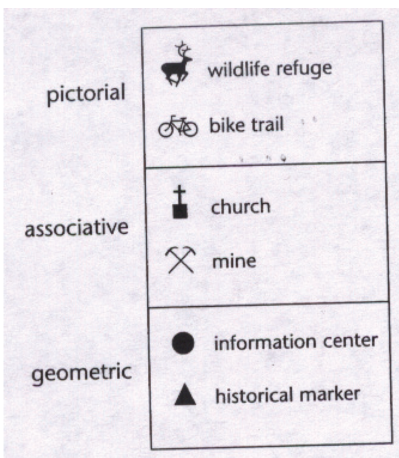


Figure 13. Examples of pictorial, associative, and geometric nominal point symbols. (Robinson et al.,1984, 65).

In choosing the class of symbol, designers have to consider the perceptual qualities of symbols, those characteristics that make finding and sorting symbols into categories easier. They also need to consider the intellectual properties of symbols, which make identifying and interpreting them easier. For example, pictorial symbols have greater immediacy, because they have strong graphic associations or resemblance with their referents, while the geometric symbols do not (Forrest and Castner, 1985).

The design of pictorial symbols uses three-dimensional effects and visual variables in order to represent the object as it is in a real world. Pictorial signs have the advantage of being easily recognized, because no sign interpretation process is necessary. It is sufficient to match the pattern of the sign to the environment. This requires that the sign is not too detailed or confusing (Bruyas et al., 1998). Robinson et al. (1984) suggest that pictorial symbols are similar in appearance to their referent and should communicate without the necessity for a legend. Glendenning states that pictorial types of symbols have been thought of as an aid in translating symbols into visual imagery. This assumption has a historical basis since early manuscript maps often utilized this type of symbol (Glendenning, 1966). Dent (1999) calls these "replicative symbols"—those that are designed to look like their real-world counterparts; they are used only to stand for tangible objects. Coastlines, trees, railroads, houses, and cars are examples. Williams indicates that replicative symbols or pictographic symbols are those that have concrete referents and project their referents by duplication or resemblance. For example, a caricature would be a replicative symbol of a man (Williams, 1956). The techniques of perspective, shading, etc. are used in such symbols to represent the third dimension. With the aid of these design features, the pictorial symbol incorporates the image or the picture of the object that being represented in a very clear drawing or picture. The visual variables (value, shape, size, color, etc.) are also used in order to represent the object very realistically (Keates, 1982).

That pictorial or semi pictorial symbols will be correctly interpreted by all viewers because they are like the referent is often assumed, one viewer's idea of, for example, a factory may differ significantly from another's. Reactions will vary even more widely when the referent is an aggregate (e.g., forest) or an abstract concept (e.g., danger) (Robinson and Petchenik, 1976). This underscores the importance of choosing pictorial symbols carefully and testing them on a variety of audiences.

The geometric class of symbol is geometric in shape; thus the icon bears no resemblance to the feature for which it stand and no graphic relationship to the object or idea it represents. Unlike pictorial symbols, geometric symbols are usually less complex in design and contain fewer clues for the identification of the object being symbolized. The map reader must have more experience in order to read the symbols placed on maps and translate them into conceptualized patterns of landscape imagery (Glendenning, 1966). Such symbols generally have geometric shapes, such as circles, squares, and triangles. They are traditionally used to represent quantities that vary from place to place; they can represent anything, require sophistication of the map user, and need a detailed legend (Dent, 1999). Robinson et al. (1984) goes far as to identify geometric symbols as "purely arbitrary" in relation to their referent. Keates (1982) points out, however, that few symbols are "purely" arbitrary. Regardless of whether they are arbitrary, abstract or conventional, geometric symbols have concrete or abstract referents that they do not resemble, and the association between symbol and referent must be learned. A dot representing a certain number of ducks would be an abstract symbol. In order to make the geometric symbol understandable, the map designer adjusts the visual variables to create a geometric symbol that contrasts with other symbols and with the map background (Williams, 1956).

The associative class falls between pictorial and geometric symbols in appearance. An associative symbol is often a more stylized version of a pictorial symbol. Robinson et al. also say that associative symbols employ a combination of geometric and pictorial characteristics to produce easily identifiable symbols. According to them, this type of class may be "quite diagrammatic compared to pictorial symbols" (1984, 287).

Pictorial, associative, and geometric symbols can be seen as occurring at different points on a continuum of generalization. One can envision the generalization of a symbol, which passes through different stages of drawing, starting with drawing the object exactly as it is in reality and continuing generalization until it reaches the abstract or the geometric shape at the other end of the continuum (Robinson et al., 1984) (figure 14.)

Figure 14. Diagram of the three categories of point symbols

Another classification by Modley recognizes pictural symbols as being image-related; those symbols refer to objects by resemblance. And being arbitrary, geometric symbols have no graphic relationship to the object or idea which they represent. Also, Modley mentions that the symbols may vary in their position on the continuum depending upon what they represent. For example, a triangle representing a duck is arbitrary, but the same triangle representing an Egyptian pyramid might be considered pictographic (Modley, 1966).

The concept of representation and meaning in mapping requires that map readers distinguish between marks that are visually arbitrary and those that retain some graphic characteristic that can be visually related to the referent. MacEachren states that the iconicity of the symbol is very high if the sign is pictorially designed and very low if the sign is a geometric, abstract marker (MacEachren, 1995). Although this distinction does not provide scholars with categories for analysis, it does allow for the establishment of a linear continuum or scale ranging from mimetic to arbitrary. The mimetic to arbitrary map symbol continuum, similar to the generalization continuum, can be used for analyzing entire maps or specific elements. For example, in mapping the phenomenon of a city, there are a great many representation alternatives (figure 15).

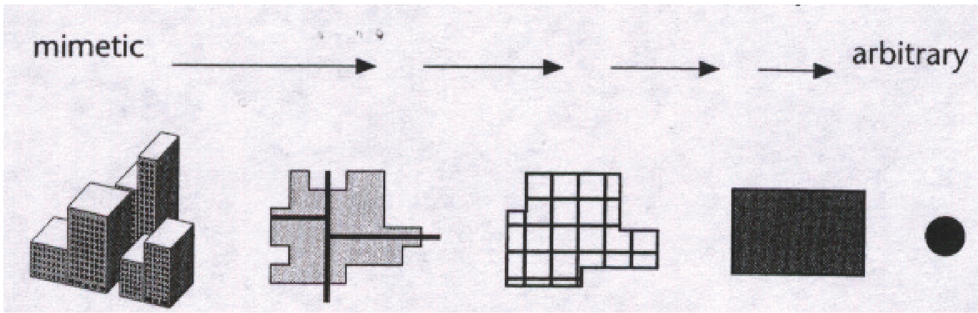


Figure 15. An example of the mimetic to arbitrary continuum of map marks for a city. (Robinson and Petchenik, 1976, 62)

Map symbology

A map can represent various geographic phenomena with their characteristics in an easy, understandable, and efficient way when it uses different kinds of the symbols. As stated by Hsu, "In the past the emphasis in symbolization has been on providing graphic solutions to practical problems of data representation rather than on studying the process of symbolization in a system of communication" (in Forrest and Castner, 1985, 12). Symbolization is the graphic coding of information and placing it into a map context. Cartographers turn to the symbolization process after they have applied classification, simplification, and exaggeration routines to features that are selected for mapping. Symbolization uses visual variables in order to represent the data summarized by classification, simplification, and exaggeration. Two important tasks that the cartographers must perform before they choose the symbols are selecting and possibly changing the level of measurement (nominal, ordinal, interval, or ratio) and choosing the dimensionality of the feature (point, line, area, or volume) (Robinson et al. 1995).

Graphic symbolism that is used to identify different phenomena on maps can also be classified into four basic categories on the basis of the dimensionality of the symbol form: point, line, area, and volume. A point symbol is used to represent or identify a geographic feature by location, and it is non-dimensional—for example, an elevation point, historical marker, or city (figure 16). A line symbol is used to represent or identify a geographic feature with linear dimensions—for example, roads, rivers, air routes, and railroad lines (figure 17). An area symbol is used to represent or identify polygons or a closed geographic feature, and it is a two-dimensional region—for example, lake, grasslands, or a county (figure 18). A volume symbol is used to depict spatial variation in the amount or quantity of a variable by three dimensional representations, such as amount of vegetation or population (figure 19) (Bies and Long, 1983)

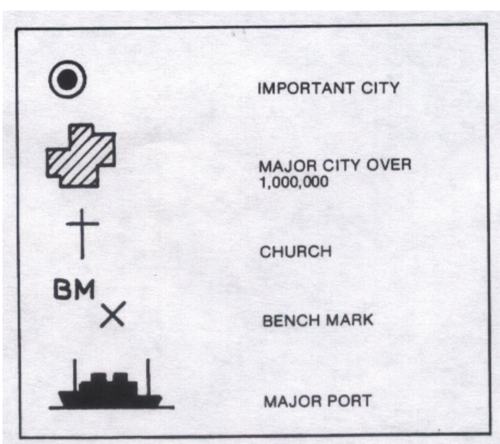


Figure 16. Point symbols. (Bies and Long, 1983, 50)

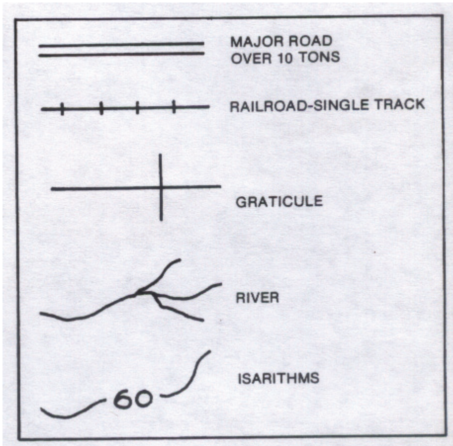


Figure 17. Line symbols. (Bies and Long, 1983, 50)

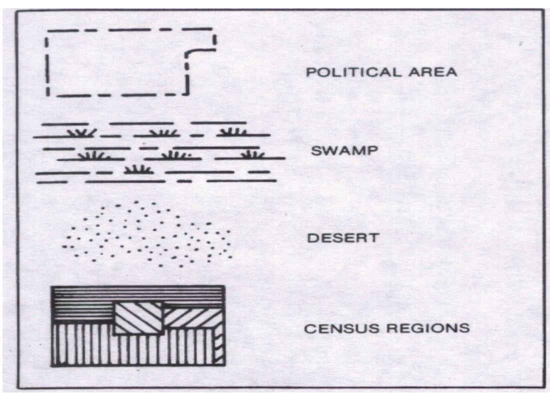


Figure 18. Area symbols. (Bies and Long, 1983, 51)

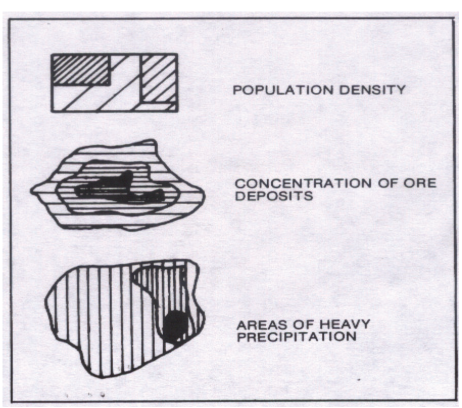


Figure 19. Volume symbols. (Bies and Long, 1983, 51)

Graphic elements

Symbolization is used in developing a map, since creating a reduced image of the real world without devising a set of symbols that stand for real world things is not possible (Dent, 1999). Cartography has a long tradition of symbolization. Cartographers largely based symbolization on convention and experience before Bertin formulated “Image Theory.” Bertin (1983) proposed seven visual variables (planar dimensions, size, value, texture, color, orientation, and shape). These became the building blocks of symbolic language and were employed to match the variables to characteristics of the data to be represented. Cartographers have been influenced by Bertin’s theory, and they have adopted his framework. Bertin placed the control and explanation for behavior in the image and overlooked the viewer. On the other hand, psychology and physiology can explain perception by processes occurring within the viewer (Filippakopoulou et al., 2008).

Bertin described two classes of variables: planar variables, (position and the plane- X, Y)and retinal variables (shape, orientation, color, texture, value and size). Bertin used the term *retinal* based on an assumption that humans have automatic preconceptual reactions to these variables at the level of retinal processing. Bertin’s image theory serves as a bridge between cartographic symbolization research and research in psychology, psychophysics, and vision (Bertin, 1983).

Map designers can make point, line, area and map symbols appear less or more distinctive and prominent by altering their shape, size, orientation, or color (hue, value, chroma). All these graphic variations are primary visual variables. On the other hand, secondary visual variables of arrangement (pattern), texture (pattern), and orientation (pattern) also affect map-reading (Robinson et al., 1995). If the data set is large, assigning a distinctive symbol to each data record is not feasible. While classifying or grouping the data is important, before they are classified, their level of measurement and whether they are qualitative or quantitative must be determined. Qualitative data are grouped under differences in type or quality and are known as nominal data. Quantitative data contain attributes that are indicative of differences in amount and can be expressed as numerical values. Different levels of measurement for quantitative data are the ordinal, interval, and ratio (Natural Resources Canada, 2008).

Visual Search Section

Introduction

Visual search is an everyday human behavior. We carry out thousands of visual searches every day, for example, when selecting items in a grocery store, or when finding a friend in a crowd, looking for lost car keys, and grabbing food from the fridge- these are some of the routine tasks that exemplify visual search. In the past two decades, visual search has been one of the most popular research topics in vision research. Also, the visual search task has become one of the most widely used measures in the study of visual perception and attention; the work of Treisman and Gelade, Wolfe, Duncan, Desimone, and other psychologists and neuroscientists researched much about human search behavior. Some visual search tasks are easy; for example, finding a red flower among green leaves only takes about 300 ms, even when there are several green leaves in the field (Treisman and Gelade, 1980). Other search tasks are more difficult. For example, finding a letter “T” among rotated “Ls” is a slow process and takes longer the more “Ls” there are. Such research has led to models of human attention in search tasks, such as the Feature Integration Theory (Treisman and Gelade, 1980; Treisman and Sato, 1990), Guided Search (Wolfe, 1994) and the Biased Competition Model (Desimone and Duncan, 1995).

The prominence of a symbol may be defined by how easy it is to find within a cluttered background. The prominence of a symbol is influenced by several factors ranging from the context in which the symbol is presented to the design of the symbol itself. Visual search for a symbol is greatly affected by the number of items in the display, as well as by the number of items proximate to the target symbol. So, the more dense the information depicted in the display (i.e., global density) or the greater the number of items in close proximity to the target symbol (i.e., local density), the less the prominence of the target symbol. Generally, the time it takes to find a target symbol increases linearly with increases in information density, whether the local or the global density. Since the global density or the local density vary from one map or chart to another, symbols may be easier to find in one context than another (Christ, 1975; Teichner and Mocharnuk, 1979).

Numerous studies discuss the topic of visual search, including studies specifically involving the variables that may affect visual search time, for example, the number of targets and distractors displayed (Cahill and Carter, 1976; Atkinson, Holmgren and Juola, 1969), the number of groups and the sizes of groups (Tullis, 1986), color (Cahill and Carter, 1976; Christ, 1975; Christner and Ray, 1961; Hopkin, 1994), complexity of targets (Treisman, 1982), number of items coded the same color category as the target (Smith, cited in Carter and Cahill, 1976), and grouping of features (Prinzmetal, 1981; Treisman, 1982).

The factors of effective visual searches that will be employed in this study are the simplicity or the complexity of target shape when displayed among a number of distractors, as well as the simplicity or the complexity of the map background.

Some maps have a large quantity of information that causes visual clutter problems if the map is not well designed. Researchers have studied the effects of information density on searching for targets and found that, when the density of the materials (elements) in the map increases, the search time increases too (Monk and Brown, 1975). Since the purpose of this study is to discover how changes in background and target affect visual search time and accuracy, a detailed definition of visual search is in order

Visual search: definition

Visual search occurs while one is looking for specific items in a complex visual scene. This kind of task is commonly performed in the real world. Researchers aiming to better understand visual search have identified two types of normally occurring processing (Treisman, 1986; Treisman and Gelade, 1980; Treisman and Gormican, 1988). During parallel searches, targets are located effortlessly; consequently, the targets emerge (pop-out) among the distractors in spite of the number of distractors that are present in the display. In serial searches the participant needs to attend to each individual object in the display until the target is located. Reaction times for serial searches are dependent upon the number of distractors.

According to the theory of cognition, visual search is a perceptual task that requires attention (Treisman, and Gelade, 1980). Visual search includes an active scan of the visual environment for a specific object or feature (the target) among other objects or features (the distractors). The effectiveness of visual search relies on the number and type of distractors that may be present. Searches are more efficient when the target is very different from the distractors. The number of targets and distractors is called the display size. The display size effect means the degree to which task performance (reaction time and/or accuracy) depends on the display size. The significance of the display size effect can differ from effectively zero (e.g., in searches for a red target among green distractors, called a feature search) to a large effect (e.g., in searches for a red X among green Xs and red Os, a conjunction search). Search tasks with a small display size effect are termed "efficient;" search tasks showing a large display size effect are referred to as "inefficient" (Treisman and Gelade, 1980).

The reader of a typical map would experience information on a number of separable dimensions (Garner 1976; Shortridge 1982; Dobson 1983). A dimension as defined by Treisman and Gelade (1980), is “the complete range of variation that is separately analyzed by some functionally independent perceptual subsystem”. Examples of dimensions are, size, orientation, location, color, texture, and shape (Kosslyn and Koenig, 1992). Also, a feature is “a particular value on a dimension”

(Treisman and Gelade, 1980, 1999), including features such as top, large, vertical, green, coarse, and round.

Treisman and Gelade built a distinction between parallel and serial search. While the search time in parallel search is independent of the number of distractors, the search time in serial search increases with the number of distractors. Also, Treisman and Gelade's Feature-Integration Theory (FIT) states that a parallel search happens when a search target has a basic feature that is unique relative to the distractors. Serial search occurs when the search target shares basic features with the distractors (Treisman and Gelade, 1980).

Treisman and others have mentioned that visual search for a target distinguished along a single stimulus dimension such as color or shape, is conducted in parallel, while the search for an object defined by the conjunction of two stimulus dimensions is conducted serially (Treisman and Gelade, 1980; Treisman,1982; and Walters, Biederman, and Weisstein, 1983).

Scientists have concluded that there were two separate types of mechanisms for finding a target: parallel and serial mechanisms. In a parallel search just one basic feature (for example, color, or motion, or orientation, or shape) distinguishes the target from the distractors. For example, in a search for a horizontal line among vertical lines, the target is distinguished from the distractors by the basic feature of orientation (figure 20). Since this horizontal line appears to pop out from the distractors, it suggests that all such items are processed in parallel or at once. In contrast, the target in a serial search is similar to the distractors in a single basic feature.

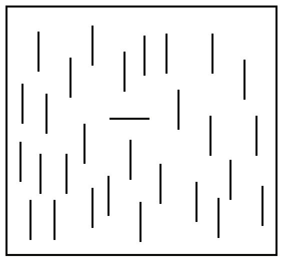


Figure 20. Parallel search for a horizontal target among vertical distractors. The target seems to pop out of the display. (Williams, 1999, 1).

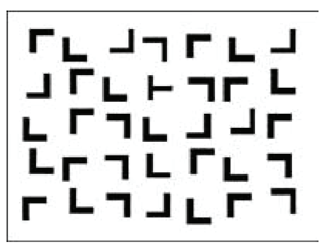


Figure 21. Serial search for T's among L's. (Williams, 1999, 1).

The example of a serial search finding a T's among L's is shown in figure 21. Since this search does not allow the target to pop out in the parallel effect; subjects must to look at the items one by one to find the "T" (Williams, 1999).

Other researchers use the terms preattentive for parallel search and attentive for serial search attentive (Wolfe, Cave, and Franzel, 1989). The preattentive vision stage is defined as visual processes that work in parallel over a large portion of the visual field. Preattentive vision means simultaneously parallel processing by the visual system of multiple target features (Treisman, 1985; Townsend, 1990). Numerous studies have demonstrated that the search for a target pattern among distractor nontarget patterns is fast and parallel if this target differs significantly from its background in some basic stimulus dimension (Nakayama and Silverman, 1986; Nothdurft, 1991, 1993). A preattentively detected stimulus appears to pop out (Saarinen, 1996), and this phenomenon allows very rapid detection of a target among the distractor field. In contrast, the attentive vision stage is defined as the visual processes that guide attention serially to an item in order to decide if this item is the target (Treisman, and Gormican, 1988).

Types of search

Feature search

Another term for parallel search is feature search. This is the procedure of searching for targets defined by a unique visual feature, such as size, color, orientation, or shape. Feature searches are usually efficient. For example, an O is rapidly found among Xs, and a red target is rapidly found if all the distracters are black (Treisman and Gelade, 1980) (figure 22).

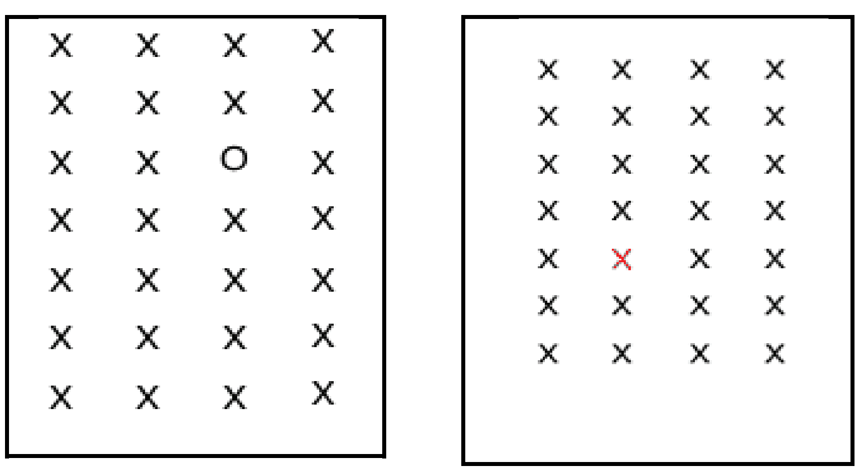


Figure 22. A feature search. (Visual search, 2009).

Conjunction search

Conjunction (or conjunctive) search, another term for serial search, happens when a target stimulus is defined by a combination of two or more features. For example, in a search for an orange square among blue squares and orange triangles, neither the single feature "orange" nor the feature "square" is enough to identify the required target, since the target has a combination of two features in this case. Conjunction searches are typically inefficient, because the subject is forced to observe each item in the search array one at a time before making a decision whether it is the search target. The search task time increases linearly with the number of distractors. This leads to the term "serial search," which means that the subject shift his/her attention serially from one object to the next, making a decision for each whether it is the target (Treisman and Gelade, 1980) (figure 23).

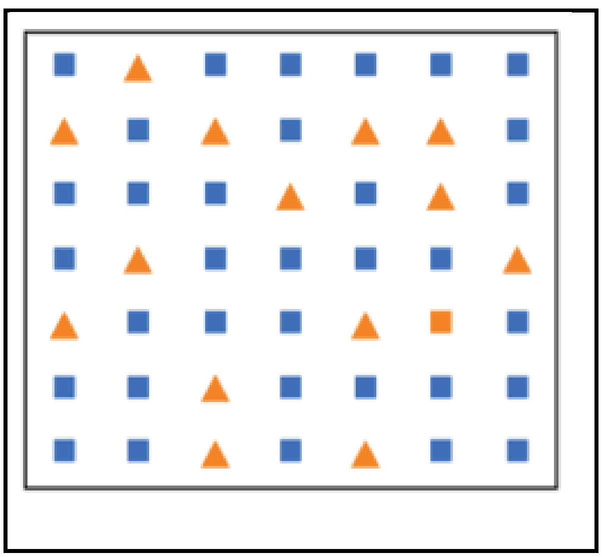


Figure 23. A conjunction search in which subjects must find the orange square.(Visual search, 2009).

Parallel and serial searches

Thus, visual search processes have often been divided into two types, the first one known as parallel, preattentive or feature search and the second known as serial stage, attentive or conjunction search, a type of search requiring attention to each item (Treisman 1988; Cave and Wolfe 1990).

Treisman's original Feature Integration Theory talked about targets with unique features that give critical information before focused attention causes them to pop out of a visual display. The viewer is directly conscious of the location of the target with the unique feature. As a result, the viewer has no need to focus attention on objects in the display. Moreover, since the target location can be determined without serially focusing attention on distractor objects, the reaction times for parallel searches are not correlated with the number of distractor objects in the displays. In conclusion, the amount of background noise has no effect on the visual search. Furthermore, the regressions between reaction time and the number of distractors should produce slopes roughly equal to 0.0 milliseconds /item for parallel searches.

On the other hand, the target objects may share features with distractor objects, causing a serial inspection of all objects. In that case, reaction time builds up with each object considered, and regressions between reaction time and the number of distractors should produce a slope considerably different from 0.0 ms/item for serial searches. Duncan and Humphreys (1992) found that the difficulty of visual search was a function of the similarity of targets and nontargets and the similarity of nontargets with one another. Their review of visual search studies points out that, while parallel searches with pop-out effects had been reported for regression slopes from 0.0 ms/item up to 6.0 ms/item, serial searches had been reported with a range between 20.0 and 30.0 ms/item. They concluded that visual search should not be categorized as either parallel or serial but along a continuum of difficulty. Parallel searches, with regression slopes nearer to 0.0 ms/item, are on the less difficult end of the continuum, whereas serial searches, with regression slopes significantly greater than 0.0 ms/item, are on the more difficult end.

Lloyd conducted an experiment with feature and conjunction searches within a map-reading context. This experiment used three types of searches (single-feature, multiple-feature, conjunction feature). The results showed that when the target symbols have unique features, they pop out of the map, while a serial search is required to find map symbols that have no unique features. Moreover, visual searches for map symbols performed in map reading contexts are controlled by the spatial locations that provide the context (Lloyd, 1997a).

Theories of visual search

Researchers in psychology and vision are working to clarify how the human visual system analyzes images. They are also finding explanations for many aspects of Bertin's theory. Bertin's theory is regarded as an organized and meaningful framework for the analysis and representation of data. Bertin created a logical symbol scheme according to graphical variables. These graphical variables consist of the size, color, value, shape, orientation, texture, and position of marks within a two-dimensional coordinate frame (Daru, 2001). Numerous theories seek to explain why some searches are preattentative and others need focal attention, such as Feature Integration Theory (Triesman, 1988), Guided Search Theory (Cave and Wolf, 1990), and Attention Engagement (Similarity) Theory (Duncan and Humphrey, 1989, 1992). Several reviews of the literature state that only a small numbers of attributes are preattentive basic features. For example, some data indicate that color, orientation, and size are basic features. Shape, line termination, closure, topological status, and curvature can probably also be considered basic features (Wolfe, and Horowitz, 2004). In his Computational Theory of Vision, Marr (1982) identifies the attributes of shape that he considers basic in forming representations at different stages of processing. If Marr's hypotheses about shape and mental representations are correct, they can be used for constructing map symbols. Some recent studies in cartography are based on the theories of psychology and vision, but they use very simple backgrounds or very simple maps that do not correspond to the usual complexity of maps (Lloyd, 1997b and Nelson et al., 1997).

Feature Integration Theory (FIT)

The aim of Treisman's (1988) Feature Integration Theory (FIT) of attention is to explain how visual information is integrated and how spaces are searched. Through multiple multi-visual search experiments, Treisman, recognized numerous characteristic affecting the extraction of the target during the preattentive stage; some of these are color, curvature, movement, shape, size, texture, and tilt. Treisman argued that unique feature targets can be detected during the preattentive stage of processing and in parallel across the visual field. For example, if the target was red and all other objects were green and yellow, the red target would pop out of the display. In this case, the search time is independent of the number of distractor objects on the map. However, if the target shares its features with distractors, the Feature Integration Theory argues that the target will not pop out of the display. Searching for the target in this case requires attention that focuses serially on each object in order to specify an object by locating and conjoining separate features. For example, if the target is a brown circle, which is defined by shape and color, and it is located among brown squares and green circles, since the target lacks a unique feature, the subject will need to focus attention on each location to search for the target; this is consistently the case when the target is a conjunction of two features (in this case, brown color and circle shape) (Treisman, 1988). The simplicity or complexity of the target will depend upon whether it is defined by a single feature or a conjunction of features as well as the group of distractors upon which the target falls. The Feature Integration Theory recognizes the difference between objects defined by a single feature and those defined by a conjunction of features.

Treisman's theory aims to clarify the effects of perceptual grouping on searching for targets, whether the target is defined by a single feature or by a conjunction of features. Figure 24 shows an example of stimuli used in Treisman (1982); the groups were formed by proximity and similarity by organizing items in homogeneous rectangular matrices. Searching for feature targets was detected preattentively, since feature targets emerge independently of perceptual grouping. In contrast, searching for conjunction targets was detected serially.

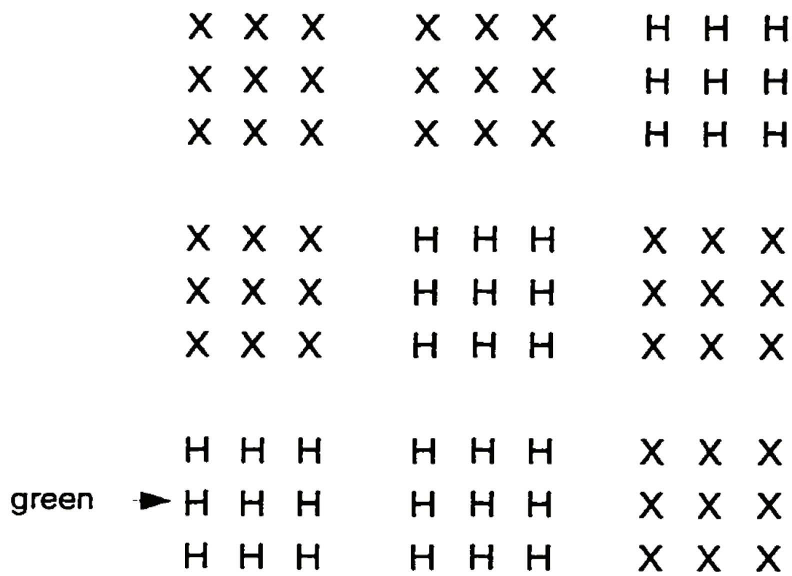


Figure 24. An example of stimuli used in Treisman (1982). All Xs are green, and all Hs are red with exception of green H target, labeled in the figure.

Studies in visual search and finding a target

A series of studies have been concerned with the process of selecting discrete targets for fixation or of finding a target among distractors. These studies have been conducted in the different fields of cartography, psychology, and human factors. The present study focuses on the speed and correctness of response of visual search for a target point symbol on a tourist map. The following discussion covers the findings of some earlier studies related to the topic of the present study.

The present study is to a large extent based on earlier work on visual search by Williams (1967, 1971). Williams conducted experiments with different characteristics of target symbols, testing how subjects used these types of information alone and in combinations. He discovered that, when one or two colors were used with other given variables (size, shape), the fixations tended to relate to color only if the target was large. Also, the results indicated that the greatest improvement occurs when the color is known, followed by size. The least improvement happens when shape is known. His basic conclusions were that search times will decrease when some visual characteristics of the target are known, such as its color, shape, or size. Williams's targets were all simple geometric shapes (circles, squares, cross, etc.) and were not in map context (Williams, 1967). Although shape was considered by Williams to be the least effective sorting characteristic, further evidence from the experimental psychological literature has demonstrated that complex shapes take more time for visual processing than simple ones (Vernon, 1971).This conflicts with some cartographic studies which pointed out that pictographic symbols would be found faster. A series of tests have also been made to compare pictorial (pictographic) symbols and abstract (geometric) symbols. One of these tests was carried out by Kilkoyne (1973), who asked his subjects to count, verify, or compare the number of times individual symbols appeared on a particular map. The symbols were overprinted in white or dark gray tones. The results showed that the search times for both pictographic and geometric symbols were slower on maps with a dark gray background than maps with a white background. Also, the pictographic symbols led the map users to be faster and more accurate in the task performance than the geometric symbols did. As discussed previously, the pictorial symbols were preferable to geometric symbols. The level of uncertainty was higher for geometric than pictorial symbols. This indicates that the abstract symbols require extra information from memory or from the legend to overcome this additional uncertainty (Kilkoyne, 1973).

Another series of tests by Phillips used pictographic, semi-pictographic, and geometric symbols. The result was that the pictographic and semi-pictographic symbols performed better than the geometric symbols (Phillips, 1973). Numerous other researches have worked more directly with discriminability of positional symbols for maps. Some of these researchers measured the confusability of symbols. An example of this type of search is Johnson's (1983) empirical evaluation of the National Park Service point "symbol" set. His study had subjects had to match symbols with labels (both with and without a legend present). From the results was derived a confusability index that was based on the number of misidentifications for each symbol. Also, the number of correct identifications in a limited time was determined; it demonstrated which symbols were highly confusable and rated low for visual search, because they look alike.

A similar study by Forrest and Castner (1985) classified symbols as being either image-related (pictorial), concept-related (associative), or abstract. Forrest and Castner worked with the design and perception of point symbols for tourist maps, testing tourist symbols, including four types of symbols ranging in abstraction from pictographic to simple geometric. Their test concluded that the geometric symbols were found faster; framed pictographic symbols were found slower, and unframed pictographic symbols were found slowest. On the other hand, geometric symbols had more identification errors than pictographic symbols. The complexity of the pictographic elements of framed symbols had no effect on visual search.

De Brailes (cited in Forrest and Castner, 1985) carried out an extensive series of tests to study the function of complex point symbols at different levels of search and association. He used three maps in his two experiments. In the first experiment, the symbols on map A varied in only hue, while on map B they varied only in form. On map C, they varied in form and color for each category. The result was that overall search times were best for map C, followed by A and B. This indicates that the performance is better with redundant coding, using both color and form, than by color only and worst with form only. On map A, De Brailes found that the darkest symbols (most of which were solid) were identified best, followed by the lightest, with the intermediate ones worst. In his second experiment, which was concerned with the location of individual symbols, the hue variable was shown to be the best variable for symbol categorization. These studies have indicated that color, when present, is the principal characteristic for selecting an object (Forrest and Castner, 1985).

Another study, conducted by Clarke (1989) analyzed the efficiency of symbols in the legends of two comparable published tourist maps by using a symbol comprehension method. The relative effectiveness was assessed with respect to the ease and accuracy with which the symbols were understood by subjects. The results of that study pointed to geometric or pictorial symbols as being inefficient, because they bear a poor resemblance to the object they were attempting to depict (Clarke, 1989).

In visual search testing, subjects are asked to detect target stimuli presented among irrelevant nontargets (distractors). Results depend on the combination of targets and nontargets used. Experimentally, it is easy to confirm that people can take up and report only a small amount of the information contained in a brief viewing of a visual display, because humans can pay attention to only a small amount of the information presented in a visual scene. People use different selection criteria (location, color, movement, etc.) to choose which information to see in a briefly glimpsed scene (Warren and Warren, 1968).

Treisman and Gelade mention that visual search has been a basic research problem for some time in spatial cognition (Treisman and Gelade, 1980). Most visual search studies have considered target and distractor symbols on plain backgrounds (Treisman, 1988) or on simple maps (Lloyd, 1997a). Cartographic studies have, in general, shown that targets with unique features, for example, color or shape will immediately pop out of a visual display, whatever the characteristics of the background information (Lloyd, 1997b).

A similar study to Williams (1967, 1971) was done by Eriksen (1953), who examined different characteristics of target symbols and how subjects used the information alone and in combinations. He found from that search becomes faster when more than one characteristic of the target is known, as compared to when only a single characteristic is known. Another study that supported the results of the two

Williams studies (1967, 1971) and that of Eriksen (1953) was done by Wolfe, Cave and Franzel (1989); they asked the subjects to search sets of items for targets that were defined by combinations of color and form, color and orientation, or color and size. The set size was varied and reaction times were measured. The results found that searches for triple combinations (color, size, and form) were easier than search for standard conjunctions and could be independent of set size. A similar study by Lloyd (1997) involved experimental objects designed with differences in color, shape, orientation and size. The time and the percentage of incorrect decisions was measured. The results indicatedthat, when the target has some unique characteristics distinguishing it from other symbols, the pop-out effect occurs. Also, pop-out effects could be produced by color differences between targets and distractor symbols or by differences that combined color with other characteristics.

A study by Huang and Chiu (2007) investigated the effect of color combinations of the figure/icon background, icon shape, and line width of the icon border on visual performance on computer display screens. The analysis showed that the icon shape significantly affected search performance. The correct response time was significantly shorter for circular icons than for triangular icons. In addition, the results demonstrated that the response time for icons with borders having a line width of 3 pixels was significantly shorter than for 2 pixels and even more so for 1 pixel. However, no effects on the error rate were found for the line width of the icon border or the icon shape.

Besides these studies investigating the role of target's characteristics in visual search, there were also some experiments testing differences between the target and nontargets. As well, there were experiments testing the similarity between the target and nontargets and between the target and the background. Varying the number of nontarget symbols in the scene influenced the amount of background information. When the target does not have a unique feature and shares features with distractor objects, the time that is needed to find the target should linearly increase as the amount of distracter information increases (Brennan and Lloyd 1993; Cave and Wolfe 1990; Duncan and Humphreys 1992; Lloyd 1988; Nelson 1995; Wolfe 1994). A study by Duncan and Humphreys (1989) found that the difficulty of the visual search increased with the similarity of targets to nontargets, while the opposite was true when there was decreased similarity among nontargets. A study by Neider and Zelinsky (2006) examined the effects of target-background similarity (TBS) on visual search. They conducted four experiments during which the participants searched for toy targets among distractors under varying conditions of set and target background similarity (TBS). The results showed that the manual errors and response time increased when there was similarity between the target and the background components. The literature on visual search processes has demonstrated clearly that the search for a target is more difficult if the array contains confusable nontargets (e.g., Gilmore, Tobias and Royer, 1985; Krumhansl and Thomas, 1977; Mclntyre, Fox, and Neale, 1970).

The effect of the background on visual search

Many previous studies have demonstrated that background color has an effect on the discriminability and appearance of color stimuli. Chromatic discrimination thresholds are smallest for stimuli that are achromatic if the background is dark or achromatic, however on chromatic backgrounds the smallest discrimination thresholds occur for stimulus chromaticities that are similar to the background chromaticity (e.g., Krauskopf and Gegenfurtner, 1992; Miyahara, Smith, and Polorny, 1993).

A study by Wolfe and others (2002) to examine the ability of the visual system to separate search items from a background, showed that when the backgrounds are similar to the search objects, the search slows, using item-by-item selection (Rosenholtz, Nagy, and Bell, 2004).

In the basic SDT (Signal detection theory) model, a participant makes independent observations of the features of elements in the display. When the target and distractors become more similar, or when the noise increases, the SDT model predicts a more difficult search. A study by Simola and Kojo (2003) measured observers' eye movements in a directed visual search task, with varied complexity of the search matrix. The results showed that reaction times were significantly higher in background noise conditions than in distraction item conditions.

Several studies have found that the similarity of the target and background items has a major effect on performance in visual search. For example, Estes (1972) had subjects carry out a forced-choice letter-detection task in which the background items consisted either of disks (dissimilar condition) or letters (similar condition). The results showed that accuracy was poorer and latencies longer with the similar background items. Corcoran and Jackson (1997) found similar results, by comparing different background elements in speeded detection tasks. Duncan (1983) and Krueger (1984) produced data that suggesting that performance differences between within-category search (e.g., a letter target among letters) and between-category search (e.g., a digit among letters) may well be accounted for by differences in relative target-background discriminability (in the case of single-target search only).

Many investigators have found other lower-level factors that influence visual search. For example, the effect of target-distractor similarity on visual search has been studied widely. Increasing target-distractor similarity in a feature display increases set-size effects (Duncan and Humphreys, 1989; Palmer, 1994; Verghese and Nakayama, 1994). It is well known that human visual contrast sensitivity decreases with increasing retinal distance from the fovea. Thus, if the retinal eccentricity of the elements in the display increases with increasing set size, performance will decrease with increasing set size (Carrasco, et al., 1995; Geisler and Chou, 1995). Increasing element density has been shown to decrease performance because of an increase in lateral inhibition and lateral masking (Carrasco et al., 1995). In addition to these factors, it has been found that the number of eye movements increases with increasing target-distractor similarity (Zelinsky, Sheinberg, and Bulthoff, 1993).

Human Factors

Research on focused and divided attention of human beings has implications for design display and display formatting. At times, humans must necessarily give attention to information concerning multiple areas, such as to different objects or different dimensions of a single object. When these multiple pieces of information must be available at the same time in the operator's working memory or decision-making system, they are described as "parallel." Because humans so often use parallel processing to understand information, displays should be designed to stress conditions of parallel processing (Wickens, 1984). The ability to locate targets in a complex background—such as a quality control inspector locating faults or scratches on sheet metal (Drury, 1979), a pilot locating targets on the ground from an aircraft (Scanlan, 1977), or a supervisor locating coded symbols on a complex video display (Teichner and Mocharnuk, 1979)—is a practical application that combines many of the characteristics of both selective and divided attention in perception (Wickens, 1984).

The literature on visual search includes the letter-search paradigm of Neisser, Novick, and Lazar (1964) combined with the Sternberg (1975) memory-search-task paradigm. However, a main difference from Neisser, et al.'s paradigm is that target elements in mainly applied search paradigms are not present in an ordered array. Instead, the target may appear anywhere in a random field. As a result, the searcher can apply neither a linear search procedure, as Neisser's subjects were able to do, nor a search guided by an internal model that generates expected locations. In addition, within the visual search paradigms, interest has focused on two general issues: developing models of search time and identifying factors that influence search speed (Wickens, 1984).

An example of the first of these was derived by Drury (1975; 1982), who has created a model that forecasts the chance of detecting a flaw in an inspected industrial commodity as a function of the time allowed for search. A two stage-process was modeled: in the first stage, the scanning and searching behavior was considered, and in the second stage, the type of detection decision was analyzed. Based on their research, Spitz and Drury (1978) concluded that these two stages are fairly independent of each other. In addition, Drury identified factors, such as fault conspicuity and the amount of surface area to be inspected, that affect the chance of locating a flaw in the first stage. Other factors, such as batch failure rate, influenced the decision component of the second stage.

The most significant general characteristic of this model is that the probability of detecting a target by the time T follows a negatively accelerating function of T. This function says that there is an optimum time during which any item should be inspected, and longer times will mean diminishing gains in accuracy. Moreover, Drury (1975; 1982) explains the way in which this optimum time should be established by arguing that factors such as the rate at which the industrial manager desires products to be inspected , the probability of fault occurrence, and the desired overall level of inspection accuracy be considered in calculations of the optimum time. Then industrial material to be inspected can be presented at a rate that is determined by this optimal time.

The second issue of research has focused on the factors that influence the speed of target detection and localization (Drury and Clement, 1978; Mocharnuk, 1978; Scanlan, 1977; Teichner and Mocharnuk, 1979). Four general conclusions can be drawn from that research:

1. The control factor of search time is the number of elements to be searched. (Drury and Clement, 1978; Mocharnuk, 1978). Whether the elements are closely or widely spaced or require little or much scanning has little effect. Therefore, scanning with wide distribution does increase search time. However, a high density of nontarget elements when the items are closely spaced does have a small slowing effect on search time. Thus, scanning and visual clutter trade off with each other when the spread of the target is varied.
2. From the basis of a summary of a large number of experimental results, Teichner and Mocharnuk (1979) conclude that overall search rate increases as the total amount of information in the display increases. This information is increased in response to different factors, such as increases in the number of items to be inspected, the number of relevant dimensions of variation, or the number of possible targets. On the other hand, an increase in search rate (item/unit time) with more items is not enough to compensate for the increased number of items that have to be inspected, so the total search time is

extended either by including more items or a larger number of related dimensions.

3. Searching for one of many targets is slower than searching for only one. Therefore, the multiple targets slow the rate of the search, a finding supported in applied search results such as in the work of Craig, 1981; Geyer, Patel, and Perry, 1979; Monk, 1976; and Sheehan and Drury, 1967. This conclusion is somewhat at odds with Neisser, Novick, and Lazar (1964), who found that the multiple letter search was as rapid as a single letter search. However, this result was found only after many days of practice.
4. Also, the different dimensions used to define a target directly affect the search rate. For example, searches for targets defined by one dimension in an array that varies only in that one dimension are more efficient than searches for targets in a multidimensional array, regardless of whether the targets are defined by one dimension (e.g., green) or two (e.g., green circle). An exception to the finding occurs when targets are redundant, that is, when two features uniquely define the target. (e.g., the target is green circle, and non targets are green or circular). Notably, color is a prominent dimension in defining targets for search, being more proficient than shape, size, or alphanumeric characters in defining targets (Christ, 1975).

Visual search research has formed relatively accurate models of human performance that can be applied to real world behavior to forecast performance in complex environments. The ability of researchers and designers to predict human performance is important because signs and symbols are central to so much human activity, including travel, business, industry, education, medicine, religion, recreation, engineering, and other fields.

Because of the value of efficient visual searches in human life, studies of individual visual codes have compared the effectiveness of different types of codes in relation to various types of tasks. Several experimental studies point out that color coding is an influential means of improving discriminability among classes of items presented in visual displays. In addition to these studies, researchers have also examined the effectiveness of color as a nonredundant code and compared it with other possible visual coding dimensions, especially shape coding. The results of studies that compare color and shape coding in information display suggest that color coding may be superior to shape coding under certain conditions. One of those studies was made by Eriksen (1952), who found in the context of a search task that visual separability based on seven hues was better than that presented by a symbol set of seven geometric forms. Also, Hitt (1961) discovered that a code of eight colors was superior to eight-valued letter, geometric shape, and configuration codes; however, it was equivalent to a numerical code in many tasks, such as in locating, counting, comparing, and verifying. Also, he found color to be inferior in an identification task. A study completed by Christner and Ray (1961), who used different eight-valued codes in a different experimental context, concluded that color was superior to numerals and shape codes in locating and counting tasks while inferior to numerals in an identifying task. Moreover, a follow-up study by Smith and Thomas (1964) attempted to measure systematically the superiority of display color coding by comparing it with different shape codes in the context of a simple task, counting a specific class of displayed items. They used four codes (aircraft shapes, geometric forms, military symbols, and color); each code included five symbols. For each of the three shapes, codes were displayed with 20, 60, or 100 symbols of the type in question, randomly located at any of 400 positions in a 20 by 20 imaginary matrix. In various parts of the study, there were three sets of displays that were used:

1. Sets with shape symbols colored randomly.
2. Sets with shape symbols all the same color but with different displays for each color.
3. Sets in which each of the five symbols of a shape class was coded a unique color, with different displays of each symbol-color combination.

Each set included separate displays for each of the three shape codes. The task of the participants was to count the number of items of a predetermined target class, such as blue, ship, triangle, or F-102 aircraft shape, depending upon the set of displays used in the particular phase of the study. In addition, both time and errors were recorded. The results showed that time and errors increased with density; but more significantly, it was clear that time and errors differed for the different types of codes, with color in the main being the best, although the results found that shape counting was a somewhat faster code and/or more accurate when color did not vary on the display, and vice versa.

Perhaps the most important aspect of the contribution of the literature in human factors to the problems of visual search lies in the information found in many textbooks. Scholars, researchers, and practitioners of human factors have been concerned with the visual presentation of information for more than half a century. This area of activity is exemplified by the work of Grether and Baker (1972), who provide a table, “Comparison of Coding Methods.” For each coding method, including geometric and pictorial shapes, they provide an evaluation (poor – fair – good). This table has been modified and extended by Sanders and McCormick (1993), who deal with the visual search situation in a large section on “information input.” The key elements of their discussion lie in the chapter discussing text, graphics, symbols, and codes (which focuses on the work by Smith and Thomas, 1964). Wickens (2000) considers attention in perception, especially selective attention and also discusses visual sampling and visual search models.

These textbook treatments of organization and simplification do not cover all of the details provided by the abundant literature in this area. But they do provide an insightful overview.

Chapter Three

Methodology

Overview of the study

Visual search is a fundamental part of many map reading activities. Research in this field provides basic behavioral information about map readers that is helpful to cartographers when making design decisions intended to improve the communication process. The experiments in this study measure time and accuracy in task performances involving visual search. More specifically, this study explores time and accuracy of users searching tourist maps for tourist sites presented as simple or complex pictorial or geometric symbols and shown against simple or complex light or dark map backgrounds. This study's methodology is adapted from the work of Smith and Thomas (1964), later adapted by Sanders and McCormick in *The Workbook for Human Factors in Engineering and Design* (1976).

The methodology of this study varies from most studies of visual search carried out in the academic fields of human factors, psychology and cartography in the following ways:

1. This study, unlike many recent visual search experiments, does not use color in its design. Since the purpose of this study is to examine the impact of symbol shape (pictorial or geometric, and simple or complex) on searching for targets, no color was needed. In addition, tourist maps are often printed economically in black and white, so in this respect these tests are similar to real map use.

2. While most visual search experiments have required participants to conduct their visual search on a blank background, whether a piece of paper or a computer screen, this study aims to assess how the background affects visual search; participants conducted their visual search against different backgrounds, varying from simple to complex.

3. While most visual search studies have asked participants to search for only one specific target among non targets, this study differs by asking the participants to count the number of target symbols displayed on the test map. This approach allowed participants tested in groups to self time their searches

4. Most studies have been concerned with accuracy rather than the time participants take for completing visual searches. This study seeks to assess how changes in background and symbol design affect the speed of searches. Time was not limited, but participants were asked to "complete tasks as quickly and accurately as possible."

5. While other studies have often varied the display set size (the number of symbols shown on the test surface), the display set size is the same throughout this study. On each of the test sheets the display set contains 100 symbols located randomly at any of 100 positions in a 20 by 20 matrix.

6. Participants in this study conducted visual search on paper test maps rather than on a computer screen, as has become common in recent years. The narrow time frame for preparing his experiment was insufficient for the development of a computer-based test. In any case there were not enough computers available to test

participants as groups in their classrooms. Since tourist maps are generally in paper format, a paper map would also approach the real-world situation of map reading.

Research study design

This study looks at the interplay between visual search processes and symbols on tourist maps. In a typical tourist map use situation, visual search will be affected by symbol design, map background and map content. The maps used in this study were designed to study visual search for tourist sites represented by simple or complex pictorial or geometric symbols and shown against simple or complex light or dark map backgrounds. The tests measure task performance in terms of both time and accuracy.

Backgrounds

Different map backgrounds were used on the test maps. Different iterations of the test included various backgrounds, with the early test including six different backgrounds and the last including nine. The reason for increasing the number of the backgrounds was that early test results suggested that changing several background designs might yield more informative results. The first six backgrounds were white, light gray, regular linear, irregular linear, imagery, and shaded relief. In subsequent testing the light gray background was dropped (because it and the white background yielded similar results). The regular and irregular linear patterns (which also yielded similar results) were combined into one test map, and the scale was reduced to create a denser pattern. In place of the initial aerial photograph bacground, a smaller-scale satellite image was added. Later that was dropped (because it and the gray background yielded similar results), and a larger-scale satellite image with a more varied and coarser texture was added. Finally, type labels identifying counties were added to the test map with the dense linear pattern.

A more detailed description of the backgrounds follows:

1. The first background was white (figure 1). The reason for choosing this kind of background was that the search for symbols would be easy, because a white background is minimal and provides maximum tonal contrast with the black symbols. The prediction for this background was that the subjects would perform quickly and accurately when searching for the target symbol among the non target symbols.

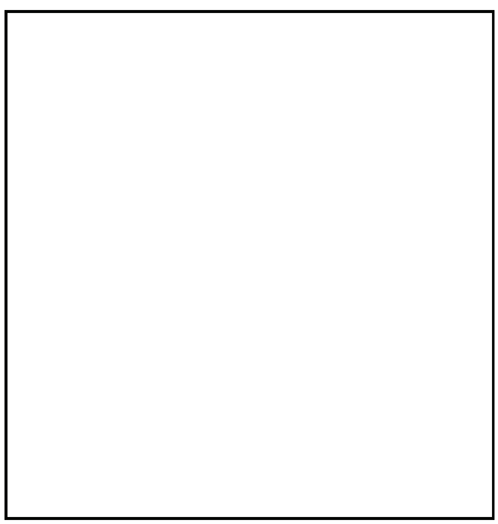


Figure 1. White background. (Reduced 35%).

2. The second background was a fine-textured (600 dpi) 40 percent tint (composed of small black dots covering 40 percent of the surface area, it has the appearance of a flat gray ink) (figure 2). Although the gray background is darker than white and thus contrasts less with the black symbols, the background is uniform. The prediction was that the subjects would perform well, although not quite as well as with the white background.

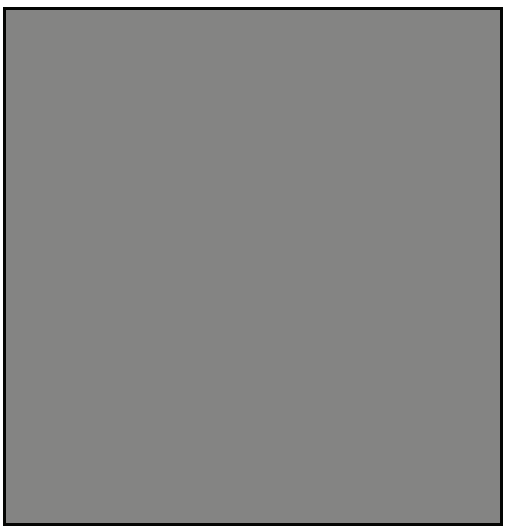


Figure 2. Gray background. (Reduced 35%).

3. The third background consisted of a regular linear pattern, in this case, county boundaries for Kansas and adjacent states (figure 3). The prediction here was that the subjects would take increased time in searching for the target symbols among the non-target symbols. It would be less easy to find the symbols, because the regular linear background would create visual noise and interfere with the search process, especially for the complex symbols with their fine linear details, which made them less compact and less bold than the simple symbols.

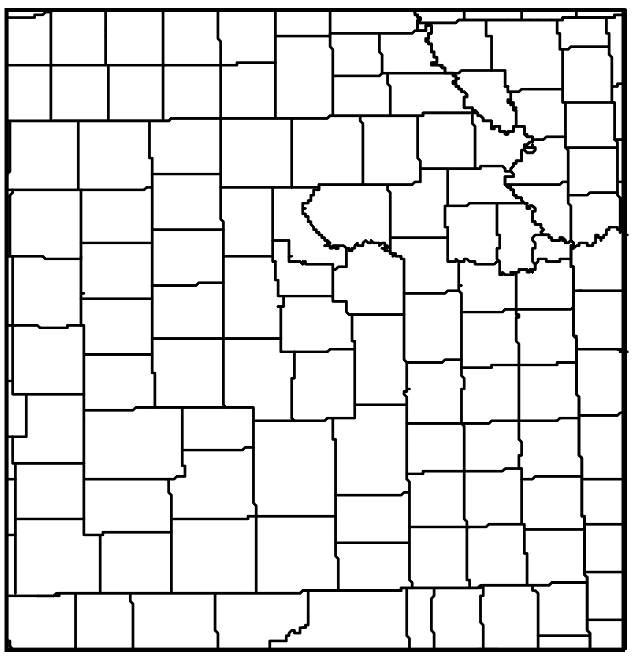


Figure 3. Regular background. (Reduced 35%) (GeoCart: National Atlas Folder, 1994).

4. The fourth background chosen was an irregular linear pattern, in this case, county boundaries for Georgia and adjacent states (figure 4). This background was chosen because searching for the target symbols among non-target symbols was expected to take more time due to the visual noise created by the irregular linear pattern. It was predicted that the subjects' performances would be considerably poorer than searches involving the white and gray backgrounds and somewhat poorer than for the regular linear pattern background. In regard to the search process, finding both kinds of symbols, whether the geometric or the pictorial, regardless of whether they are simple or complex, was predicted to be difficult. This is because the contrast between the symbols and the background is lower compared to the regular linear pattern.

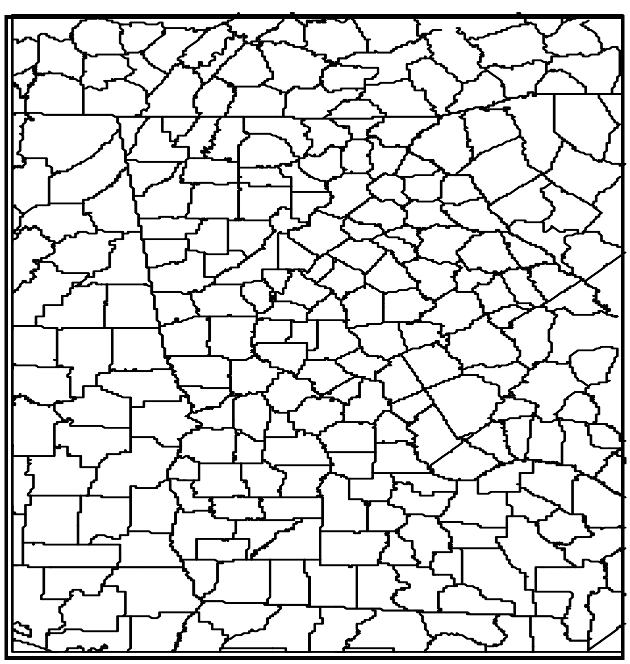


Figure 4. Irregular background. (Reduced 35%) (GeoCart: National Atlas Folder, 1994).

.

5. The fifth background chosen was an aerial photograph of Ithaca, New York (downloaded from http://fhia.org/pictures/aerialmap.jpg in 2008) at a scale of 1:20,000, but initial testing showed that it was too large in scale. A change was made to test with a background taken from a satellite image of Kansas City, Missouri-Kansas at a scale of 1:100,000 (U.S. Geological Survey, 1984) (figure 5). It was predicted that the varied textures and shades of gray would interfere with visual search, causing longer times and lower accuracy than for the white, gray, and linear pattern backgrounds.

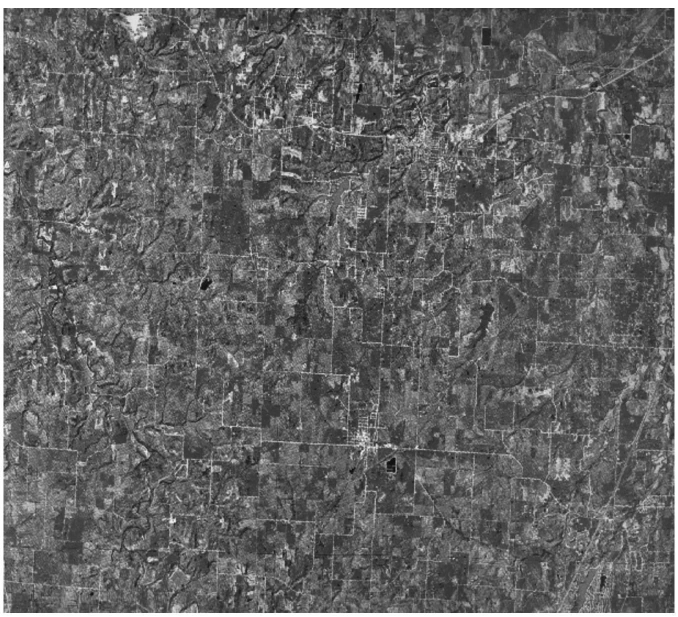


Figure 5. A satellite image background of Kansas City, Kansas (U.S. Geological Survey, 1984). (Reduced 35%).

6. The Kansas City image was replaced in later tests by a satellite image of Al-Ain, a city in the United Arab Emirates, with a scale of 1:24,000 (figure 6). This change was made because it was expected that the coarser-texture larger-scale features in the Al-Ain aerial photograph would make the symbols harder to find. It was also expected that the variation of the gray tones of the masses of unclear features in the aerial photograph would complicate background-symbol contrast, thus increasing search time and decreasing accuracy.

Figure 6. Portion of a satellite image of Al-Ain (Downloaded from Google Earth, and comverted to a black-and-white image) (Reduced 35%).

7. The seventh background chosen a shaded relief of Canton of Grisons (downloaded from http://www.reliefshading.com /examples/imhof_grisons.html) at scale of 1:100,000, but initial testing showed that it had two tones of color (black and white) which made confused for the searchers. A change was made to choose a portion of a digital shaded-relief image of Alaska (1997), with a scale of 1:2500, 000 (U.S. Geological Survey, Reston, Virginia, 1997) (figure 7). This background was chosen because the topographic shading forms a complex pattern and includes a range of light to dark gray tones. The resultant visual noise and highly variable symbol-background contrast would, it was expected, interfere with visual search. The prediction was that the subjects would spend more time searching for symbols on this background than any of the others and that the performances would be low.

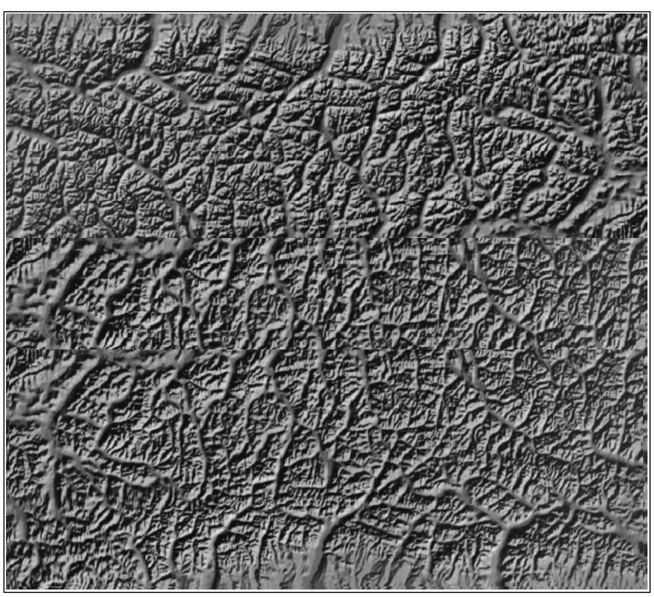


Figure 7. Shaded relief background (U.S. Geological Survey, Digital Shaded Relief Map of Alaska, 1997). (Reduced 35%).

8. The eighth background chosen was a dense linear pattern (a combination of regular and irregular linear patterns) formed by county boundaries of the southeastern portion of the U.S. states, from Illinois to Pennsylvania and Mississippi to South Carolina (figure 8). County boundaries coinciding with state boundaries were omitted in order to reduce reconcilability of the geographical area represented. This background was added later in the testing process, because analyses of earlier tests had shown no significant difference in performance between the less dense regular linear and irregular linear patterns. Combining both patterns in one test image and reducing the scale of the test map created a denser, “noisier”, linear pattern. Consequently, it was expected that searching for symbols against this background would be harder than for the larger-scale linear patterns.

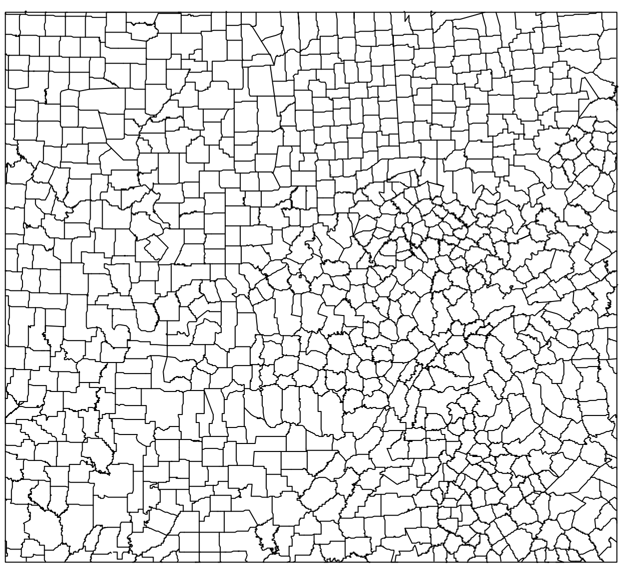


Figure 8. Dense linear pattern background. (Reduced 35%) (GeoCart: National Atlas Folder, 1994).

.

9. The ninth background consisted of a dense linear pattern (approximately the same geographic area as figure 8, but rotated to align the place names) with the addition of names identifying the counties (figure 9). State boundaries are included in this background. This background was chosen, because it was expected that the inclusion of type in the background would increase the complexity of the image. It was predicted it would be difficult to find the symbols on this background, thus lowering accuracy and increasing search time.

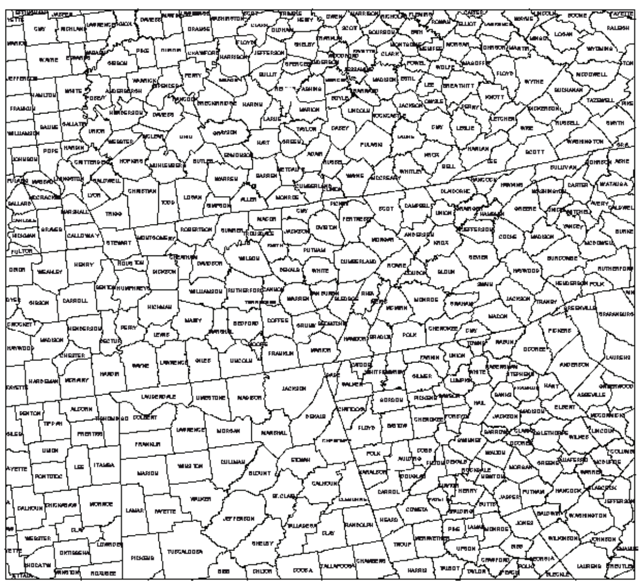


Figure 9. Dense linear pattern with type background. (Reduced 35%) (GeoCart: National Atlas Folder, 1994).

In summary, test backgrounds with varying kinds and amounts of textural noise and with various tones (or combinations of tones) ranging from white to dark gray were selected. It was expected that highly textured and darker backgrounds would interfere with visual search more than others, increasing the amount of search time and reducing accuracy.

Symbols

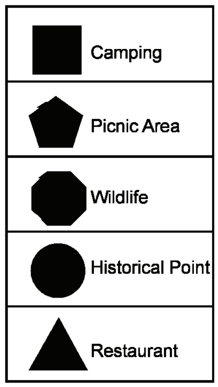
The symbols used on the test maps were also designed with expected test results in mind. The symbols selected included simple and complex versions of both pictorial and geometric point symbols. Twenty symbols suitable for representing tourist features were selected from fonts available in Microsoft Word and in the U. S National Park Service Pictographs Symbols (U.S. National Park Service).

The twenty symbols were divided into four groups of five symbols. Group one included five simple geometric symbols. Group two included five complex geometric symbols. Group three included five simple pictorial symbols. Group four included five complex pictorial symbols.

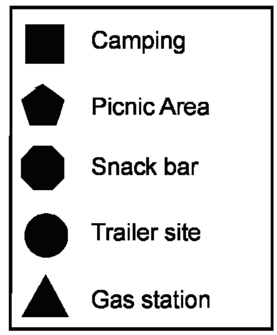
Pilot testing included selected symbols from all four groups of symbols. After analyzing these initial test results, it was decided that some symbols should be changed for the later tests with the aim of gaining more informative results. As a result of the changes, the final design of the study included five groups of symbols (simple geometric, “initial” complex geometric, “revised” complex geometric, “revised” simple pictorial, and “revised” complex pictorial).

Here follows a brief explanation of each group of symbols, describing the different symbols in each set and giving the reasons for choosing to test these symbols.

1. Simple geometric point symbols



Initial design



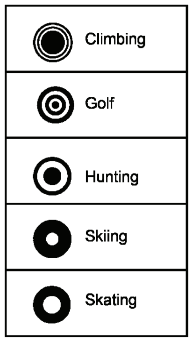
Revised design

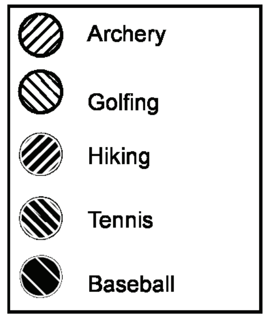
Figure 10. Initial and revised design of the simple geometric point symbols.

Several considerations led to the choice of the symbols for the simple geometric group. First these are indeed simple geometric shapes. Also, each of them is a distinctly different shape, although the circle and the octagon are more similar in shape than the other symbols. Because of their different shapes, scaling the symbols to the same size could not be done by simple measurement of width or area; instead, scaling them to approximately the same visual weight was done by eye. Each shape was assigned arbitrarily to represent a feature (figure 10). It was decided to avoid a possible association of the triangle with the shape of a tent by assigning the triangle, first to represent a restaurant and later a gas station. Because none of these symbols has an inherent meaning associated with the feature it represents, the map user has to look at the map legend to identify them.

The symbols were used at two different sizes, with the first (large) size used in the pilot test and 111 test 1. The sizes of the symbols were reduced and the feature designated, changed for all subsequent tests.

2. Complex geometric point symbols





Initial design **Revised design**

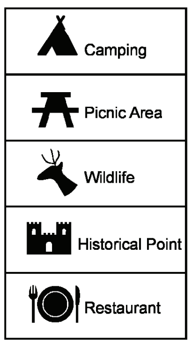
Figure 11. Initial and revised design of the complex geometric point symbols.

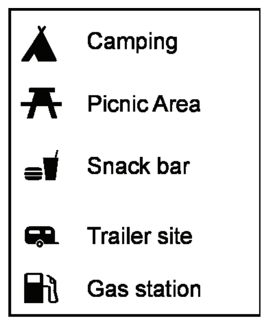
The initial design of the complex geometric point symbols was chosen for a number of reasons. First, these geometric symbols are more complex in shape than the simple geometric symbols. Also, each symbol is similar to the others; they share some characteristics of circular shape. Because they are geometric symbols, their shapes do not have a specific meaning that can be connected to the map's tourist features.

The initial design of each of the symbols had the spaces between the elements of the circles transparent, letting the background show through. After analyzing the early test results, it was decided to change the spaces between the circular elements to opaque white, so the black-and-white symbols would contrast more with the map background. Also, the size of the symbols was reduced.

In a later iteration, however, a new design was introduced to make the complex geometric point symbols more similar to one another (figure 11). They are all circular symbols of the same size, but they are filled with different linear patterns which differ in orientation. It was expected that the increased similarity and the necessity to differentiate the symbols according to two visual variables, line pattern type and orientation, would make the visual search task more difficult.

3. Simple pictorial point symbols





Initial design **Revised design**

Figure 12. Initial and revised design of the simple pictorial point symbols.

The simple pictorial symbols included in the pilot test and the GEOG 111 first test were later revised in size and in shape. Therefore three symbols (wildlife, historical point, and restaurant) were replaced with new symbols (snack bar, trailer site, and gas station). The symbols in the simple pictorial point symbols group were chosen, are simple in shape. Also, they look very different from each other. Since they are pictorial symbols, they are simplified representations of the way the features look in actuality. Such symbols are widely used in recreation area signage and should be familiar. Each of them has a specific meaning that can be related to its shape; they are associative. Also, like the simple geometric symbols, they have a solid black fill which gives them more visibility than outlined symbols would have. Their sizes have approximately the same visual weight.

a. Camping symbol

The realistic characteristics of the selected symbol are the shape of the teepee; there are two tent poles at the top of the teepee, and the little white triangle represents the doorway.

b. Picnic area symbol

This symbol was chosen from different kinds of picnic area symbols, because it shows only a picnic table (no chairs, trees, etc.). It is simple.

c. Snack bar symbol

This symbol for the snack bar was chosen, because its features clearly transmit the meaning of the symbol. The drink with a straw and the burger represent the food available at a snack bar.

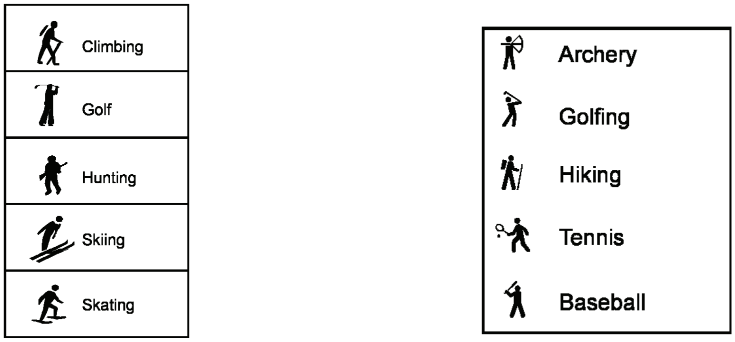
d. Trailer site symbol

This symbol for trailer site was chosen because the shape looks the same as a trailer site from the real world.

e. Gas Station

This gas station symbol was selected, because it is simple, yet clearly represents a gas pump with hose.

4. Complex pictorial point symbols



Initial design **Revised design**

Figure 13. Initial and revised design of the complex pictorial point symbols.

The symbols in the complex pictorial point symbols group were chosen for several reasons. One is that these pictorial symbols are more complex in their shape when compared to the simple pictorial point symbols. The complex pictorial point symbols look similar to one another, because they share some of their characteristics. Each of them shows a standing individual person in a position representative of the activity depicted. Each individual is using equipment associated with their activity. The archer holds a bow and arrow, the golfer a golf club, the hiker a backpack and staff, the tennis player a tennis racket and ball, and the baseball player a bat. These attributes are quite small, so discriminating among the complex pictorial symbols should be more subtle and difficult than for the simple pictorial symbols. Although all of the complex pictorial symbols have solid black fill, their complicated shapes are less compact and thus less densely black than the simple pictorial symbols.

The five symbols used for most of the testing replaced almost entirely an original set. Only the “climbing” symbol, redesigned as “hiking” was retained. Hunting, skiing and skating were replaced by archery, tennis and baseball, with appropriate symbols. A different golfing symbol was utilized.

Test backgrounds with varying kinds and amounts of textural noise and with various tones (or combinations of tones) ranging from white to dark gray were selected. It was expected that more highly textured and darker backgrounds would interfere with visual search more than others and that the test results would reflect this.

In summary, test symbols with differing shapes, either geometric or pictorial, were selected. The geometric symbols have arbitrarily assigned meanings, while the pictorial symbols are associative. The simple geometric and pictorial symbols were selected to be as different from one another in shape as possible, with the expectation that this would make them easy to discriminate. The complex geometric and pictorial symbols were selected to be similar to the other symbols in their group in terms of shape and other features, with the expectation that this would make them harder to discriminate.

Thus, both the background types and the kinds of symbols should affect searching for symbols. The subject has to pick out occurrences of a target symbol distributed across the map from among different kinds of symbols. The critical relationship between the background of the map and the symbols, as well as among the symbols, is expected to be the degree of contrast. When the characteristics of the background are similar to the characteristics of the symbol, the search should be harder. When the characteristics of the group of symbols being tested are similar, visual search should also be harder.

Method of Testing

a. Participants

The participants were students from the University of Kansas who were taking classes in geography, cartography, and related fields, ages 19-45, male and female. Participants were given credit in their courses for taking part in the experiment. All participants (male and female) had normal or corrected-to-normal vision.

b. Materials and Apparatus

Since time was the dependent variable in this study, a timer was used to enable the participants to self-monitor the time they spent in counting the target symbols. The timer that was used was available online at URL: http://www.online-stopwatch.com/full-screen-stopwatch/. A laptop computer and a big screen projector in the classroom were used to display the online watch, which displayed the time by hours, minutes, seconds, and milliseconds.

The test material included a packet of the map sheets. Each sheet in the packet included a variety of map backgrounds, symbol groups, and target symbols (figure 14). Each map sheet was different in its background, symbol group and target symbol from the preceding and following test sheet in the packet. Also, the test packets being used were assembled in different order using a random ration procedure and handed

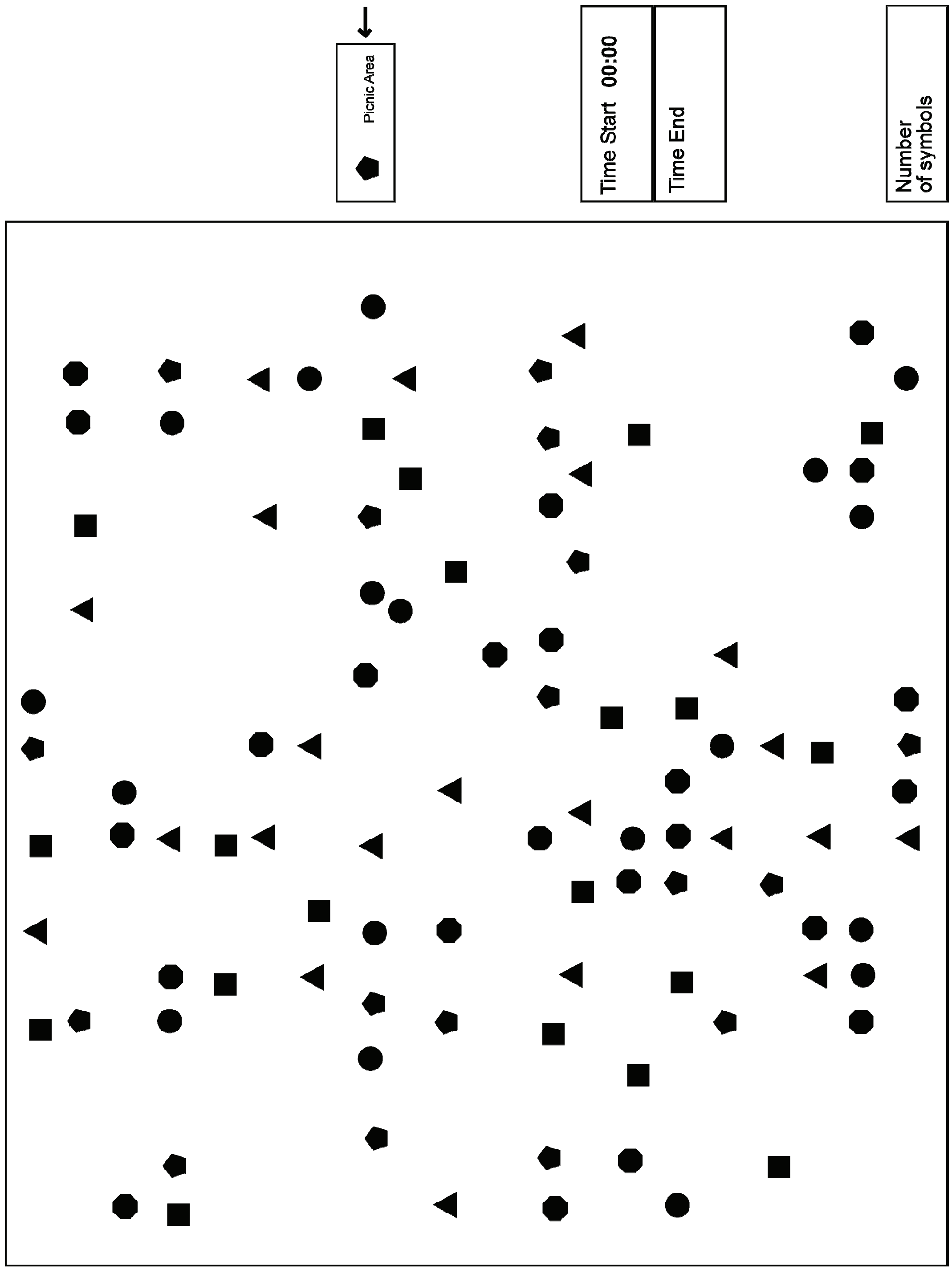


Figure 14. An example of a test sheet (Reduced 72%)

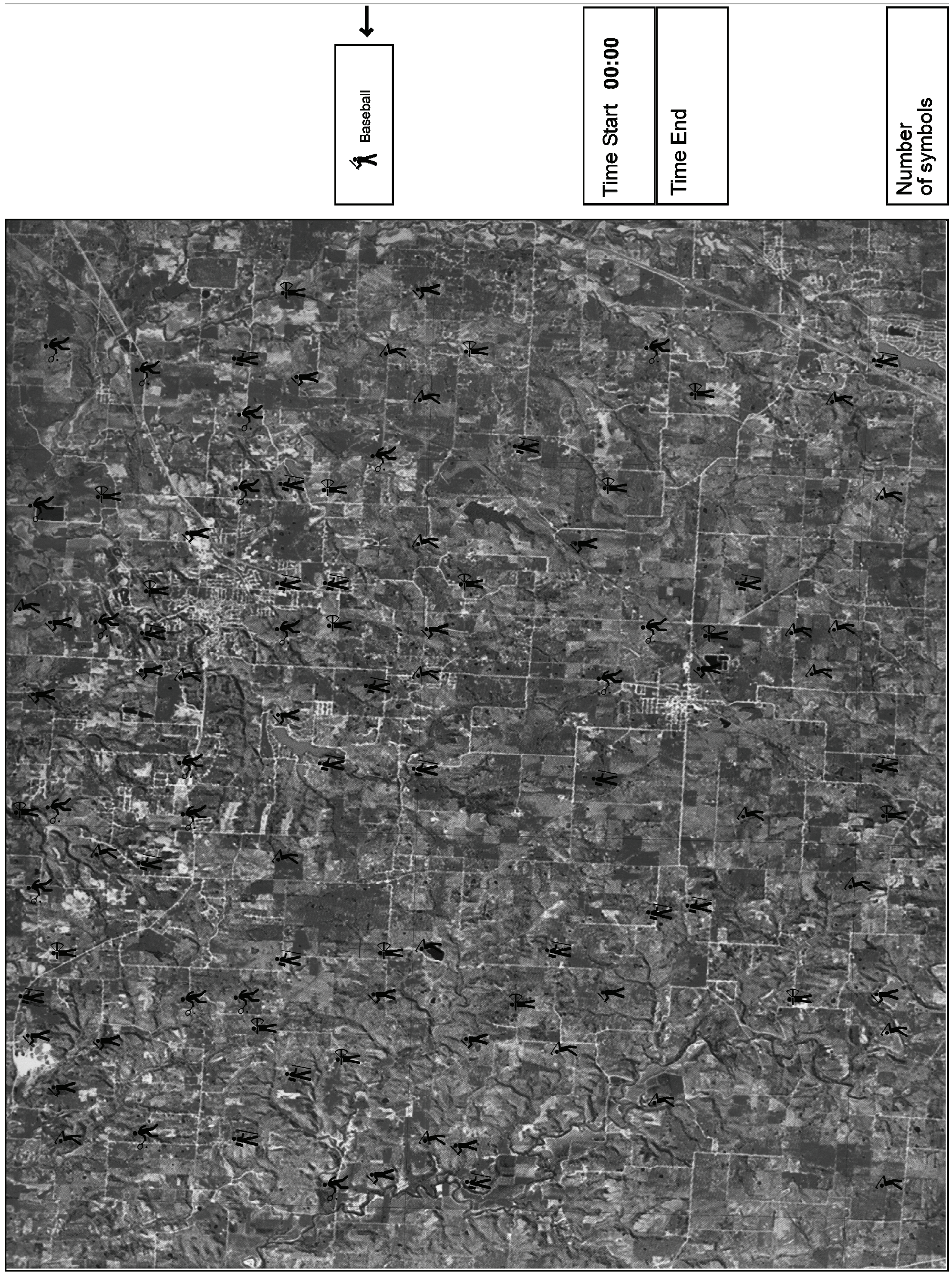


Figure 15. Another example of a test sheet (Reduced 72%)

out alternately, so neighboring students would not be doing the same test sheet at the same time.

c. Design

The test design included a mixture of two independent variables: different backgrounds and different symbol groups. The design of each map test sheet included a background and one group of symbols consisting of the five different symbols in that group. Each symbol group was displayed with 100 symbols that were randomly located at positions in a 20-by-20 matrix. Therefore, the distribution of each symbol group was different from the other groups. Additionally, the orientation of the distribution of each symbol group was different with each background (figure 14). Each map test sheet included a background with a target and distractors. In the earlier design of the map sheet the legend contained all five symbols, and the target symbol was indicated by an arrow. Also, the start time box, the end time box, and the number of symbols box were connected to each other. But from the pilot test and the first test results it seemed that the participants were confused about the target symbol, even though it was indicated by the arrow. Some of the participants counted another symbol, not the one indicated by the arrow; also they entered in the end-time box the number of the counted symbols, and they entered in the number-of-symbols box the end time. So a decision was made to revise the design of the legend for the next tests. The new design of map sheet had a legend that included just the target symbol and the designation of the feature it represented. Also, on each map sheet three blank boxes were placed under the legend for the subject to fill in. The first box was for recording the start time (minutes: seconds); the second box was for recording the end time; and the third box, which was separated from the two above, was for recording the number of symbols counted. The purpose of creating these boxes was to enable participants to record the total time they took in completing the search and to write down the number of target symbols that they found (figure 14).

d. Procedure:

At the start of the test, the researcher presented an oral explanation of directions to the subjects and pointed out the significance of the test and the importance of their participation. Also, the researcher explained the nature of the problem and gave them an idea of the test process by providing them with a warm up exercise. In the warm up exercise, the participating students were asked to find differences between three pairs of cartoon panels collected from *the Kansas City Star*, 2008, all displayed on background extracted from a cartoon made by Palnik, P., 1978, which also had the theme of search (figure 15).

After the warm up, the test packet was passed to the participants. In order to show the participants how to proceed with the test, the researcher put a practice test sheet in the front of the test packet. After starting and finishing the practice test, the students were permitted to ask the researcher questions, which the researcher answered.

Next they started the real test. When the researcher set the start time at 00.00 (minutes and seconds), the participants started the task of counting the occurrences of

Figure 15. The warm up exercise in finding the six differences among these cartoons.

the target symbol shown in the legend of the first test sheet as quickly and accurately as possible. As soon as any participant finished his or her count of the target symbol occurrences, then s/he looked at the timer to note the time when s/he finished, recording this time in the appropriate box on the test sheet before entering the number of target symbols that s/he found. Participants who finished their tasks earlier than others were not permitted to turn the next sheet until all the participants finished the same test sheet, at which time everyone received an order from the researcher to turn to the next sheet, and so on until they finished all the sheets.

Chapter Four

Preliminary Tests

Pilot Test [GEOG 210 and GEOG 311]

The purpose of doing the pilot test was to examine how the backgrounds and the symbol groups would perform as initially designed. There was also a need to know the time that the participants would need for taking the test. The pilot test involved GEOG 210 and GEOG 311, two classes studying cartography during the fall semester 2008. The total number of participants from these two courses was 25.

The pilot test had two main components. The first component was the map backgrounds on which the four different symbol groups were displayed. The following six backgrounds (BK) were tested: white (BK1), gray (BK2), regular linear (BK3), irregular linear (BK4), imagery (BK5), and shaded relief map (BK6) (figure 1).

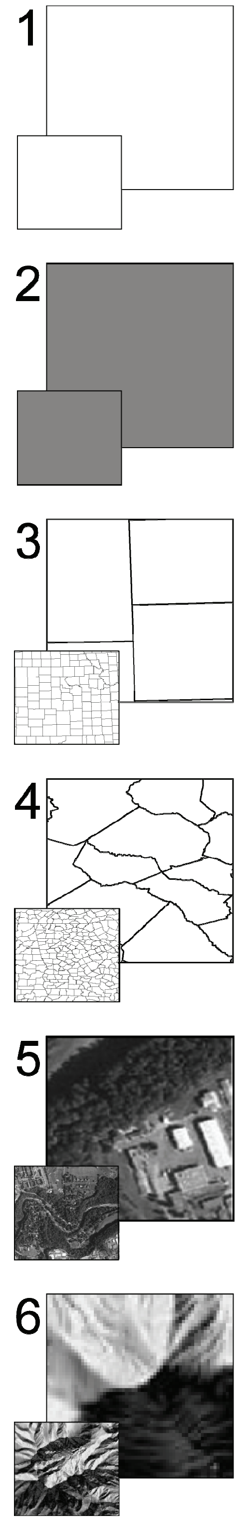


Figure 1. Backgrounds used in pilot test (lower left: reduced thumbnail image of entire background, upper right: original-size extract from background).

The second component was four symbol groups being tested with these six backgrounds: simple geometric(SG1), complex geometric (SG2), simple pictorial (SG3), and complex pictorial (SG4). Each group consisted of five different symbols, one or more of which were tested with each background. Time and accuracy were the response variables for each test.

The test results for the backgrounds led to the decision that the BK5 (imagery) was too large in scale with too detailed landscape features, and it was replaced with smaller-scale imagery. The BK6 (shaded relief) background proved to be too high in contrast, with primarily dark and light tones and with insufficient middle tones. It was replaced with a shaded relief image with a better range of tones. No changes were made to the symbol groups.

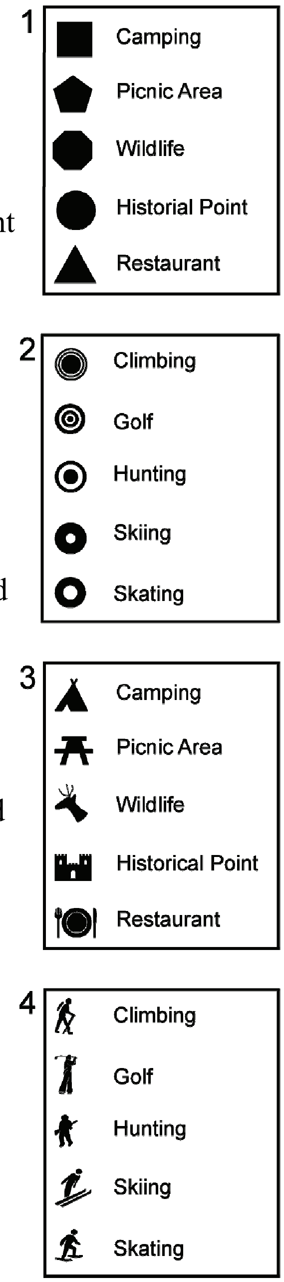


Figure 2. Symbols used in pilot test

GEOG 111: "Dress Rehearsal"

The results of the first of two tests carried out in GEOG 111 (an introductory course in map use) early in spring semester 2009 follow. This analysis begins with the five backgrounds (BK) tested with the four different symbol groups: white (BK1), regular linear (BK2), irregular linear (BK3), imagery (BK4), and shaded relief map (BK5). The analysis considers next the four symbol groups: simple geometric (SG1), complex geometric (SG2), simple pictorial (SG3), and complex pictorial (SG4). Each symbol group included five different symbols, one or more of which were tested with each background. Time and the accuracy were the response variables for each test.

Results of the Background Analysis

The background system was analyzed according to the two dependent variables, time and accuracy. Tables 1 and 2 list descriptive statistics for each variable: the total number of searches, the mean search times, and the standard deviations for each background type for time and accuracy.

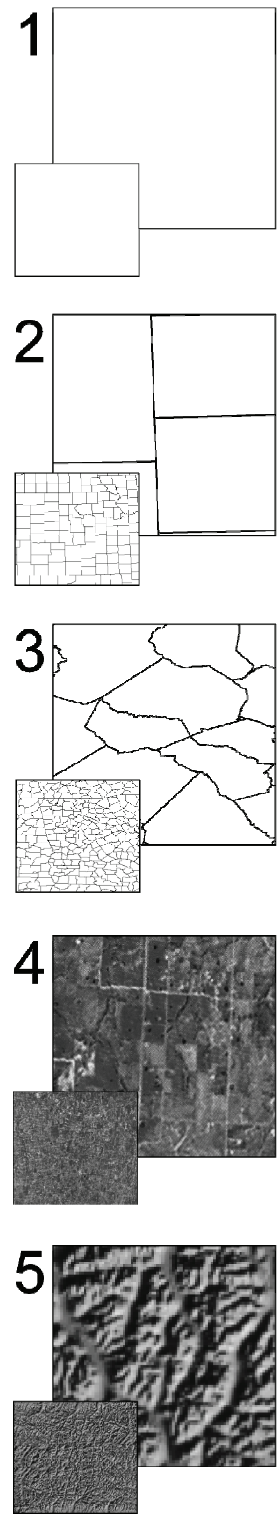


Figure 3. Backgrounds used in dress rehearsal (lower left: reduced thumbnail image of entire background, upper right: original-size extract from background).

Table 1. Descriptive Statistics for Search Time for the Five Different Backgrounds

Descriptives									
						95% Confidence Interval for Mean			
		N	Mean	Std. Deviation	Std. Error	Lower Bound	Upper Bound	Minimum	Maximum
Time	White BK1	228	18.86	6.411	0.425	18.03	19.7	8	45
	Regular linear BK2	71	22.35	6.723	0.798	20.76	23.94	10	40
	Irregular linear BK3	61	25.2	7.298	0.934	23.33	27.07	13	52
	Imagery BK4	95	19.8	5.89	0.604	18.6	21	8	37
	Shaded relief BK5	81	26.85	7.563	0.84	25.18	28.52	12	53
	Total	536	21.42	7.31	0.316	20.8	22.04	8	53

The mean search times for the five backgrounds varied from 18.86 to 26.85 seconds, and the standard deviations varied from 5.89 to 7.56. Analysis of Variance (ANOVA) and *t* tests for follow up analyses were used to determine significant differences between the combinations of backgrounds and symbol groups. Analysis of Variance shows that there are significant differences in the search times, F (4, 531) = 28.552, $p < .001$. Also, there are significant differences in the mean search accuracy among the backgrounds, F (4, 531) = 8.55, $p < .001$ (Table 3). The response time with BK1 (white) ($\bar{x}$ = 18.86, s = 6.41) and BK4 (imagery) ($\bar{x}$ = 19.80, s = 5.89) are significantly faster than that of the other backgrounds. The *t* tests showed there was

Table 2. Descriptive Statistics for Search Accuracy for the Five Different Backgrounds

Descriptives

		N	Mean	Std. Deviation	Std. Error	95% Confidence Interval for Mean Lower Bound	95% Confidence Interval for Mean Upper Bound	Minimum	Maximum
Percent Correct	White BK1	228	92.6%	9.34%	0.62%	91.43%	93.87%	47.00%	100%
	Regular linear BK2	71	93.1%	8.97%	1.06%	91.02%	95.26%	60.00%	100%
	Irregular linear BK3	61	89.2%	13.8%	1.78%	85.71%	92.81%	33.00%	100%
	Imagery BK4	95	93.7%	9.03%	0.93%	91.95%	95.63%	55.00%	100%
	Shaded relief BK5	81	85.1%	18.0%	2.01%	81.15%	89.15%	15.00%	100%
	Total	536	91.4%	11.8%	0.51%	90.39%	92.41%	15.00%	100%

Table 3. Significant Differences of Backgrounds

ANOVA

		Sum of Squares	df	Mean Square	F	Sig.
%Correct	Between Groups	4560.526	4	1140.131	8.553	.000
	Within Groups	70786.034	531	133.307		
	Total	75346.560	535			
Time	Between Groups	5060.507	4	1265.127	28.552	.000
	Within Groups	23528.044	531	44.309		
	Total	28588.550	535			

significantly faster search times for BK1 and BK4 than the other backgrounds (Table 4). Additionally, these show that the response times for BK3 (irregular linear) ($\bar{x}$ = 25.20, s = 7.29) and BK5 (shaded relief) ($\bar{x}$ = 26.85, s =7.56) were significantly slower than with the other backgrounds. The t tests also showed that there was no significant difference between BK3 and BK5 (p = .192). Further, participants had significantly slower search times for BK3 and BK5 than the other backgrounds, t (140) = 1.31, p < .010 (Table 4).

Table 4. *t* Tests for Equality of Means (Time) among Backgrounds

Independent Samples Test							
t-test for Equality of Means (Time)							
Backgrounds	t	df	Sig. (2-tailed)	Mean Difference	Std. Error Difference	95% Confidence Interval of the Difference	
						Lower	Upper
BK1 * BK4	-1.224	321	0.222	-0.936	0.765	-2.441	0.569
BK1 * BK2	-3.957	297	0	-3.488	0.882	-5.223	-1.753
BK1 * BK3	-6.65	287	0	-6.333	0.952	-8.207	-4.458
BK1 * BK5	-9.175	307	0	-7.988	0.871	-9.701	-6.275
BK4 * BK2	2.599	164	0.01	2.552	0.982	0.613	4.491
BK4 * BK3	-5.08	154	0	-5.397	1.062	-7.495	-3.298
BK4 * BK5	-6.948	174	0	-7.052	1.015	-9.055	-5.049
BK2 * BK3	-2.33	130	0.021	-2.845	1.221	-5.26	-0.429
BK2 * BK5	-3.853	150	0	-4.5	1.168	-6.807	-2.192
BK3* BK5	-1.31	140	0.192	-1.655	1.263	-4.152	0.842

Table 2 shows that the mean search accuracy (percentage) for the individual backgrounds varied from 85.1 to 93.7, and the standard deviations varied from 8.97 to 18.08. Analysis of Variance indicates that there were also differences between the backgrounds in search accuracy (p <0.001) (Table 3). The t tests of the mean search accuracy for each of the background types indicate that there were no significant differences among BK1 (white) ($\bar{x}$ = 92.6, s = 9.3) and BK2 (regular linear) ($\bar{x}$ = 93.1, s = 8.9), and BK4 (imagery) ($\bar{x}$ = 93.7, s =9.0). Participants

Table 5. *t* Tests for Equality of Means (Accuracy) among Backgrounds

Independent Samples Test							
t-test for Equallity of Means (Accuracy)							
Backgrounds	t	df	Sig. (2-tailed)	Mean Difference	Std. Error Difference	95% Confidence Interval of the Difference	
						Lower	Upper
BK1 * BK4	-1.006	321	0.315	-1.14%	1.13%	-3.36%	1.09%
BK1 * BK2	-0.387	297	0.699	-0.49%	1.26%	-2.96%	1.99%
BK1 * BK3	2.251	287	0.025	3.39%	1.51%	0.43%	6.36%
BK1 * BK5	4.742	307	0	7.51%	1.58%	4.39%	10.62%
BK4 * BK2	-0.459	164	0.647	-0.65%	1.41%	-3.44%	2.14%
BK4 * BK3	2.472	154	0.015	4.53%	1.83%	0.91%	8.15%
BK4 * BK5	4.099	174	0	8.64%	2.11%	4.48%	12.80%
BK2 * BK3	1.933	130	0.055	3.88%	2.01%	-0.09%	7.85%
BK2 * BK5	3.377	150	0.001	7.99%	2.37%	3.32%	12.67%
BK3* BK5	1.479	140	0.141	4.11%	2.78%	-1.38%	9.61%

searching these backgrounds had higher accuracy than with other backgrounds (Table 5). Additionally, BK3 (irregular linear) ($\bar{x}$ = 89.2, s = 13.8) and BK5 ($\bar{x}$ = 85.1, s = 18.08) resulted in significantly less accurate searches than with the other backgrounds. There was no significant difference between BK3 (irregular linear) and BK5 (shaded relief) (p = .141); participants had significantly slower search times with BK3 and BK5 (shaded relief) than with the other backgrounds (Table 5).

Summarizing the Results of the Background Analysis

It would appear from these analyses that BK1 (white) and BK4 (imagery) performed best for the search task, both in terms of search time and accuracy. The fastest search time for BK1 was expected, since the background is white and provides no noise to affect the visual search process. White also provides maximum contrast with the black symbols. It was expected that testing the symbol groups with this background would reflect the actual differences between the symbol groups and between the individual symbols. However, it was not expected that BK4 would perform similarly: the two backgrounds seem very different. This first test suggests that BK4 resembled BK1 in unexpected ways that caused the results to be similar to the results for BK1. For example, the scale of the imagery for the Kansas City, Missouri-Kansas area. This scale (1:100, 000) is small enough to avoid showing the landscape features of the area "obviously." Also there was an effect of uniform texture, without big differences in landforms, over the entire area of the imagery, so it looked like a rather uniform gray background. There was a similar range of gray tones over all of the imagery. There were no black or white areas except the light roads on the imagery, which divided it into the sections and could thus have aided systematic, area-by-area counting.

The similarity in results between BK1 and BK4 indicated the need for some revision of the test. One solution was to make the imagery larger than 1:100,000, perhaps 1:24,000, or 1:25,000, or 1:50,000, so the background would be more varied. Also, changing the scale would enlarge landscape features large enough to affect visual search. In addition, the light roads mentioned before would no longer be in the imagery. It was expected that replacing the imagery background in the next test with different imagery would take these factors into account and would generate different results.

The results for search accuracy were highest for BK4, BK2, and BK1. The resemblance between BK1 and BK4, which both produced similar results in search time, as well as accuracy, have already been discussed. Recall that, in the Pilot Test, a plain gray background (BK2) was used; it was discarded from subsequent testing because the basic results from the searches on the gray background were almost exactly the same as those on the white background. A new BK2, since it included (as noise) only a widely spaced, low density regular linear pattern (county boundaries), appears to have helped the test subjects in their counting task, because the linear network divided the area, and apparently aided the organization of the search process.

The results showed that BK3 and BK5 were the slowest in mean search time and accuracy. The result with respect BK5 was expected because of the complex characteristics of the shaded relief background, but the lack of significant difference between BK3 and BK5 was unexpected. The question has to be asked: what makes BK3 and BK5 perform similarly in both search time and accuracy? BK3 obviously looked different from BK5. However, a review of the symbols that were tested with BK3 and BK5 found that there were no matches between the symbols that were tested with these backgrounds. The particular symbols tested with these backgrounds in the next test, given a more thorough and balanced examination, might generate different results. It would be important to test the same symbols with these backgrounds, so there would be a chance to compare the search directly.

In summary, the following changes were applied to the design of the next test:

1. Exchanging BK4 with new imagery showing more variation in landscape features.
2. Enlarging the scale of BK4 to 1:24,000, or 1:25,000, or 1:50,000.
3. Creating a new background, with a dense linear pattern, to complement the existing regular and irregular linear backgrounds. This could be done by reducing the scale of the county base map to produce a denser linear pattern containing areas of both regularity (rectangularity) and irregularity.

Results of the Symbol Analysis

The symbol system was analyzed using the two dependent variables: time and accuracy. Tables 6 and 7 show the number of searches, the mean search times, and the standard deviations for both time and accuracy for each symbol group. As noted, participants were using four different symbol groups. Analysis of Variance shows that there are significant differences in the mean search times for the backgrounds, F $(3, 532) = 41.108$, $p < .001$. Further, there are significant differences in search accuracy among the backgrounds, $F\ (3, 532) = 10.991$, $p < .001$ (Table 8). The mean search times for individual symbol groups vary from 17.80 to 26.40 seconds, and the standard deviations from 5.485 to 8.351 (Table 6). The response time for SG3 (simple pictorial) ($\bar{x} = 17.80$, $s = 5.485$) was significantly faster than for the other three symbol groups. The t tests showed participants had a significantly faster search time for SG3 than the other symbol groups. Additionally, response time of SG4 ($\bar{x} = 26.40$, $s = 8.351$) was

Table 6. Descriptive Statistics for Search Time of the Four Different Symbol Groups

Descriptives									
						95% Confidence Interval for Mean			
		N	Mean	Std. Deviation	Std. Error	Lower Bound	Upper Bound	Minimum	Maximum
Time	Simple geometric SG 1	128	22.01	5.964	0.527	20.96	23.05	11	38
	Complex geometric SG 2	142	19.87	6.343	0.532	18.81	20.92	8	38
	Simple pictorial SG 3	137	17.8	5.485	0.469	16.87	18.72	8	33
	Complex pictorial SG 4	129	26.4	8.351	0.735	24.94	27.85	9	53
	Total	536	21.42	7.31	0.316	20.8	22.04	8	53

Table 7. Descriptive Statistics for Search Accuracy of the Four Different Symbol Groups

Descriptives

		N	Mean	Std. Deviation	Std. Error	95% Confidence Interval for Mean		Minimum	Maximum
						Lower Bound	Upper Bound		
Percent Correct	Simple geometric SG 1	128	93.12%	7.91%	0.70%	91%	94%	62%	100%
	Complex geometric SG 2	142	92.61%	12.11%	1.02%	90%	94%	15%	100%
	Simple pictorial SG 3	137	93.31%	8.83%	0.75%	91%	94%	56%	100%
	Complex pictorial SG 4	129	86.33%	15.74%	1.39%	83%	89%	26%	100%
	Total	536	91.40%	11.87%	0.51%	90%	92%	15%	100%

Table 8. Significant Differences of Symbol Groups

ANOVA

		Sum of Squares	df	Mean Square	F	Sig.
Time	Between Groups	5379.986	3	1793.329	41.108	.000
	Within Groups	23208.565	532	43.625		
	Total	28588.550	535			
Percent Correct	Between Groups	4397.232	3	1465.744	10.991	.000
	Within Groups	70949.328	532	133.363		
	Total	75346.560	535			

significantly slower than the other backgrounds, and the *t* tests showed that the participants had a significantly slower search time for SG4 than the other symbol groups (Table 9).

The means of search accuracy for individual symbol groups varied from 86.30 percent to 93.31 percent, and the standard deviations varied from 7.90 to 15.74 (Table 7). However, *t*-tests showed that there were no significant differences between SG1, SG2 and SG3 in search accuracy; further, SG1 ($\bar{x}$ = 93.12, s = 7.91), SG2 ($\bar{x}$ = 92.61, s = 12.11), and SG3 ($\bar{x}$ = 93.31, s = 8.83) were found to be significantly more accurate than the other symbol groups. Additionally, SG4 ($\bar{x}$ = 86.33, s = 15.74) was found significantly less accurate than the other symbol groups (Table 10).

Table 9. *t*-Tests for Equality of Means (Time) among Symbol Groups

Independent Samples Test							
t-test for Equallity of Means (Time)							
Symbol Group	t	df	Sig. (2-tailed)	Mean Difference	Std. Error Difference	95% Confidence Interval of the Difference	
						Lower	Upper
SG3 * SG2	2.912	277	0.004	2.071	0.711	0.671	3.47
SG3 * SG1	5.989	263	0	4.212	0.703	2.827	5.597
SG3 * SG4	9.982	264	0	8.6	0.862	6.903	10.296
SG2 * SG1	-2.85	268	0.005	-2.142	0.752	-3.621	-0.662
SG2 * SG4	-7.287	269	0	-6.529	0.896	-8.293	-4.765
SG1 * SG4	-4.844	255	.000	-4.388	.906	-6.171	-2.604

Summarizing the Results of the Symbol Analysis

It would appear from the analyses that SG3 performed best for the search task, both in terms of search time and accuracy. The fastest search time was expected to be for symbols in SG3 since the symbols in the group are simple in design; also, each differs from the others in the set. These characteristics enable them to be easy to search for, and produce fastest search times.

The highest search accuracy was found with SG3, SG1, and SG2. The simplicity of SG3's characteristics has been mentioned already. The high degree of accuracy for SG1 could also have been because each symbol was simple in its characteristics. The high degree of accuracy in searches involving SG2 probably resulted because SG2 was tested with backgrounds BK1 and BK4, which were the fastest in search time.

However, the results showed SG4 to be the slowest symbol group in both search time and accuracy, a result that was expected because of the complexity of the symbols in the group. Additionally, all of the symbols looked similar to each other, making them difficult to differentiate.

The results encouraged the following design changes for the next test:

1. Creating a new design for SG2 to make the symbols harder to differentiate.
2. Replacing all five symbols in SG4 to be certain that they were all at the same design and level of complexity.
3. Reducing the sizes of the symbols in all symbol groups to make them more typical of actual tourist maps.

Chapter Five

GEOG 104: Day One

While means and standard deviations are important indicators of task performance, they do not specify the significance of individual factors. So, to gain more information from the data and to test the hypotheses, Analysis of Variance (ANOVA) and *t* tests for follow-up analyses were used to ascertain significant differences between the combinations of the backgrounds and the symbol groups. According to the

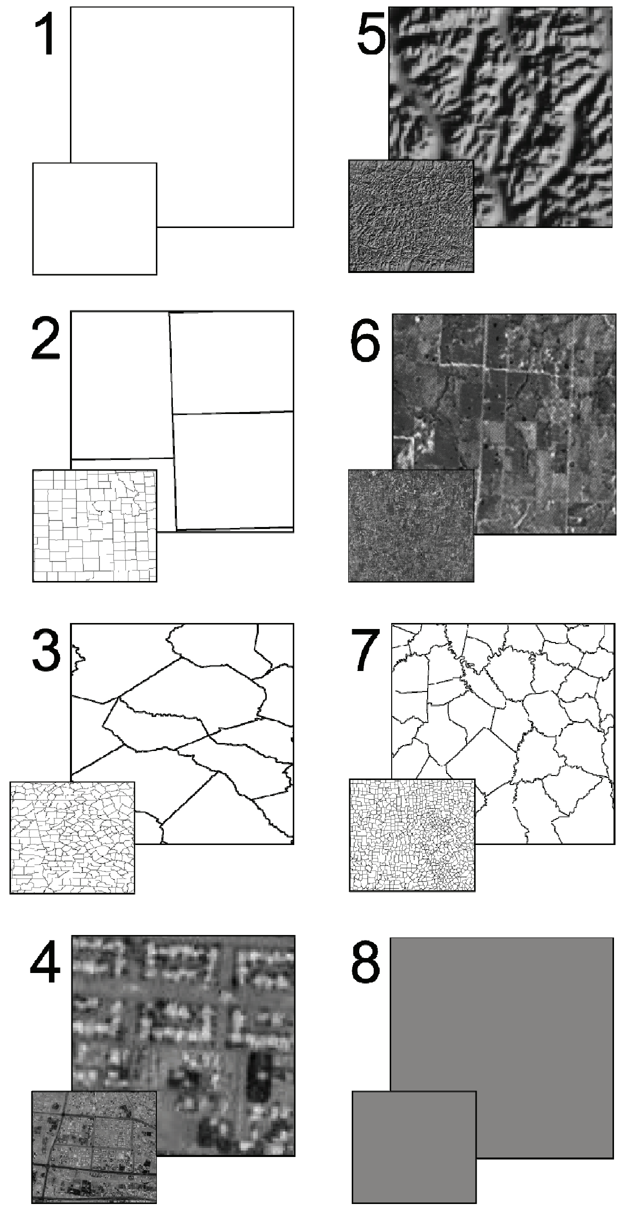


Figure 1. Backgrounds used on day one with GEOG 104 (lower left: reduced thumbnail image of entire background, upper right: original-size extract from background).

results gained from the tests in GEOG 111, some changes and additions to the GEOG 104 test design were necessary in order to avoid the problems encountered in GEOG 111.

Besides the five backgrounds that were tested in GEOG 111, there were three background changes: different imagery (BK4), a dense linear pattern (BK7), and the gray background (BK8). Five symbol groups were tested; simple geometric symbol group (SG1), initial complex geometric symbol group (SG2), simple pictorial symbol group (SG3), complex pictorial symbol group (SG4), and a revised complex geometric symbol group (SG5). Further, the 104 test utilized small symbols in addition to the large symbols tested in GEOG 111.

The analysis of the GEOG 104 test results was divided into three parts: the first part to analyze the small size of the four different symbol groups (SG1, SG2, SG3, and SG4), the second part to analyze the large size of the four different symbol groups (SG1, SG2, SG3, and SG4), and, at the end of these two analyses, there was a

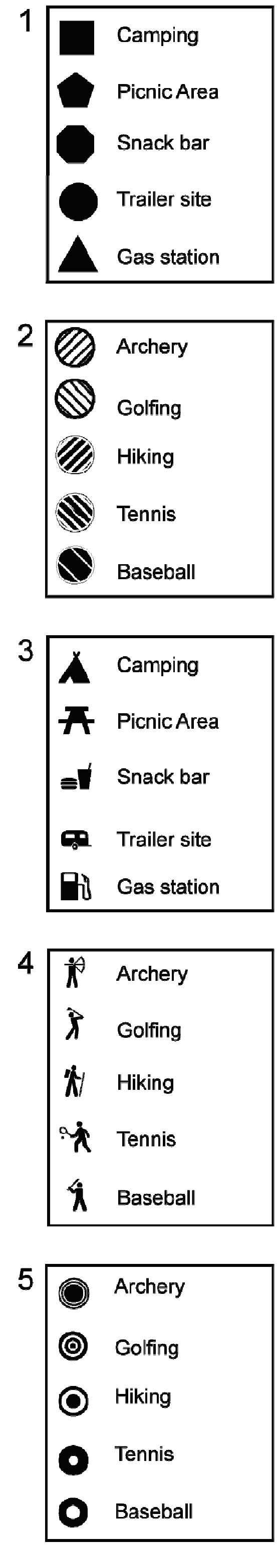


Figure 2. Symbols used on day one with GEOG 104.

comparison in the task performance between the two sizes, an analysis of SG5, and a comparison of the results of SG2 and SG5.

Analysis 1: Small-Sized Symbols against Various Backgrounds

This analysis consisted of two sections. The first section was the analysis of results for backgrounds tested with the four different symbol groups. The following eight backgrounds (BK) were tested: white (BK1), regular linear (BK2), irregular linear (BK3), revised imagery (BK4), shaded relief (BK5), initial imagery (BK6), dense linear (BK7), and the gray background (BK8). The second part of the analysis was of the results for each symbol group tested with the eight different types of backgrounds. Four symbol groups were tested with these eight backgrounds: simple geometric (SG1), complex geometric (SG2), simple pictorial (SG3) and complex pictorial (SG4). Each group consisted of five different symbols, one or more of each group having been tested with each background. Time and the accuracy were the response variables for each test.

The Background Analysis

The backgrounds were analyzed according to the two dependent variables: time and accuracy. Descriptive statistics for each variable are listed in Tables 1 and 2. These show the total number of the searches, the mean search times, and the standard deviations for each background type for time and accuracy.

Table 1. Descriptive Statistics of Search Time for the Eight Different Backgrounds

Descriptive									
						95% Confidence Interval for Mean			
Time		N	Mean	Std. Dev.	Std. Error	Lower Bound	Upper Bound	Minimum	Maximum
	White	483	26.68	11.24	0.511	25.68	27.69	6	74
	Regular Linear	487	28.67	11.588	0.525	27.64	29.71	6	80
	Irregular Linear	535	29.76	10.23	0.442	28.89	30.63	8	79
	New Imagery	511	29.92	10.18	0.451	29.04	30.81	7	80
	Shaded Relief	513	36.2	13.11	0.579	35.06	37.33	9	76
	Old Imagery	535	30.93	12.13	0.525	29.89	31.96	5	68
	Dense Linear	512	28.32	10.16	0.447	27.44	29.2	7	60
	Gray	392	31.05	12.51	0.632	29.81	32.29	8	95
	Total	3968	30.2	11.70	0.186	29.84	30.57	5	95

The mean search times for the different backgrounds varied from 26.68 to 36.20 seconds, and the standard deviations varied from 10.11 to 13.11. Analysis of Variance showed significant differences in mean search times among the backgrounds, F (7, 3960) = 30.828, $p < .001$. Also, there were significant differences in mean search accuracy among the backgrounds, F (7, 3960) =18.562, $p < .001$ (Table 3).

Table 2. Descriptive Statistics of Search Accuracy for the Eight Different Backgrounds

Descriptive									
						95% Confidence Interval for Mean			
		N	Mean	Std. Deviation	Std. Error	Lower Bound	Upper Bound	Minimum	Maximum
Percent Correct	White	483	90.499	16.375	0.7451	89.035	91.963	0	100
	Regular Linear	487	89.345	14.7897	0.6702	88.028	90.662	5	100
	Irregular Linear	535	88.888	14.6869	0.635	87.641	90.136	0	100
	New Imagery	511	85.709	17.829	0.7887	84.159	87.258	0	100
	Shaded Relief	513	82.425	19.7742	0.8731	80.709	84.14	0	100
	Old Imagery	535	85.149	17.489	0.7561	83.664	86.634	0	100
	Dense Linear	512	88.456	15.7834	0.6975	87.085	89.826	4.3	100
	Gray	392	80.837	21.8537	1.1038	78.667	83.007	0	100
	Total	3968	86.54	17.6047	0.2795	85.992	87.088	0	100

Table 3. Table of the Significant Differences of Backgrounds

ANOVA						
		Sum of Squares	df	Mean Square	F	Sig.
Percent Correct	Between Groups	39059.41	7	5579.915	18.562	.000
	Within Groups	1190420	3960	300.611		
	Total	1229479	3967			
Time	Between Groups	28072.85	7	4010.407	30.828	.000
	Within Groups	515149.2	3960	130.088		
	Total	543222.1	3967			

The response time with BK1 (White) ($\bar{x}$ = 26.68, s = 11.24) is significantly faster than the other backgrounds. A group of t tests showed significant differences between BK1 and the other backgrounds (Table 4). Additionally, the response times with BK5 (shaded relief) ($\bar{x}$ = 36.20, s = 13.11) are significantly slower than the other backgrounds (Table 1).

Table 2 shows that the search accuracy for the different backgrounds varied from 80.83 to 90.49, and the standard deviations from 14.68 to 21.58. Analysis of Variance showed differences between the backgrounds in search accuracy ($p < .001$) (Table 3). The t tests for mean search accuracy for the background types showed no significant differences between BK1 ($\bar{x}$ = 90.49, s = 16.37), BK2 ($\bar{x}$ = 89.34, s = 14.78), BK3 ($\bar{x}$ = 88.88, s = 14.68), and BK7 ($\bar{x}$ = 88.45, s =15.78). These

Table 4. *t* Tests for Equality of Means (Time) among Backgrounds

Independent Samples Test							
t-test for Equality of Means (Time)							
Backgrounds	t	df	Sig. (2-tailed)	Mean Difference	Std. Error Difference	95% Confidence Interval of the Difference	
						Lower	Upper
BK1 * BK7	-2.417	993	0.016	-1.637	0.677	-2.966	-0.308
BK1 * BK2	-2.715	968	0.007	-1.99	0.733	-3.429	-0.552
BK1 * BK3	-4.57	1016	0	-3.076	0.673	-4.396	-1.755
BK1 * BK4	-4.767	992	0	-3.24	0.68	-4.574	-1.907
BK1 * BK6	-5.766	1016	0	-4.242	0.736	-5.686	-2.798
BK1 * BK8	-5.429	873	0	-4.365	0.804	-5.943	-2.787
BK1 * BK5	-12.26	994	0	-9.514	0.776	-11.036	-7.991
BK7 * BK2	-0.514	997	0.607	-0.353	0.687	-1.702	0.996
BK7 * BK3	-2.287	1045	0.022	-1.439	0.629	-2.673	-0.204
BK7 * BK4	-2.526	1021	0.012	-1.603	0.635	-2.849	-0.358
BK7 * BK6	-3.764	1045	0	-2.605	0.692	-3.963	-1.247
BK7 * BK8	-3.624	902	0	-2.728	0.753	-4.206	-1.251
BK7 * BK5	-10.767	1023	0	-7.877	0.732	-9.312	-6.441
BK2 * BK3	-1.59	1020	0.112	-1.085	0.683	-2.425	0.254
BK2 * BK4	-1.812	996	0.07	-1.25	0.69	-2.604	0.103

Table 4 (continued). *t* Tests for Equality of Means (Time) among Backgrounds

Independent Samples Test							
t-test for Equality of Means (Time)							
Backgrounds	t	df	Sig. (2-tailed)	Mean Difference	Std. Error Difference	95% Confidence Interval of the Difference	
						Lower	Upper
BK2 * BK6	-3.02	1020	0.003	-2.252	0.744	-3.71	-0.792
BK2 * BK8	-2.91	877	0.004	-2.375	0.815	-3.97	-0.776
BK2 * BK5	-9.59	998	0	-7.523	0.784	-9.06	-5.985
BK3 * BK4	-0.26	1044	0.794	-0.165	0.631	-1.40	1.074
BK3 * BK6	-1.69	1068	0.09	-1.166	0.686	-2.51	0.18
BK3 * BK8	-1.72	925	0.085	-1.29	0.748	-2.75	0.179
BK3 * BK5	-8.88	1046	0	-6.438	0.725	-7.86	-5.016
BK4 * BK6	-1.44	1044	0.15	-1.002	0.694	-2.36	0.361
BK4 * BK8	-1.48	901	0.137	-1.125	0.756	-2.60	0.358
BK4 * BK5	-8.54	1022	0	-6.273	0.734	-7.71	-4.833
BK6 * BK8	-0.15	925	0.88	-0.123	0.818	-1.72	1.481
BK6 * BK5	-6.75	1046	0	-5.272	0.78	-6.802	-3.741
BK8 * BK5	-5.97	903	0	-5.148	0.862	-6.841	-3.456

backgrounds had higher accuracy levels than the other backgrounds (Table 5). Additionally, BK8 ($\bar{x}$ = 80.83, s = 21.85) and BK5 ($\bar{x}$ = 82.42, s = 19.77) yielded significantly less accurate searches.

Table 5. *t* Tests for Equality of Means (Accuracy) among Backgrounds

Independent Samples Test							
t-test for Equality of Means (Accuracy)							
Backgrounds	t	df	Sig. (2-tailed)	Mean Difference	Std. Error Difference	95% Confidence Interval of the Difference	
						Lower	Upper
BK1 * BK7	2.004	993	0.045	2.0434	1.0195	0.0427	4.0441
BK1 * BK3	1.655	1016	0.098	1.6108	0.9735	-0.2996	3.5211
BK1 * BK4	4.405	992	0	4.7904	1.0876	2.6562	6.9247
	5.023	1016	0	5.3501	1.0651	3.2601	7.4402
BK1 * BK8	7.471	873	0	9.6624	1.2933	7.124	12.2008
BK1 * BK5	6.995	994	0	8.0745	1.1542	5.8094	10.3395
BK7 * BK3	-0.459	1045	0.646	-0.4326	0.9418	-2.2806	1.4154
BK7 * BK4	2.609	1021	0.009	2.747	1.0528	0.6812	4.8129
BK7 * BK6	3.207	1045	0.001	3.3068	1.031	1.2836	5.3299
BK7 * BK8	6.084	902	0	7.619	1.2522	5.1614	10.0767
BK7 * BK5	5.396	1023	0	6.0311	1.1177	3.8378	8.2244

Table 5 (continued). *t* Tests for Equality of Means (Accuracy) among Backgrounds

Independent Samples Test							
t-test for Equality of Means (Accuracy)							
Backgrounds	t	df	Sig. (2-tailed)	Mean Difference	Std. Error Difference	95% Confidence Interval of the Difference	
						Lower	Upper
BK2 * BK4	3.498	996	0	3.6363	1.0396	1.5963	5.6764
BK2 * BK6	4.121	1020	0	4.1961	1.0183	2.1979	6.1943
BK2 * BK8	6.86	877	0	8.5083	1.2404	6.0739	10.9428
BK2 * BK5	6.242	998	0	6.9204	1.1087	4.7446	9.0961
BK3 * BK4	3.154	1044	0.002	3.1797	1.0081	1.2015	5.1578
BK3 * BK6	3.787	1068	0	3.7394	0.9874	1.802	5.6768
BK3 * BK8	6.703	925	0	8.0516	1.2011	5.6943	10.4089
BK3 * BK5	6.024	1046	0	6.4637	1.073	4.3582	8.5692
BK4 * BK6	0.513	1044	0.608	0.5597	1.0921	-1.583	2.7027
BK4 * BK8	3.688	901	0	4.872	1.3211	2.2791	7.4648
BK4 * BK5	2.791	1022	0.005	3.284	1.1768	0.9748	5.5932
BK6 * BK8	3.334	925	0.001	4.3122	1.2934	1.774	6.8505
BK6 * BK5	2.365	1046	0.018	2.7243	1.152	0.4638	4.9848
BK8 * BK5	-1.14	903	0.253	-1.5879	1.3887	-4.313	1.1375

The Background Analysis

From the analyses, it is clear that BK1 performed best for the search task, both in terms of search time and accuracy. The fast search times with BK1 were expected, since the background is white. Therefore, testing the symbol groups with this background should reveal the difference between the symbol groups and even between each symbol. The results in search time and accuracy confirm that most of the four symbol groups were found faster and more accurately on BK1 than on the other backgrounds (Table 6).

Also, the results showed that the highest search accuracy is found with BK1, BK2, BK3, and BK7. The results of the several *t* tests indicate no significant difference between BK1, BK2, BK3, and BK7; all of them produced nearly the same results in accuracy. The *t* tests indicate no significant difference between BK2 and BK3 in terms of search time, and no significant difference between BK2 and BK7 in terms of search time. So, these results suggest that these backgrounds produce the same results in terms of search accuracy. The results in mean search accuracy indicate that most of the four symbol groups are found more accurately when placed on BK1, BK2, BK3, and BK7 compared to the other backgrounds (Table 7).

The reason that BK1 was found most accurately and quickly is that it is white and produces no "noise" that has an impact on the search process. The regular linear pattern that divides BK2 into areas probably guides the searcher in finding the targets, thus achieving high accuracy. Similarly, the high degree of accuracy in searches on

BK3 (irregular linear) and the similarity in results between BK3 and BK2 (regular linear) in search time and accuracy may be a result of the patterns of lines, which divide the background into areas and, consequently, helped participants in the counting of the target symbols.

Although the analysis shows no significant difference between BK7 and BK1 or between BK2 and BK3, this result was surprising. While BK2, BK3, and BK7 all have linear patterns, these patterns are different; for example, the size of the regular linear pattern in BK2 is large, while the linear pattern in BK7 is dense and mixes regular and irregular linear patterns, and its size is very small compared to BK2 and BK3. The similarity in results between BK1, BK2, BK3, and BK7 prompted some revision of the test. One alteration was to create a new dense linear pattern background including type (i. e., county names), so this background would appear different from BK1, BK2 and BK3. Adding the new dense linear pattern with type background in the next test was expected to generate different results.

The results indicated that BK8 and BK5 were the slowest in mean search time and accuracy. This result for BK5 was expected because of the complex characteristics of this background, and the same was expected with BK8, since it has a gray tone that reduces contrast between the symbols and the background. Notably, results in mean search time and accuracy showed that most of the four symbol groups were slower and less accurate with BK8 and BK5 (Tables 6 and 7).

Table 6. Time of the Different Backgrounds and Symbol Groups

Time * Background * Symbol Group				
Time				
Background	Symbol Group	Mean	N	Std. Deviation
White	Simple Geometric	23.76	109	7.489
	Complex Geometric	29.38	133	12.32
	Simple Pictorial	21.5	133	8.166
	Complex Pictorial	32.7	108	12.462
Regular Linear	Simple Geometric	25.58	133	8.332
	Complex Geometric	33.24	110	13.415
	Simple Pictorial	22.15	134	8.197
	Complex Pictorial	35.8	110	10.789
Irregular Linear	Simple Geometric	28.16	134	8.621
	Complex Geometric	30.02	133	10.857
	Simple Pictorial	25.5	134	7.815
	Complex Pictorial	35.37	134	10.736
New Imagery	Simple Geometric	27.67	134	9.296
	Complex Geometric	30.04	133	10.745
	Simple Pictorial	26.98	136	7.885
	Complex Pictorial	36.29	108	10.391

Table 6 (continued). Time of the Different Backgrounds and Symbol Groups

Time * Background * Symbol Group				
Time				
Background	Symbol Group	Mean	N	Std. Deviation
Shaded Relief	Simple Geometric	31.5	109	9.829
	Complex Geometric	31.05	134	10.864
	Simple Pictorial	33.75	134	11.155
	Complex Pictorial	47.43	136	12.59
Old Imagery	Simple Geometric	28.47	133	10.025
	Complex Geometric	27.63	133	9.735
	Simple Pictorial	25.31	134	8.257
	Complex Pictorial	42.16	135	12.31
Dense Linear	Simple Geometric	27.01	134	10.371
	Complex Geometric	30.31	135	10.87
	Simple Pictorial	24.57	134	8.218
	Complex Pictorial	32.06	109	9.132
Gray	Simple Geometric	31.4	98	13.834
	Complex Geometric	36.38	98	13.633
	Simple Pictorial	25.76	98	9.63
	Complex Pictorial	30.66	98	10.187

Table 7. Accuracy of the Different Backgrounds and Symbol Groups

Percent Correct * Background * Symbol Group				
Percent Correct				
Background	Symbol Group	Mean	N	Std. Deviation
White	Simple Geometric	93.915	109	7.4148
	Complex Geometric	81.571	133	26.4235
	Simple Pictorial	95.553	133	6.3241
	Complex Pictorial	91.822	108	9.8618
Regular Linear	Simple Geometric	93.634	133	9.2616
	Complex Geometric	81.906	110	23.8219
	Simple Pictorial	91.881	134	7.6718
	Complex Pictorial	88.51	110	12.0503
Irregular Linear	Simple Geometric	93.893	134	7.3626
	Complex Geometric	81.695	133	23.9151
	Simple Pictorial	91.934	134	7.1662
	Complex Pictorial	87.979	134	10.2814
New Imagery	Simple Geometric	89.71	134	12.2164
	Complex Geometric	79.504	133	27.178
	Simple Pictorial	90.265	136	9.6619
	Complex Pictorial	82.647	108	14.0299

Table 7. Accuracy of the Different Backgrounds and Symbol Groups

Percent Correct * Background * Symbol Group				
Percent Correct				
Background	Symbol Group	Mean	N	Std. Deviation
Shaded Relief	Simple Geometric	87.51	109	11.6463
	Complex Geometric	79.167	134	30.2673
	Simple Pictorial	88.301	134	10.8092
	Complex Pictorial	75.769	136	15.7009
Old Imagery	Simple Geometric	88.693	133	12.7044
	Complex Geometric	78.656	133	26.1458
	Simple Pictorial	92.524	134	7.9418
	Complex Pictorial	80.734	135	13.9848
Dense Linear	Simple Geometric	92.333	134	10.6858
	Complex Geometric	84.218	135	23.7784
	Simple Pictorial	91.935	134	7.4613
	Complex Pictorial	84.661	109	14.0473
Gray	Simple Geometric	92.857	98	14.4897
	Complex Geometric	64.457	98	28.8651
	Simple Pictorial	96.778	98	6.7863
	Complex Pictorial	69.255	98	5.1577

Results of the Symbol Analysis

Table 8. Descriptive Statistics for Search Time for the Four Symbol Groups

Descriptive						95% Confidence Interval for Mean			
		N	Mean	Std. Deviation	Std. Error	Lower Bound	Upper Bound	Minimum	Maximum
Time	Simple Geometric	984	27.84	10.01	0.319	27.21	28.46	7	95
	Complex Geometric	1009	30.77	11.70	0.368	30.04	31.49	6	80
	Simple Pictorial	1037	25.69	9.372	0.291	25.12	26.26	5	70
	Complex Pictorial	938	37.07	12.41	0.406	36.27	37.87	6	92
	Total	3968	30.2	11.70	0.186	29.84	30.57	5	95

Table 9. Descriptive Statistics for Search Accuracy for the Four Symbol Groups

Descriptive						95% Confidence Interval for Mean			
		N	Mean	Std. Deviation	Std. Error	Lower Bound	Upper Bound	Minimum	Maximum
Percent Correct	Simple Geometric	984	91.565	11.1091	0.3541	90.87	92.26	4.3	100
	Complex Geometric	1009	79.34	26.7779	0.843	77.686	80.994	0	100
	Simple Pictorial	1037	92.237	8.4789	0.2633	91.72	92.754	50	100
	Complex Pictorial	938	82.715	14.1027	0.4605	81.811	83.618	11.1	100
	Total	3968	86.54	17.6047	0.2795	85.992	87.088	0	100

The symbol system was analyzed according to the two dependent variables: time and accuracy. Tables 8 and 9 show the total number of searches, mean search times, and standard deviations for time and accuracy for each symbol group. Analysis of Variance shows significant differences in search times among the symbol groups, F (3, 3964) = 199.129, $p < .001$. Also, there are significant differences in the search accuracy among the symbol groups, F (3, 3964) =148.926, $p < .001$ (Table 10). The mean search times for individual symbol groups varied from 25.69 to 37.07 seconds, and the standard deviations from 9.37 to 12.41 (Table 8). The response time of SG3 ($\bar{x} = 25.69$, $s = 9.37$) is significantly faster than the other symbol groups. The response time of SG4 ($\bar{x} = 37.07$, $s = 12.41$) was significantly slower than the other symbol groups (Table 11).

Table 10. Significant Differences of Symbol Groups

ANOVA						
		Sum of Squares	Df	Mean Square	F	Sig.
Percent Correct	Between Groups	124536.6	3	41512.22	148.926	.000
	Within Groups	1104942	3964	278.744		
	Total	1229479	3967			
Time	Between Groups	71143.62	3	23714.54	199.129	.000
	Within Groups	472078.4	3964	119.091		
	Total	543222.1	3967			

Table 11. ***t*** **Tests for Equality of Means (Time) among Symbol Groups**

Independent Samples Test							
t-test for Equallity of Means (Time)							
Symbol Group	t	df	Sig. (2-tailed)	Mean Difference	Std. Error Difference	95% Confidence Interval of the Difference	
						Lower	Upper
SG3 * SG1	-4.97	2019	.000	-2.143	0.431	-2.989	-1.297
SG3 * SG2	-10.837	2044	.000	-5.073	0.468	-5.991	-4.155
SG2 * SG1	-5.999	1991	.000	-2.93	0.488	-3.887	-1.972
SG2 * SG4	-11.53	1945	.000	-6.303	0.547	-7.375	-5.231
SG1 * SG4	-17.983	1920	.000	-9.233	0.513	-10.24	-8.226

Table 12. ***t*** **Tests for Equality of Means (Time) among Symbol Groups**

Independent Samples Test							
t-test for Equality of Means (Accuracy)							
Symbol Group	t	df	Sig. (2-tailed)	Mean Difference	Std. Error Difference	95% Confidence Interval of the Difference	
						Lower	Upper
SG3 * SG1	1.533	2019	0.125	0.6718	0.4383	-0.1877	1.5313
SG3 * SG2	14.768	2044	0	12.897	0.8733	11.1843	14.6097
SG2 * SG1	13.252	1991	0	12.2252	0.9225	10.416	14.0344
SG2 * SG4	-3.442	1945	0.001	-3.3749	0.9806	-5.298	-1.4517
SG1 * SG4	15.321	1920	0	8.8504	0.5777	7.7175	9.9833

The mean search accuracy for individual symbol groups varied from 79.34 to 92.23, and the standard deviations from 8.47 to 26.77. *t* tests showed that there was no significant difference between SG3 ($\bar{x}$ = 92.23, s = 8.47) and SG1 ($\bar{x}$ = 91.56, s =11.10) which were significantly more accurate than the other symbol groups.

Additionally, SG2 ($\bar{x}$ = 79.34, s = 26.77) was found significantly less accurate than the other three symbol groups (Table 12).

It would appear from these analyses, then, that SG3 performs best for the search task, both in terms of search time and accuracy. The fastest search time was expected to be for the symbols in SG3, since the symbols in the group are simple in design and shape; also, each differs distinctly from the others. Their characteristics make the symbols in SG3 easy to search and, consequently, this will produce fast search times. In comparison to the other symbol groups, SG3 produces faster times than most of the backgrounds (Table 6).

In addition, the results showed SG4 to be slower in search time than the other symbol groups, a result that was expected because of the complexity of the SG4 symbols; the symbols all look similar to each other. Results in the search time showed that SG4 produced the slowest times on most of the backgrounds (Table 6).

The results indicate that SG2 symbols were found most slowly and least accurately, a result that was expected because of the complexity of the SG2 design: all of the symbols look very similar to each other. In particular, the orientation of each symbol created confusion; some of searchers probably counted both left- and right-oriented symbols as the same. The difference in orientation as the main variable in the design was not effective. Further, the transparency in the design caused low contrast between the symbols and the background. It was decided that these symbols should be opaque (with a white fill) in order to be more visible on any background.

Chapter Six

GEOG 104: Large-Size Symbols on Various Backgrounds

This analysis consists of two sections. The first section is the analysis of backgrounds that were tested with the four different symbol groups. The following seven backgrounds (BK) were tested: white (BK1), regular linear pattern (BK2), irregular linear pattern (BK 3), revised imagery (BK4), shaded relief (BK5), initial imagery (BK6), and dense linear (BK7). The second part of the analysis tested each symbol group with the seven different types of backgrounds. Four symbol groups (SG) were tested with the five backgrounds: simple geometric (SG1), complex geometric (SG2), simple pictorial (SG3) and complex pictorial (SG4). Each group consisted of five different symbols, one or more of which were tested with each background. Time and accuracy were the response variables for each test.

The Background Analysis

The background system was analyzed according to the two dependent variables: time and accuracy. Descriptive statistics for each variable are listed in tables 1 and 2. These show the total number of the searches, the mean search times, and the standard deviations of each background type for time and accuracy, respectively.

Table 1. Descriptive Statistics of Search Time for the Seven Different Backgrounds

Descriptives									
						95% Confidence Interval for Mean			
		N	Mean	Std. Deviation	Std. Error	Lower Bound	Upper Bound	Minimum	Maximum
Time	White	68	25.25	10.876	1.319	22.62	27.88	10	51
	Regular Linear	63	21.56	9.713	1.224	19.11	24	7	54
	Irregular Linear	60	26.08	9.136	1.179	23.72	28.44	9	58
	New Imagery	60	26.73	9.88	1.276	24.18	29.29	14	67
	Shaded Relief	45	29.67	8.965	1.336	26.97	32.36	15	57
	Old Imagery	46	30.74	10.385	1.531	27.66	33.82	14	59
	Dense Linear	62	22.11	11.465	1.456	19.2	25.02	7	51
	Total	404	25.65	10.533	0.524	24.62	26.68	7	67

Table 2. Descriptive Statistic of Search Accuracy for the Seven Different Backgrounds

Descriptives									
						95% Confidence Interval for Mean			
		N	Mean	Std. Deviation	Std. Error	Lower Bound	Upper Bound	Minimum	Maximum
Percent Correct	White	68	91.067	9.1129	1.1051	88.861	93.272	55	100
	Regular Linear	63	89.981	10.3803	1.3078	87.367	92.595	54.5	100
	Irregular Linear	60	87.752	14.1038	1.8208	84.109	91.396	9.5	100
	New Imagery	60	84.337	21.5442	2.7813	78.771	89.902	0	100
	Shaded Relief	45	84.46	12.1407	1.8098	80.812	88.107	43.5	100
	Old Imagery	46	81.886	21.0393	3.1021	75.638	88.133	5.3	100
	Dense Linear	62	91.64	8.9175	1.1325	89.376	93.905	60.9	100
	Total	404	87.712	14.7257	0.7326	86.272	89.153	0	100

The mean search times for individual backgrounds varied from 21.56 to 30.74 seconds, and the standard deviations from 8.96 to 11.46. The analysis of variance shows significant differences in the mean search times among the backgrounds, F (6, 397) = 6.22, $p < .001$. Also, there are significant differences in the mean search accuracy among the backgrounds, F (6, 397) = 3.81, $p < .001$ (Table 3).

Table 3. Significant Differences of Backgrounds

ANOVA						
		Sum of Squares	df	Mean Square	F	Sig.
Percent Correct	Between Groups	4767.476	6	794.579	3.818	.000
	Within Groups	82621.27	397	208.114		
	Total	87388.75	403			
Time	Between Groups	3841.784	6	640.297	6.22	.000
	Within Groups	40865.7	397	102.936		
	Total	44707.49	403			

The response time with BK2 ($\bar{x}$ = 21.56, s = 9.71) and BK7 ($\bar{x}$ = 22.11, s = 11.46) was found to be significantly faster than that of the other backgrounds. The t test showed significant difference between BK2 and BK7 and the other backgrounds (Table 4). The response times with BK5 ($\bar{x}$ = 29.67, s =8.96) (shaded relief) and BK6 ($\bar{x}$ =30.74, s =10.38) (initial imagery) are significantly slower than with the other backgrounds.

Table 4. *t* Tests for Equality of Means (time) among Backgrounds

Independent Samples Test							
t-test for Equallity of Means (Time)							
Backgrounds	t	df	Sig. (2-tailed)	Mean Difference	Std. Error Difference	95% Confidence Interval of the Difference	
						Lower	Upper
BK2 * BK7	-.293	123	.770	-.557	1.900	-4.317	3.203
BK1 * BK7	-1.601	128	.112	-3.137	1.960	-7.015	.741
BK2 * BK1	-2.045	129	.043	-3.694	1.807	-7.270	-.119
BK1 * BK4	-.804	126	.423	-1.483	1.846	-5.136	2.170
BK1 * BK3	-.466	126	.642	-.833	1.789	-4.373	2.706
BK1 * BK5	-2.262	111	.026	-4.417	1.953	-8.286	-.547
BK7 * BK3	-2.111	120	.037	-3.970	1.881	-7.694	-.247
BK2 * BK3	-2.660	121	.009	-4.528	1.702	-7.898	-1.158
BK3 * BK4	-.374	118	.709	-.650	1.737	-4.090	2.790
BK3 * BK5	-2.005	103	.048	-3.583	1.787	-7.128	-.039
BK4 * BK6	-2.023	104	.046	-4.006	1.980	-7.932	-.080
BK4 * BK5	-1.566	103	.120	-2.933	1.873	-6.649	.782
BK6 * BK5	-.527	89	.600	-1.072	2.036	-5.117	2.972

Table 2 shows that the mean search accuracy for the different backgrounds varied from 81.88 to 91.64, and the standard deviations from 8.91 to 21.54. The analysis of variance showed differences between the backgrounds in search accuracy ($p < .001$) (Table 3). The *t* test of the mean search accuracy for each of the background types showed no significant differences between BK7 ($\bar{x}$ = 91.64, s = 8.91) and BK1 ($\bar{x}$ = 91.06, s = 9.11), BK 2 ($\bar{x}$ = 89.98, s = 10.38), and BK3 ($\bar{x}$ = 87.75, s =14.10) (Table 5). Additionally, BK5 ($\bar{x}$ = 84.46, s = 12.14), BK4 ($\bar{x}$ = 84.33, s = 21.544), and BK6 ($\bar{x}$ = 81.88, s = 21.03) resulted in significantly less accurate searches than the other backgrounds.

Table 5. *t* Tests for Equality of Means (Accuracy) among Backgrounds

Independent Samples Test							
t-test for Equallity of Means (Accuracy)							
Backgrounds	t	df	Sig. (2-tailed)	Mean Difference	Std. Error Difference	95% Confidence Interval of the Difference	
						Lower	Upper
BK2 * BK7	-.958	123	.340	-1.6590	1.7321	-5.0877	1.7696
BK1 * BK7	.362	128	.718	.5735	1.5840	-2.5606	3.7076
BK2 * BK1	-.637	129	.525	-1.0855	1.7037	-4.4563	2.2853
BK1 * BK4	2.350	126	.020	6.7298	2.8643	1.0615	12.3981
BK1 * BK3	1.597	126	.113	3.3143	2.0755	-.7929	7.4216
BK1 * BK5	3.300	111	.001	6.6070	2.0022	2.6395	10.5744
BK7 * BK3	1.826	120	.070	3.8878	2.1291	-.3277	8.1033
BK2 * BK3	1.002	121	.319	2.2288	2.2255	-2.1771	6.6347
BK3 * BK4	1.027	118	.306	3.4155	3.3243	-3.1676	9.9985
BK3 * BK5	1.255	103	.212	3.2926	2.6229	-1.9093	8.4946
BK4 * BK6	.586	104	.559	2.4513	4.1796	-5.8370	10.7395
BK4 * BK5	-.034	103	.973	-.1228	3.5761	-7.2151	6.9694
BK6 * BK5	.713	89	.478	2.5741	3.6115	-4.6018	9.7500

Results of the Background Analysis

It would appear from the analyses that BK2 (regular linear) and BK7 (dense linear) perform best for the search task, both in terms of search time and accuracy. The fastest search time probably occurred with BK2, since the linear network of the background divided the area and would have helped participants to count the symbols quickly and accurately. Although BK7, as mentioned in the analyses of part one, has a dense linear pattern that add to the difficulty of visual search, the results found no significant difference between BK2 and BK7. That means that search performance is fast and accurate with this kind of (linear) background. The results in mean search time and accuracy showed that most of the four symbol groups have faster search times and higher accuracy with BK2 and BK7 than the other backgrounds (Table 6).

The results show that BK5 (shaded relief) and BK6 (imagery) were slowest in both mean search time and accuracy. The result for BK5 was expected because of the complex characteristics of this background. The same prediction was made for BK6, since its gray tone lowers contrast between symbols and background (Table 7).

The *t* test results showed no significant difference between BK7, BK1, BK2, and BK3; all of them produced similar results in terms of accuracy. The results in the mean search accuracy indicated that most of the symbol groups have higher accuracy with BK7, BK1, BK2, and BK3 than the other backgrounds (Table 7).

Moreover, the results showed that BK5, BK4 imagery, and BK6 were the slowest in search accuracy. This result for BK5 was expected because of the complex characteristics of this background. The same prediction was made for BK4 and BK6, since both have a gray tone that causes low contrast between the symbols and the background. Notably, results in the mean search time and accuracy showed that most of the four symbol groups have slower times and less accuracy with BK5 and BK6 than with the other backgrounds (Table 6 and Table 7).

Table 6. Time of the Different Backgrounds and Symbol Groups

Time * Background * SymbolGroup				
Time				
Background	SymbolGroup	Mean	N	Std. Deviation
White	Simple Geometric	20.05	21	8.009
	Simple Pictorial	14.8	15	4.663
	Complex Pictorial	33.56	32	7.87
	Total	25.25	68	10.876
Regular Linear	Simple Geometric	18.46	13	3.95
	Complex Geometric	37	8	9.457
	Simple Pictorial	16.29	28	4.76
	Complex Pictorial	26.14	14	10.076
	Total	21.56	63	9.713
Irregular Linear	Simple Geometric	26.73	15	6.649
	Complex Geometric	33.92	13	10.492
	Simple Pictorial	22.59	32	7.598
	Total	26.08	60	9.136
New Imagery	Simple Geometric	21.69	13	6.316
	Complex Geometric	26.91	32	9.113
	Complex Pictorial	30.73	15	12.349
	Total	26.73	60	9.88

Table 6 (continued). Time of the Different Backgrounds and Symbol Groups

Time * Background * SymbolGroup				
Time				
Background	SymbolGroup	Mean	N	Std. Deviation
Shaded Relief	Simple Geometric	32.53	32	8.614
	Simple Pictorial	22.62	13	5.221
	Total	29.67	45	8.965
Old Imagery	Complex Geometric	30.5	14	13.025
	Complex Pictorial	30.84	32	9.239
	Total	30.74	46	10.385
Dense Linear	Complex Geometric	14.27	15	6.66
	Simple Pictorial	17.97	32	5.889
	Complex Pictorial	38.8	15	6.93
	Total	22.11	62	11.465
Total	Simple Geometric	25.37	94	9.233
	Complex Geometric	27.3	82	11.846
	Simple Pictorial	18.92	120	6.607
	Complex Pictorial	32.13	108	9.672
	Total	25.65	404	10.533

Table 7. Accuracy of the Different Backgrounds and Symbol Groups

Percent Correct * Background * SymbolGroup				
Percent Correct				
Background	SymbolGroup	Mean	N	Std. Deviation
White	Simple Geometric	95.744	21	5.8664
	Simple Pictorial	97.46	15	3.5392
	Complex Pictorial	85	32	8.89
	Total	91.067	68	9.1129
Regular Linear	Simple Geometric	93.846	13	6.1758
	Complex Geometric	69.886	8	13.2939
	Simple Pictorial	92.28	28	5.3975
	Complex Pictorial	93.277	14	6.0418
	Total	89.981	63	10.3803
Irregular Linear	Simple Geometric	85.882	15	11.2931
	Complex Geometric	73.993	13	20.9032
	Simple Pictorial	94.219	32	5.2532
	Total	87.752	60	14.1038
New Imagery	Simple Geometric	92.308	13	5.9799
	Complex Geometric	79.865	32	27.6724
	Complex Pictorial	86.97	15	10.8476
	Total	84.337	60	21.5442

Table 7 (continued). Accuracy of the Different Backgrounds and Symbol Groups

Percent Correct * Background * SymbolGroup				
Percent Correct				
Background	SymbolGroup	Mean	N	Std. Deviation
Shaded Relief	Simple Geometric	81.929	32	12.5483
	Simple Pictorial	90.688	13	8.6359
	Total	84.46	45	12.1407
Old Imagery	Complex Geometric	72.624	14	34.9158
	Complex Pictorial	85.937	32	8.6969
	Total	81.886	46	21.0393
Dense Linear	Complex Geometric	98.667	15	2.9681
	Simple Pictorial	91.493	32	7.4648
	Complex Pictorial	84.928	15	10.633
	Total	91.64	62	8.9175
Total	Simple Geometric	88.73	94	11.0635
	Complex Geometric	80.163	82	25.6916
	Simple Pictorial	93.062	120	6.4443
	Complex Pictorial	86.614	108	9.3046
	Total	87.712	404	14.7257

The Symbol Analysis

The symbol system was analyzed according to the two dependent variables: time and accuracy. Tables 8 and 9 show the total number of the searches, the mean search times, and the standard deviation of time and accuracy for each symbol group, respectively.

Table 8. Descriptive Statistics for Search Time for the Four Different Symbol Groups

Descriptive									
						95% Confidence Interval for Mean			
		N	Mean	Std. Deviation	Std. Error	Lower Bound	Upper Bound	Minimum	Maximum
Time	Simple Geometric	94	25.37	9.233	0.952	23.48	27.26	11	57
	Complex Geometric	82	27.3	11.846	1.308	24.7	29.91	8	59
	Simple Pictorial	120	18.92	6.607	0.603	17.72	20.11	7	38
	Complex Pictorial	108	32.13	9.672	0.931	30.28	33.97	14	67
	Total	404	25.65	10.533	0.524	24.62	26.68	7	67

Table 9. Descriptive Statistic for Search Accuracy for the Four Different Symbol Groups

Descriptive						95% Confidence Interval for Mean			
		N	Mean	Std. Deviation	Std. Error	Lower Bound	Upper Bound	Minimum	Maxi mum
Percent Correct	Simple Geometric	94	88.73	11.0635	1.1411	86.464	90.996	43.5	100
	Complex Geometric	82	80.163	25.6916	2.8372	74.518	85.808	0	100
	Simple Pictorial	120	93.062	6.4443	0.5883	91.897	94.227	61.1	100
	Complex Pictorial	108	86.614	9.3046	0.8953	84.839	88.389	55	100
	Total	404	87.712	14.7257	0.7326	86.272	89.153	0	100

The analysis of variance shows significant differences in the mean search times among the backgrounds, $F(3,400) = 39.44$, $p < .001$. Also, there are significant differences in the mean search accuracy among the backgrounds, $F(3, 400) = 14.05$, $p < .001$ (Table 10).

Table 10. Significant Differences of Symbol Groups

ANOVA						
		Sum of Squares	df	Mean Square	F	Sig.
Percent Correct	Between Groups	8334.989	3	2778.33	14.058	.000
	Within Groups	79053.76	400	197.634		
	Total	87388.75	403			
Time	Between Groups	10206.79	3	3402.262	39.446	.000
	Within Groups	34500.7	400	86.252		
	Total	44707.49	403			

The mean search times for individual symbol groups varied from 18.92 to 32.13 seconds, and the standard deviation from 6.60 to 11.84 (Table 8). The response time for SG 3 ($\bar{x}$= 18.92, s = 6.60) wass significantly faster than the other symbol groups. The *t* test showed participants achieving significantly faster search time with SG3 than the other symbol groups, $p < .001$. Additionally, the response time of SG4 ($\bar{x}$ = 32.13, s = 9.67) was significantly slower than the other backgrounds (Table 11).

Table 11. ***t*** **Tests for Equality of Means (Time) among Symbol Groups**

Independent Samples Test							
t-test for Equallity of Means (Time)							
Symbol Group	t	df	Sig. (2-tailed)	Mean Difference	Std. Error Difference	95% Confidence Interval of the Difference	
						Lower	Upper
SG3 * SG1	5.957	212	.000	6.456	1.084	4.319	8.592
SG3 * SG2	6.433	200	.000	8.388	1.304	5.817	10.959
SG3 * SG4	-12.145	226	.000	-13.213	1.088	-15.357	-11.069
SG2 * SG1	-1.214	174	.226	-1.933	1.591	-5.073	1.208
SG2 * SG4	3.089	188	.002	4.825	1.562	1.744	7.906
SG1 * SG4	-5.058	200	.000	-6.757	1.336	-9.392	-4.123

The mean search accuracy for individual symbol groups varied from 80.16 to 93.06, and the standard deviation from 6.44 to 25.69 (Table 9). Since the *t* test showed significant differences between SG3 in mean search accuracy, SG3 ($\bar{x}$ = 93.06, *s* = 6.44) was found to be significantly more accurate than the other symbol groups. Additionally, SG2 ($\bar{x}$ = 80.16, *s* = 25.69) was significantly less accurate than the other symbol groups (Table 12).

Table 12. *t* Tests for Equality of Means (Time) among Symbol Groups

Independent Samples Test							
t-test for Equallity of Means (Accuracy)							
Symbol Group	t	df	Sig. (2-tailed)	Mean Difference	Std. Error Difference	95% Confidence Interval of the Difference	
						Lower	Upper
SG3 * SG1	-3.584	212	.000	-4.3324	1.2087	-6.7150	-1.9498
SG3 * SG2	-5.268	200	.000	-12.8988	2.4485	-17.7270	-8.0707
SG3 * SG4	6.132	226	.000	6.4480	1.0516	4.3758	8.5201
SG2 * SG1	2.937	174	.004	8.5664	2.9172	2.8088	14.3240
SG2 * SG4	2.411	188	.017	6.4509	2.6755	1.1729	11.7288
SG1 * SG4	1.476	200	.141	2.1155	1.4332	-.7106	4.9417

Results of the Symbol Analysis

It would appear from the analyses, then, that SG 3 performs best for the search task, both in terms of search time and accuracy. The fastest search time was expected to be for symbols in SG3 since the symbols in the group are simple in design and each differs clearly from the others. All of their individual characteristics enable them to be easy to search for and, consequently this will produce fast search times (Table 6 and Table 7).

In addition, the results found that SG4 was slower in search time than the other symbol groups, a result that was expected because of the complexity of the SG4 symbol designs; all of the symbols look similar to each other.

Moreover, the results showed that SG2 had lower accuracy with the most of the backgrounds than the other symbol groups, a result that was expected because of the complexity of the SG2 design; all of the symbols look similar to each other. Specifically, the different orientations of the linear elements symbols confused participants, so that some of the searchers counted similar symbols with both left and right orientations as target symbols. Orientation in the symbol design did not contribute to search accuracy. Additionally, the transparency in the symbol's design apparently caused low contrast between the symbols and the background. To avoid this problem, it was decided that the symbol should be opaque (with white fill) in order to stand out from the background (Table 7).

Comparison between the Performance of the Symbol Size with the Backgrounds and in the Symbol Groups

Table 13 . Comparison between the Performance of the Searches, in Both Search Time and Accuracy, of the Backgrounds and the Symbol Groups

Symbol Size	Fast time	Slow time	High accuracy	Low accuracy
small	BK 1	BK 5, BK8	BK 1, BK 2, BK 3, BK 7	BK 8, BK 5
large	BK 2, BK 7	BK 5, BK 6	BK 7,BK 1, BK 2, BK 3	BK 5, BK4, BK 6
Symbol Size	Fast time	Slow time	High accuracy	Low accuracy
small	SG 3	SG 4	SG 1,SG 3	SG 2
large	SG 3	SG 4	SG 3	SG 2

The results in Table 13 show the background type and symbol group with the fastest and slowest times, and those with the highest and lowest accuracies for the small and large symbols.

In regard to the backgrounds, the results indicate that the fastest search time for small-sized symbols occurred on BK1 (white), while the fastest search times for the large symbol size was achieved on BK2 (regular linear) and BK7 (dense linear). Also, the highest accuracy in searches for symbols of both sizes was achieved on the same backgrounds: BK1, BK2, BK3 (irregular linear), and BK7. These results indicate that size had no effect on the accuracy variable. In contrast, the slowest search time with the small symbol size was in searches on BK5 (shaded relief), while the slowest search time for large-sized symbols occurred on BK5 and BK6 (old imagery). In addition, the lowest levels of accuracy in searches for the small symbol size was found in searches against BK5 and BK8 (gray). In searches for large-sized symbols, the lowest levels in accuracy were found in searches performed on BK5, BK4 (new imagery), and BK6. It seems from these results that the same backgrounds that produced the slowest searches also produced the least accurate searches. This result corresponds to the characteristics and the complexities of these backgrounds.

In regard to the symbol groups, the results show that the fastest search times for symbol groups of both sizes was achieved in searches for SG3. Also, the highest levels of accuracy in searches for the small-sized symbols were achieved in searches for SG1 and SG3, and the highest accuracy with the large symbol size was in SG3. In searches for symbols of both sizes, the slowest search time was in SG4 and the lowest accuracy was in SG2. This indicates that the size had no effect on the time and accuracy variables.

Table 14 shows the total number of searches, mean search times, and the standard deviations for symbol sizes, large and small, in time and accuracy. The response time for large-size symbols ($\bar{x}$ = 25.65, s = 10.33) is significantly faster than for small-size symbols ($\bar{x}$ = 30.2, s = 11.70). Although the t test showed that participants achieved significantly faster times with the large size in the mean search time, t (4370) = -7.512, $p < .001$, it also showed that the participants' performances with the large size ($\bar{x}$ = 87.71, s = 14.72) and the small size ($\bar{x}$ = 86.54, s = 17.60) were not significantly different in search accuracy, t (4370) = 1.293, p= 1.96 (Table 15).

Table 14. Symbol Size, Large Vs. Small

Descriptives

		N	Mean	Std. Deviation	Std. Error	95% Confidence Interval for Mean Lower Bound	95% Confidence Interval for Mean Upper Bound	Minimum	Maximum
Time	Large	404	25.65	10.533	.524	24.62	26.68	7	67
	Small	3968	30.20	11.702	.186	29.84	30.57	5	95
	Total	4372	29.78	11.672	.177	29.44	30.13	5	95
Percent Correct	Large	404	87.712	14.7257	.7326	86.272	89.153	.0	100.0
	Small	3968	86.540	17.6047	.2795	85.992	87.088	.0	100.0
	Total	4372	86.648	17.3606	.2626	86.133	87.163	.0	100.0

Table 15. *t* Tests of Symbol Size, Large Vs. Small

Independent Samples Test

		t-test for Equality of Means						
		t	df	Sig. (2-tailed)	Mean Difference	Std. Error Difference	95% Confidence Interval of the Difference Lower	Upper
Time	Equal variances assumed	-7.512	4370	.000	-4.550	.606	-5.738	-3.363
	Equal variances not assumed	-8.185	509.841	.000	-4.550	.556	-5.643	-3.458
Percent Correct	Equal variances assumed	1.293	4370	.196	1.1725	.9066	-.6048	2.9498
	Equal variances not assumed	1.495	527.687	.135	1.1725	.7841	-.3679	2.7129

Analysis of Variance shows significant differences in the mean search times among the large size and the small size, F (1, 4370) =56.433, $p < .001$. Also, it shows no significant differences in the mean search accuracy between the small size and the large size, F (1, 4370) =1.673, p= 0.196 (Table 16). These results indicate that the large size is more visible than the small size. Thus, it was counted faster than the small size.

Table 16. Significant Differences of Symbol Size, Large Vs. Small

ANOVA

		Sum of Squares	df	Mean Square	F	Sig.
Time	Between Groups	7592.329	1	7592.329	56.433	.000
	Within Groups	587929.545	4370	134.538		
	Total	595521.874	4371			
Percent Correct	Between Groups	504.113	1	504.113	1.673	.196
	Within Groups	1316867.841	4370	301.343		
	Total	1317371.955	4371			

Table 17 shows the total number of searches, mean search times, and standard deviations for marked and unmarked symbols during the visual search process, for both time and accuracy. Students were asked not to mark the symbols on the page as they counted them; however, some students disregarded this instruction. Did this make a difference? The response time with unmarked symbols ($\bar{x}$ = 29.43, s = 11.60) is significantly faster than the marked ($\bar{x}$ = 34.20, s = 11.67), t (4370) = -7.147, p <

.001. Participants who did not mark symbols ($\bar{x}$ = 86.42, s = 17.61) were less accurate than those who did ($\bar{x}$ = 89.40, s =13.61) , t (4370) = -2.988, p <.003.

Table 17. Table of the Marked and Unmarked in Symbols

Group Statistics

	marked	N	Mean	Std. Deviation	Std. Error Mean
Time	Not Marked	4045	29.43	11.601	.182
	Marked	327	34.20	11.673	.646
Percent Correct	Not Marked	4045	86.425	17.6110	.2769
	Marked	327	89.405	13.6168	.7530

Table 18. *t* Tests of Marked and Unmarked Symbols

		t-test for Equality of Means						
		t	df	Sig. (2-tailed)	Mean Difference	Std. Error Difference	95% Confidence Interval of the Difference	
							Lower	Upper
Time	Equal variances assumed	-7.1	4370	0	-4.769	0.667	-6.077	-3.461
	Equal variances not assumed	-7.1	379.938	0	-4.769	0.671	-6.088	-3.45
Percent	Equal variances assumed	-2.9	4370	0.003	-2.9798	0.9972	-4.934	-1.024
Correct	Equal variances not assumed	-3.7	419.508	0	-2.9798	0.8023	-4.556	-1.402

Analysis of Variance shows significant differences in search times between the marked and unmarked symbols, F (1, 4370) = 51.08, $p < .001$ (Table 18). Also, it shows significant differences in search accuracy between the marked and unmarked symbols, F (1, 4370) = 8.92, $p <.003$ (Table 19). These results indicate that marking symbols had a distinct impact on the visual search process. Marking symbols yielded better accuracy, but more time was required to perform this additional step.

Table 19. Significant Differences for Marked and Unmarked Symbol

ANOVA

		Sum of Squares	df	Mean Square	F	Sig.
Time	Between Groups	6880.884	1	6880.884	51.083	.000
	Within Groups	588640.990	4370	134.700		
	Total	595521.874	4371			
Percent Correct	Between Groups	2686.343	1	2686.343	8.929	.003
	Within Groups	1314685.611	4370	300.843		
	Total	1317371.955	4371			

Initial Complex Geometric Symbol Group (SG 5) on Various Backgrounds

This analysis compares the results for the initial complex geometric symbol group (SG5) on seven backgrounds, and also the results of SG5 with the results of SG2. Symbols from SG5 were searched for on seven backgrounds (BK): white (BK1), regular linear (BK2), irregular linear (BK3), revised imagery (BK4), shaded relief (BK5), initial imagery (BK6), and dense linear (BK7). SG5 consisted of five different symbols, and one or more were tested with each background.

The Background Analysis

The background system was analyzed according to the two dependent variables, time and accuracy. Descriptive statistics for each variable, listed in Tables

Table 20. Descriptive Statistics for Search Time for the Seven Different Backgrounds

Descriptives									
						95% Confidence Interval for Mean			
		N	Mean	Std. Deviation	Std. Error	Lower Bound	Upper Bound	Minimum	Maximum
Time	White BK 1	28	17.86	7.24	1.368	15.05	20.66	8	35
	Regular Linear BK 2	26	14.08	3.773	0.74	12.55	15.6	7	25
	Irregular Linear BK 3	30	18.2	7.227	1.32	15.5	20.9	5	35
	New Imagery BK 4	26	21.19	4.427	0.868	19.4	22.98	14	33
	Shaded Relief BK 5	30	25.63	9.118	1.665	22.23	29.04	10	58
	Old Imagery BK 6	30	27.77	5.876	1.073	25.57	29.96	15	39
	Dense Linear BK 7	26	18.81	5.543	1.087	16.57	21.05	11	31
	Total	196	20.68	7.792	0.557	19.59	21.78	5	58

Table 21. Descriptive Statistics for Search Accuracy for the Seven Different Backgrounds

Descriptives									
						95% Confidence Interval for Mean			
		N	Mean	Std. Deviation	Std. Error	Lower Bound	Upper Bound	Minimum	Maximum
Percent Correct	White BK 1	28	95.357	6.2048	1.1726	92.951	97.763	75	100
	Regular Linear BK 2	26	90.132	8.1697	1.6022	86.832	93.431	79.2	100
	Irregular Linear BK 3	30	92.723	8.1773	1.493	89.67	95.777	66.7	100
	New Imagery BK 4	26	90.132	10.6806	2.0946	85.818	94.446	66.7	100
	Shaded Relief BK 5	30	94.361	6.5678	1.1991	91.909	96.814	75	100
	Old Imagery BK 6	30	84.444	22.1925	4.0518	76.158	92.731	0	100
	Dense Linear BK 7	26	97.034	4.3761	0.8582	95.267	98.802	85	100
	Total	196	91.967	11.6713	0.8337	90.323	93.612	0	100

20 and 21, show the total number of searches, mean search times, and standard deviations for each background for both time and accuracy. The mean search times varied from 14.08 to 27.77 seconds, and the standard deviations varied from 3.77 to 9.11. Analysis of Variance shows significant differences in search times among the backgrounds, F (6,189) =15.36, $p < .001$. There are also significant differences in search accuracy, F (6,189) = 4.08, $p <. 001$ (Table 22).

Table 22. Significant Differences of Backgrounds

ANOVA						
		Sum of Squares	df	Mean Square	F	Sig.
Time	Between Groups	3881.903	6	646.984	15.369	.000
	Within Groups	7956.485	189	42.098		
	Total	11838.39	195			
Percent Correct	Between Groups	3051.357	6	508.56	4.088	.000
	Within Groups	23511.53	189	124.4		
	Total	26562.88	195			

Table 23. *t* Tests for Equality of Means (Time) among Backgrounds

Independent Samples Test t-test for Equallity of Means (Time)							
Backgrounds	t	df	Sig. (2-tailed)	Mean Difference	Std. Error Difference	95% Confidence Interval of the Difference	
						Lower	Upper
BK1 * BK7	-.539	52	.592	-.951	1.765	-4.492	2.591
BK1 * BK3	-.180	56	.858	-.343	1.901	-4.151	3.465
BK1 * BK5	3.580	56	.001	7.776	2.172	3.425	12.127
BK7 * BK3	-.349	54	.729	-.608	1.742	-4.101	2.885
BK2 * BK3	-2.614	54	.012	-4.123	1.577	-7.285	-.961
BK2 * BK4	-6.237	50	.000	-7.115	1.141	-9.407	-4.824
BK2 * BK5	-10.19	54	.000	-13.690	1.343	-16.383	-10.997
BK3 * BK4	1.833	54	.072	2.992	1.633	-.281	6.266
BK3 * BK5	3.499	58	.001	7.433	2.124	3.181	11.685
BK4 * BK6	-4.669	54	.000	-6.574	1.408	-9.398	-3.751
BK6 * BK5	-1.077	58	.286	-2.133	1.980	-6.098	1.831

The response time with BK2 ($\bar{x}$=14.08, s =3.77) was found to be significantly faster than the other backgrounds. t tests showed significant difference between BK2 and the other backgrounds, p = < .001 (Table 24). Additionally, t tests showed that the response times with BK5 (shaded relief) ($\bar{x}$= 25.63, s = 9.11) and BK6 (initial imagery) ($\bar{x}$= 27.77, s = 5.87) were significantly slower than with the other backgrounds (Table 23).

Table 21 shows that the mean search accuracy for the backgrounds varied from 84.44 to 97.03, and the standard deviations varied from 4.37 to 22.19. Analysis of Variance showed differences between the backgrounds in search accuracy (p < .001) (Table 22). t tests of the mean search accuracy for each of the background types

Table 24. *t* Tests for Equality of Means (Accuracy) among Backgrounds

Independent Samples Test							
t-test for Equallity of Means (Accuracy)							
Backgrounds	t	df	Sig. (2-tailed)	Mean Difference	Std. Error Difference	95% Confidence Interval of the Difference	
						Lower	Upper
BK1 * BK7	-1.14	52	.260	-1.6773	1.4716	-4.6303	1.2758
BK1 * BK3	1.374	56	.175	2.6338	1.9164	-1.2052	6.4729
BK1 * BK5	-.593	56	.556	-.9960	1.6805	-4.3625	2.3704
BK7 * BK3	-2.40	54	.020	-4.3111	1.7930	-7.9058	-.7164
BK2 * BK3	-1.18	54	.242	-2.5917	2.1901	-6.9827	1.7992
BK2 * BK4	.000	50	1.000	-.0005	2.6371	-5.2974	5.2964
BK2 * BK5	1.235	54	.222	5.6871	4.6052	-3.5457	14.9200
BK3 * BK4	-1.02	54	.309	-2.5912	2.5239	-7.6513	2.4688
BK3 * BK5	.855	58	.396	1.6378	1.9149	-2.1953	5.4709
BK4 * BK6	1.192	54	.239	5.6876	4.7729	-3.8815	15.2568
BK6 * BK5	2.347	58	.022	9.9167	4.2255	1.4584	18.3749

showed no significant differences between BK7 ($\bar{x}$= 97.03, s = 4.37), BK1 ($\bar{x}$ = 95.35, s = 6.20), and BK5 ($\bar{x}$ = 94.36, s = 6.56) (Table 24). Further, BK3 ($\bar{x}$= 84.46, s = 12.14), BK4 ($\bar{x}$= 48.33, s = 21.544), BK2 ($\bar{x}$ = 90.13, s = 8.16), and BK6 ($\bar{x}$ = 81.88, s =21.03) produced significantly less accurate searches (Table 24).

The Background Analysis

It would appear from the analyses, then, that BK2 performs best for the search time task. The fast search time with BK2 appears to be due to the linear nature of the background, which divided the area and thus enabled participants to count the symbols quickly (Table 25).

Moreover, the results found that searches performed on BK5 and BK6 produced the slowest mean search times. The result for BK5 was expected because of the complex characteristics of this background. Similar predictions were made in regard to BK6, since it has a gray tone that causes low contrast between the symbols and the background. Also, the results showed that the highest mean search accuracy was found with BK7, BK1, and BK5. *t* test results also showed no significant difference among these three. The results were as expected for BK1, but high accuracy for BK7 and BK5 was unexpected because of the complex characteristics of the shaded relief background, However, the participants took a long time doing the search, and that could have helped to improve accuracy (Table 26).

In contrast, the results found that BK3, BK4, BK2, and BK6 were lowest in mean search accuracy. The low results for searches on BK2 and BK3 could have

Table 25. Time of the Different Backgrounds and Symbol Groups

Time

Background	Symbol Group	Mean	N	Std. Deviation
White	Old complex geometric	17.86	28	7.240
	Total	17.86	28	7.240
Regular Linear	Old complex geometric	14.08	26	3.773
	Total	14.08	26	3.773
Irregular Linear	Old complex geometric	18.20	30	7.227
	Total	18.20	30	7.227
New Imagery	Old complex geometric	21.19	26	4.427
	Total	21.19	26	4.427
Shaded Relief	Old complex geometric	25.63	30	9.118
	Total	25.63	30	9.118
Old Imagery	Old complex geometric	27.77	30	5.876
	Total	27.77	30	5.876
Dense Linear	Old complex geometric	18.81	26	5.543
	Total	18.81	26	5.543
Total	Old complex geometric	20.68	196	7.792
	Total	20.68	196	7.792

occurred, because these two backgrounds were fast in time. The poor results were predicted for searches on BK4 and BK6, since both have a gray tone that causes low contrast between the symbols and the background (Table 26).

Table 27 shows the total number of the searches, the mean search times, and the standard deviations for SG5 in both large and small sizes. The response time for the large size ($\bar{x}$= 20.10, s =7.68) was not significantly different from the small size ($\bar{x}$= 21.27, s = 7.88), t (149) = -1.045, p =.297. Also, the t test showed that the

Table 26. Accuracy of the Different Backgrounds and Symbol Groups

Percent Correct

Background	Symbol Group	Mean	N	Std. Deviation
White	Old complex geometric	95.357	28	6.2048
	Total	95.357	28	6.2048
Regular Linear	Old complex geometric	90.132	26	8.1697
	Total	90.132	26	8.1697
Irregular Linear	Old complex geometric	92.723	30	8.1773
	Total	92.723	30	8.1773
New Imagery	Old complex geometric	90.132	26	10.6806
	Total	90.132	26	10.6806
Shaded Relief	Old complex geometric	94.361	30	6.5678
	Total	94.361	30	6.5678
Old Imagery	Old complex geometric	84.444	30	22.1925
	Total	84.444	30	22.1925
Dense Linear	Old complex geometric	97.034	26	4.3761
	Total	97.034	26	4.3761
Total	Old complex geometric	91.967	196	11.6713
	Total	91.967	196	11.6713

Table 27. SG5 Size, Large Vs. Small for Time and Accuracy

Group Statistics

	size	N	Mean	Std. Deviation	Std. Error Mean
Time	Large	98	20.10	7.689	.777
	Small	98	21.27	7.889	.797
Percent Correct	Large	98	92.571	13.9585	1.4100
	Small	98	91.364	8.8469	.8937

Table 28. *t* Tests of the SG5 Size, Large vs. Small, for Time and Accuracy

Independent Samples Test

		t-test for Equality of Means						
							95% Confidence Interval of the Difference	
		t	df	Sig. (2-tailed)	Mean Difference	Std. Error Difference	Lower	Upper
Time	Equal variances assumed	-1.045	194	.297	-1.163	1.113	-3.358	1.032
	Equal variances not assumed	-1.045	193.872	.297	-1.163	1.113	-3.358	1.032
Percent Correct	Equal variances assumed	.723	194	.470	1.2074	1.6694	-2.0850	4.4999
	Equal variances not assumed	.723	164.102	.471	1.2074	1.6694	-2.0888	4.5037

participants' performances with the large size ($\bar{x}$ = 92.57, s = 13.95) and the small size ($\bar{x}$= 91.36, s = 8.84) were not significantly different in the search accuracy, t

(149) =.723, *p* =.471 (Table 28).These results indicate that differences within this size range have no effect on the visual search process for this symbol group.

Symbol Comparison, SG5 and SG2

Table 29 shows the total number of searches, mean search times, and standard deviations for time and accuracy for the initial complex geometric symbol group, SG5, and the revised complex geometric symbol group, SG2.

Table 29. Comparison of SG2 and SG5 in Time and Accuracy

Group Statistics

	SymbolGroup	N	Mean	Std. Deviation	Std. Error Mean
Time	Complex Geometric-SG 2	1091	30.51	11.743	.356
	Complex geometric-SG 5	196	20.68	7.792	.557
Percent Correct	Complex Geometric-SG 2	1091	79.402	26.6872	.8080
	Complex geometric-SG 5	196	91.967	11.6713	.8337

Analysis of Variance shows significant differences in the mean search times between the symbol groups, F (1, 1285) =127.04, $p < .001$. Also, there are significant differences in the mean search accuracy between the symbol groups, F (1, 1285) =41.988, $p < .001$ (Table 30). The response time of SG5 ($\bar{x}$ = 20.68, s =7.79) is significantly faster than that for SG2 ($\bar{x}$= 30.51, s =11.74), t (1285) =11.27, $p < .001$ (Table 31).

Table 30. Significant Differences of SG2 and SG5 in Time and Accuracy

ANOVA

		Sum of Squares	df	Mean Square	F	Sig.
Time	Between Groups	16029.770	1	16029.770	127.041	.000
	Within Groups	162139.099	1285	126.178		
	Total	178168.869	1286			
Percent Correct	Between Groups	26234.415	1	26234.415	41.988	.000
	Within Groups	802870.522	1285	624.802		
	Total	829104.938	1286			

Table 31. *t* Tests between SG2 and SG5 for Time and Accuracy

Independent Samples Test

		t-test for Equality of Means						
		t	df	Sig. (2-tailed)	Mean Difference	Std. Error Difference	95% Confidence Interval of the Difference Lower	Upper
Time	Equal variances assumed	11.271	1285	0	9.822	0.871	8.113	11.532
	Equal variances not assumed	14.873	375.422	0	9.822	0.66	8.524	11.121
Percent Correct	Equal variances assumed	-6.48	1285	0	-12.5656	1.9392	-16.37	-8.761
	Equal variances not assumed	-10.824	633.391	0	-12.5656	1.1609	-14.84	-10.28

One significant difference between SG5 and SG2 revealed by the *t* tests was in mean search accuracy. Symbols in SG5 were found at a significantly higher level of accuracy ($\bar{x} = 91.96$, $s = 11.67$) than symbols in SG2 ($\bar{x} = 79.40$, $s = 26.68$). The *t* test showed participants achieved significantly higher accuracy in searches for SG5 than SG2, $t\ (1285) = -6.48$, $p < .001$ (Table 31).

It seems that the design of the revised complex geometric symbol group is more complex than the initial design. The major element of the difference is the orientation of the symbol pattern fill, and this confused the participants and increased their errors. As a result, the symbols were identified with significantly less accuracy than those in the initial complex geometric symbol group. Design plays a significant role in making a symbol group more or less complex and, consequently, this affects either time or accuracy or both in task performance.

Chapter Seven

GEOG 104: Data Analysis of All Tests

In the previous chapters the analysis of the data was covered in two separate sections, one for the background and one for symbols. In this chapter all of the GEOG 104 test data is analyzed in order to link these two sections together (Figure 1). The first section looks at the results for the eight backgrounds that were tested with the five symbol groups. They included the following eight backgrounds (BK): white (BK1), regular linear pattern (BK2), irregular linear pattern (BK3), new imagery (BK4), shaded relief (BK5), old imagery (BK6), dense linear pattern (BK7), and the gray background (BK8).

The second part of the analysis looks at the results for each of the five symbol groups tested with the eight different types of backgrounds. The five symbol groups (SG) tested were: simple geometric (SG1), complex geometric (SG2), simple pictorial (SG3) and complex pictorial (SG4), and old complex geometric symbol group (SG5). Each group consisted of five different symbols, one or more of which was tested with each background. Time and accuracy were the response variables for the test.

Results of All Backgrounds and All Symbol Groups Together

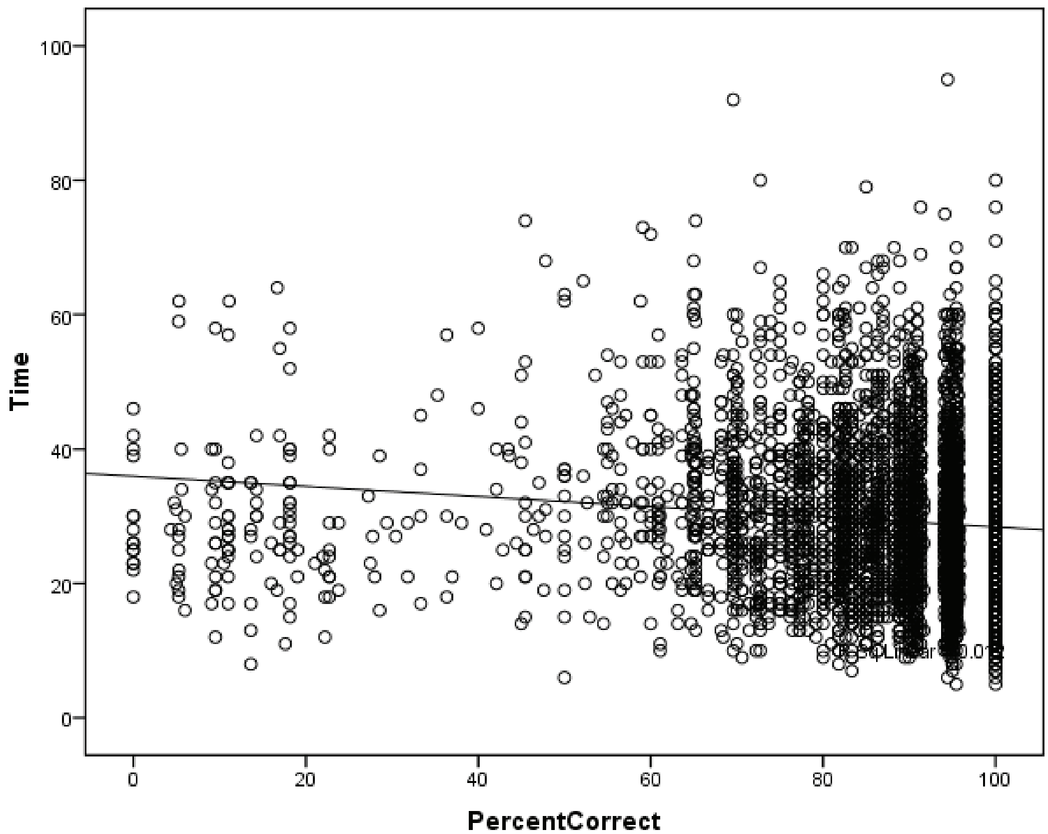


Figure 1. The 4568 responses to the tests administered in GEOG 104, involving all symbol groups and all backgrounds.

Figure 1 shows the distribution of the participants' performances on the GEOG 104 tests for all of the backgrounds and symbol groups together. Descriptive statistics for each variable are listed in Table 1: the total number of searches, the minimum and maximum search times and accuracy levels, the mean search times, and the standard deviations for time and accuracy.

Table 1. Descriptive Statistics for Time and Accuracy for GEOG 104 Tests.

Descriptive Statistics					
	N	Minimum	Maximum	Mean	Std. Deviation
Time	4568	5	95	29.39	11.679
Percent Correct	4568	0	100	86.876	17.188

The mean search times for all 4568 responses covering all backgrounds and all symbol groups was 29.39 seconds. The individual results varied from 5 to 95 seconds, with a standard deviation of 11.68. The mean search accuracy for all responses for all backgrounds and symbol groups was 86.88, with a range from 0 to 100, and a standard deviation of 17.19.

Results of the Different Five Symbol Groups for Each Background

The following section covers the analysis of the eight backgrounds that were tested with the five different symbol groups. In Figure 2 are plotted the 4568 responses, each point symbolized to show the background of the responses. Figure 3 shows on eight graphs the performances of the five different symbol groups in search time and accuracy for each background. Note that the color of each symbol represents the symbol group for each response. While it is apparent that there is a great deal of similarity in the patterns for these eight sets of responses, further examination will reveal significant differences.

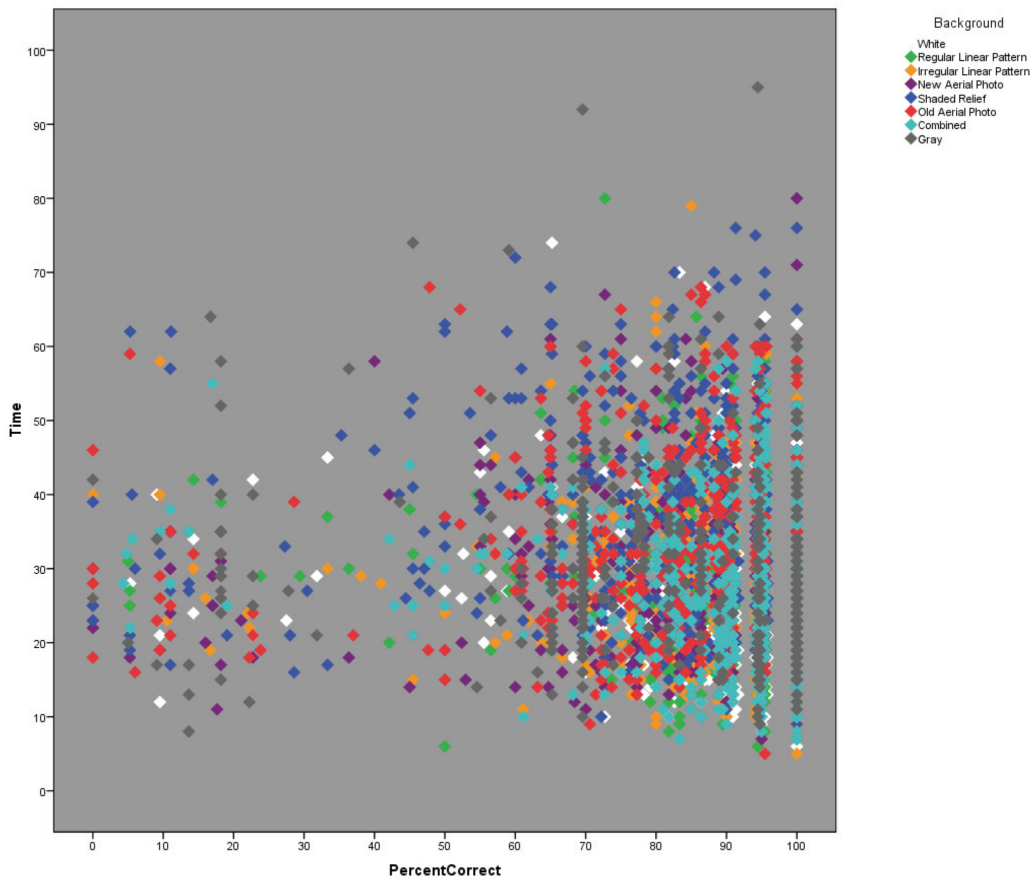


Figure 2. The 4568 responses to the series of tests administered in GEOG 104, all backgrounds.

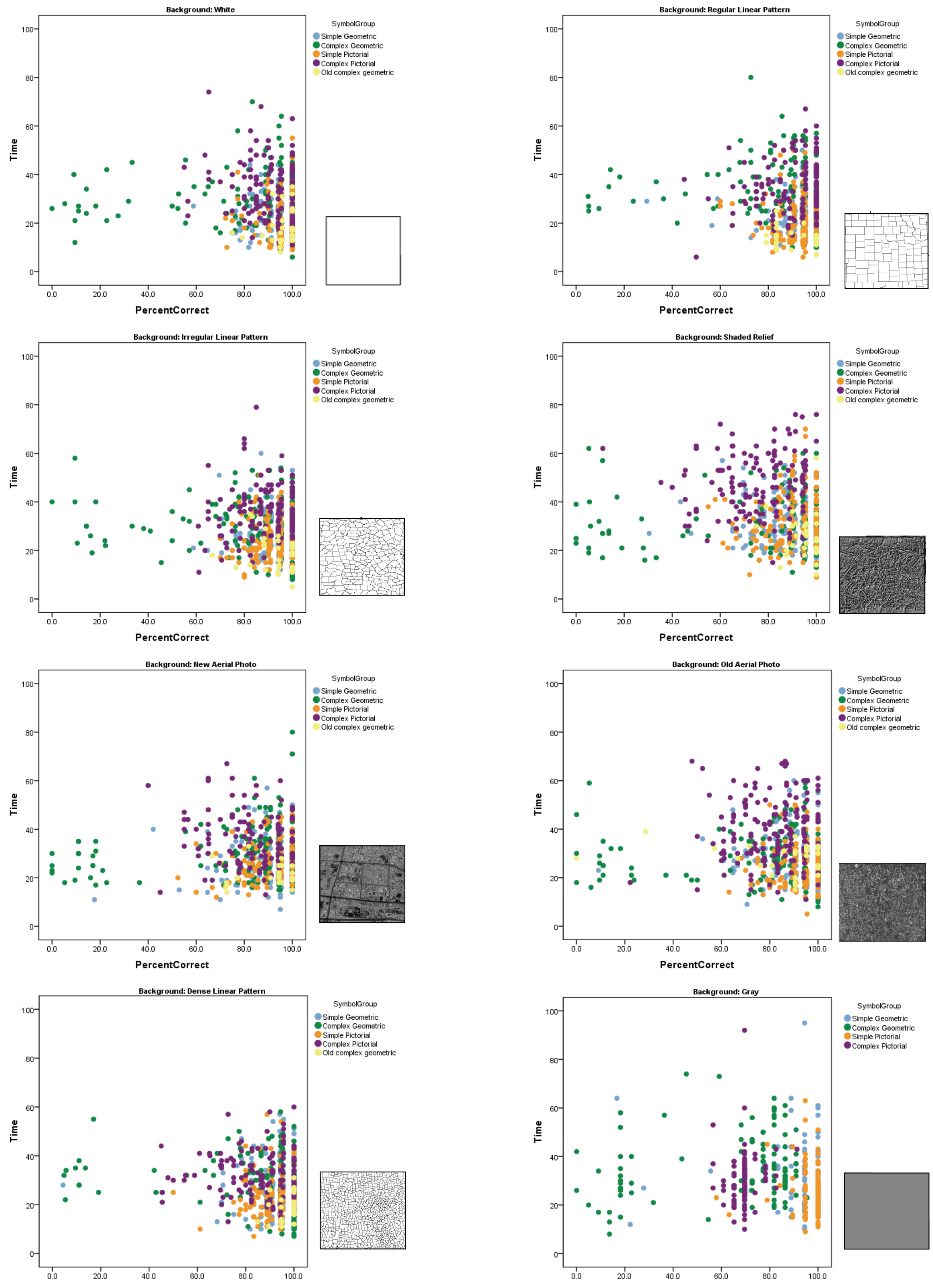


Figure 3. Results for the different symbol groups for each background show dense short-time high-accuracy clustering in the lower right, especially for the simple pictorial and old complex geometric symbol groups

Results for the Symbol Groups on the White Background

Table 2. Descriptive Statistics for Symbol Groups in Search Time on the White Background

Descriptives									
		N	Mean	Std. Deviation	Std. Error	95% Confidence Interval for Mean: Lower Bound	95% Confidence Interval for Mean: Upper Bound	Minimum	Maximum
Time on the White BK	Simple Geometric SG1	130	23.16	7.667	.672	21.83	24.49	10	44
	Complex Geometric SG2	133	29.38	12.320	1.068	27.26	31.49	6	70
	Simple Pictorial SG3	148	20.82	8.127	.668	19.50	22.14	9	55
	Complex Pictorial SG4	140	32.90	11.554	.977	30.97	34.83	11	74
	Old complex geometric SG5	28	17.86	7.240	1.368	15.05	20.66	8	35
	Total	579	26.09	11.189	.465	25.17	27.00	6	74

Table 3. Descriptive Statistics for Symbol Groups in Accuracy on the White Background

Descriptives									
						95% Confidence Interval for Mean			
		N	Mean	Std. Deviation	Std. Error	Lower Bound	Upper Bound	Minimum	Maximum
Percent Correct on the White BK	Simple Geometric SG1	130	94.210	7.1987	.6314	92.961	95.459	58.8	100
	Complex Geometric SG2	133	81.571	26.4235	2.2912	77.039	86.104	.0	100
	Simple Pictorial SG3	148	95.747	6.1188	.5030	94.753	96.741	72.2	100
	Complex Pictorial SG4	140	90.262	10.0377	.8483	88.585	91.940	55.0	100
	Old complex geometric SG5	28	95.357	6.2048	1.1726	92.951	97.763	75.0	100
	Total	579	90.801	15.3662	.6386	89.546	92.055	.0	100

The symbol system was analyzed using the two dependent variables, time and accuracy. Tables 2 and 3 show the number of searches, mean search times, and the standard deviations of both time and accuracy for each symbol group. Analysis of Variance shows that there are significant differences in the mean search times for the symbol groups, $F\ (4, 574) = 37.70$, $p < .001$. Further, there are significant differences in search accuracy among the symbol groups, $F\ (4, 574) = 20.531$, $p < .001$ (Table 4).

Table 4. Significant Differences of Symbol Groups on the White Background

ANOVA[a]

		Sum of Squares	df	Mean Square	F	Sig.
Time	Between Groups	15055.594	4	3763.899	37.704	.000
	Within Groups	57300.914	574	99.827		
	Total	72356.508	578			
Percent Correct	Between Groups	17082.522	4	4270.631	20.531	.000
	Within Groups	119395.479	574	208.006		
	Total	136478.002	578			

The mean search times for symbol groups varied from 17.86 to 32.90 seconds, and the standard deviations from 7.66 to 12.32 (Table 2). The response times for SG3 (simple pictorial) ($\bar{x}$ = 20.82, s = 12.32) and SG5 (old complex geometric) ($\bar{x}$ = 17.86, s = 7.24) were significantly faster than the other three symbol groups. The response time for SG4 ($\bar{x}$ =32.90, s = 11.55) was significantly slower than the other groups (Table 5).

Table 5. *t* Tests for Equality of Means (Time) among Symbol Groups on the White Background

Independent Samples Test							
t-test for Equality of Means (Time)							
Symbol Group	t	df	Sig. (2-tailed)	Mean Difference	Std. Error Difference	95% Confidence Interval of the Difference	
						Lower	Upper
SG3 * SG2	6.937	279	.000	8.558	1.234	6.130	10.987
SG3 * SG1	2.463	276	.014	2.344	.952	.471	4.217
SG3 * SG4	-10.309	286	.000	-12.082	1.172	-14.389	-9.775
SG2 * SG1	-4.898	261	.000	-6.214	1.269	-8.713	-3.716
SG2 * SG4	-2.439	271	.015	-3.524	1.445	-6.369	-.679
SG1 * SG4	-8.096	268	.000	-9.738	1.203	-12.107	-7.370
SG1 * SG5	3.352	156	.001	5.304	1.582	2.179	8.430
SG2 * SG5	4.770	159	.000	11.519	2.415	6.749	16.289
SG3 * SG5	1.796	174	.074	2.960	1.648	-.292	6.213
SG4 * SG5	6.625	166	.000	15.043	2.271	10.560	19.526

The mean search accuracy for individual symbol groups varied from 81.57 percent to 95.74 percent, and the standard deviation varied from 6.11 to 26.42 (Table 3). The *t* tests showed that there were no significant differences between SG1 ($\bar{x}$ = 94.21, s = 7.19), SG3 ($\bar{x}$= 95.74, s = 6.11), and SG5 ($\bar{x}$=95.35, s = 6.20), and that they are more accurate than the other symbol groups. Additionally, SG2 ($\bar{x}$ = 81.57, s = 26.42) was found significantly less accurate than the other symbol groups (Table 6).

Table 6. *t* Tests for Equality of Means (Accuracy) among Symbol Groups on the White Background

Independent Samples Test							
t-test for Equality of Means (Accuracy)							
Symbol Group	t	df	Sig. (2-tailed)	Mean Difference	Std. Error Difference	95% Confidence Interval of the Difference	
						Lower	Upper
SG3 * SG2	-6.341	279	.000	-14.1753	2.2355	-18.5758	-9.7748
SG3 * SG1	-1.923	276	.055	-1.5365	.7988	-3.1090	.0360
SG3 * SG4	5.632	286	.000	5.4843	.9737	3.5677	7.4008
SG2 * SG1	5.266	261	.000	12.6388	2.4002	7.9126	17.3650
SG2 * SG4	-3.626	271	.000	-8.6910	2.3966	-13.4094	-3.9726
SG1 * SG4	3.689	268	.000	3.9478	1.0702	1.8408	6.0548
SG1 * SG5	-.782	156	.435	-1.1469	1.4660	-4.0428	1.7489
SG2 * SG5	-2.738	159	.007	-13.7857	5.0341	-23.7281	-3.8434
SG3 * SG5	.308	174	.758	.3896	1.2638	-2.1047	2.8838
SG4 * SG5	-2.585	166	.011	-5.0947	1.9708	-8.9858	-1.2036

It would appear from the analyses that SG3 (simple pictorial) and SG5 (old complex geometric) perform best in the search task, both in terms of search time and accuracy. The fastest search time was expected to be for symbols in SG3, since the symbols in this group are simple in design, and each differs distinctly from the others in the set. However, SG5 was not expected to be fast in time with high accuracy, since the characteristics of the five symbols in the set are similar. The reason here could be, because it was against the white background, which provides the best conditions for the visual search task. Note, also, that the symbol that was being tested against the white background was for Archery, which is slightly different from the other four symbols.

Moreover, the results found that SG4 was the slowest symbol group in search time, a result that was expected because of the complexity of the symbols and their group similarity. The low accuracy of SG5 must be due to the complexity of the symbol design.

Results of the Symbol Groups on the Regular Linear Pattern Background

Table 7. Descriptive Statistics of Symbol Groups in Search Time on the Regular Linear Background

Descriptives									
						95% Confidence Interval for Mean			
		N	Mean	Std. Deviation	Std. Error	Lower Bound	Upper Bound	Minimum	Maximum
Time on the Regular Linear BK	Simple Geometric SG1	146	24.95	8.284	.686	23.59	26.30	11	50
	Complex Geometric SG2	118	33.49	13.188	1.214	31.09	35.90	10	80
	Simple Pictorial SG3	162	21.14	8.016	.630	19.89	22.38	6	50
	Complex Pictorial SG4	124	34.71	11.104	.997	32.74	36.68	6	67
	Old complex geometric SG5	26	14.08	3.773	.740	12.55	15.60	7	25
	Total	576	27.24	11.722	.488	26.28	28.20	6	80

Table 8. Descriptive Statistics of Symbol Groups in Accuracy on the Regular Linear Background

Descriptives									
		N	Mean	Std. Deviation	Std. Error	95% Confidence Interval for Mean		Minimum	Maximum
						Lower Bound	Upper Bound		
Percent Correct on the Regular Linear BK	Simple Geometric SG1	146	93.652	9.0137	.7460	92.178	95.127	29.4	100.0
	Complex Geometric SG2	118	81.091	23.4192	2.1559	76.821	85.361	5.0	100.0
	Simple Pictorial SG3	162	91.950	7.3163	.5748	90.814	93.085	60.0	100.0
	Complex Pictorial SG4	124	89.048	11.6118	1.0428	86.984	91.112	45.0	100.0
	Old complex geometric SG5	26	90.132	8.1697	1.6022	86.832	93.431	79.2	100.0
	Total	576	89.450	14.1230	.5885	88.294	90.606	5.0	100.0

The symbol groups were analyzed using the two dependent variables: time and accuracy. Tables 7 and 8 show the number of searches, mean search times, and the standard deviations for both time and accuracy. The Analysis of Variance shows that there are significant differences in the mean search times for the symbol groups, F (4, 571) = 58.05, $p < .001$. Further, there are significant differences in search accuracy among the symbol groups, F (4, 571) = 16.47, $p < .001$ (Table 9).

Table 9. Significant Differences of Symbol Groups on the Regular Linear Background

ANOVA[a]

		Sum of Squares	df	Mean Square	F	Sig.
Time	Between Groups	22840.429	4	5710.107	58.051	.000
	Within Groups	56165.460	571	98.363		
	Total	79005.889	575			
Percent Correct	Between Groups	11867.407	4	2966.852	16.476	.000
	Within Groups	102822.063	571	180.074		
	Total	114689.470	575			

The mean search times for the symbol groups varied from 14.08 to 34.71 seconds, and the standard deviations varied from 3.77 to 13.18 (Table 7). The response time for SG5 (old complex geometric) ($\bar{x}$ = 14.08, s = 3.77) was significantly faster than the other symbol groups. Additionally, average response times for SG2 ($\bar{x}$ =33.49, s = 13.18) and SG4 ($\bar{x}$ =34.71, s = 11.10) was significantly slower than the other symbol groups (Table 10).

Table10. *t* Tests for Equality of Means (Time) among Symbol Groups on the Regular Linear Background

Independent Samples Test							
t-test for Equality of Means (Time)							
Symbol Group	t	df	Sig. (2-tailed)	Mean Difference	Std. Error Difference	95% Confidence Interval of the Difference	
						Lower	Upper
SG3 * SG2	9.716	278	.000	12.356	1.272	9.852	14.859
SG3 * SG1	4.099	306	.000	3.809	.929	1.981	5.638
SG3 * SG4	-12.003	284	.000	-13.574	1.131	-15.800	-11.348
SG2 * SG1	-6.420	262	.000	-8.546	1.331	-11.168	-5.925
SG2 * SG4	-.779	240	.437	-1.218	1.564	-4.300	1.864
SG1 * SG4	-8.259	268	.000	-9.764	1.182	-12.092	-7.437
SG1 * SG5	6.557	170	.000	10.868	1.657	7.596	14.140
SG2 * SG5	7.422	142	.000	19.415	2.616	14.243	24.586
SG3 * SG5	4.405	186	.000	7.059	1.602	3.898	10.220
SG4 * SG5	9.341	148	.000	20.633	2.209	16.268	24.998

The mean search accuracy for individual symbol groups varied from 81.09 percent to 93.65 percent, and the standard deviations from 7.3 to 23.41 (Table 8). The *t* tests showed that there were no significant differences in accuracy between SG1 ($\bar{x}$ = 93.65, s = 9.01), SG3 ($\bar{x}$= 91.95, s = 7.31), and SG5 ($\bar{x}$= 90.13, s = 8.16). Additionally, SG2 ($\bar{x}$ =81.09, s = 23.41) was found significantly less accurate than the other symbol groups (Table 11).

Table 11. *t* Tests for Equality of Means (Accuracy) among Symbol Groups on the Regular Linear Background

Independent Samples Test							
t-test for Equality of Means (Accuracy)							
Symbol Group	t	df	Sig. (2-tailed)	Mean Difference	Std. Error Difference	95% Confidence Interval of the Difference	
						Lower	Upper
SG3 * SG2	-5.545	278	.000	-10.8584	1.9583	-14.7135	-7.0034
SG3 * SG1	1.828	306	.069	1.7029	.9317	-.1305	3.5362
SG3 * SG4	2.581	284	.010	2.9014	1.1240	.6889	5.1139
SG2 * SG1	5.960	262	.000	12.5613	2.1077	8.4112	16.7114
SG2 * SG4	-3.373	240	.001	-7.9570	2.3590	-12.6041	-3.3100
SG1 * SG4	3.665	268	.000	4.6043	1.2564	2.1307	7.0779
SG1 * SG5	1.860	170	.065	3.5209	1.8933	-.2166	7.2584
SG2 * SG5	-1.938	142	.055	-9.0404	4.6650	-18.2622	.1814
SG3 * SG5	1.157	186	.249	1.8180	1.5711	-1.2815	4.9176
SG4 * SG5	-.452	148	.652	-1.0834	2.3954	-5.8171	3.6503

It would appear from the analyses that SG5 performs best for the search task, both in terms of search time and accuracy. Within SG5 the characteristics of the symbols are similar; the search here was against a regular linear pattern background, which divided the background into areas and may have helped in the visual search task. Further, note that the symbol tested was golfing, which is slightly different than the other four symbols.

The results showed that the highest mean search accuracy was for SG3, SG5, and SG1. One reason for this could be that all the symbols are distinctly different from each other in many ways, so high accuracy was expected. The high degree of accuracy for SG1 could also be, because the symbols are all simple in their characteristics. The high degree of accuracy in the searches involving symbols in SG5 could be, because SG5 was tested with the regular linear background, and the golfing symbol tested was distinctive from the other four symbols.

Moreover, the results found that SG2 was the slowest symbol group in mean search time and accuracy, a result that was expected because of the complexity of the symbols in the SG2 group. These symbols also look similar to each other, which makes them harder to distinguish.

Results of the Symbol Groups on the Irregular Linear Background

Table 12. Descriptive Statistics for Symbol Groups in Search Time on the Irregular Linear Background

Descriptives									
						95% Confidence Interval for Mean			
		N	Mean	Std. Deviation	Std. Error	Lower Bound	Upper Bound	Minimum	Maximum
Time on the Irregular Linear BK	Simple Geometric	149	28.01	8.436	.691	26.65	29.38	12	60
	Complex Geometric	146	30.36	10.847	.898	28.59	32.14	8	58
	Simple Pictorial	166	24.94	7.836	.608	23.74	26.14	9	51
	Complex Pictorial	134	35.37	10.736	.927	33.53	37.20	11	79
	Old complex geometric	30	18.20	7.227	1.320	15.50	20.90	5	35

Table 13. Descriptive Statistic of Symbol Groups in Accuracy on the Irregular Linear Background

Descriptives									
						95% Confidence Interval for Mean			
		N	Mean	Std. Deviation	Std. Error	Lower Bound	Upper Bound	Minimum	Maximum
Percent Correct on the Irregular Linear BK	Simple Geometric	149	93.086	8.1625	.6687	91.765	94.408	58.8	100.0
	Complex Geometric	146	81.009	23.6994	1.9614	77.132	84.885	.0	100.0
	Simple Pictorial	166	92.374	6.8846	.5343	91.319	93.429	70.0	100.0
	Complex Pictorial	134	87.979	10.2814	.8882	86.222	89.735	60.9	100.0
	Old complex geometric	30	92.723	8.1773	1.4930	89.670	95.777	66.7	100.0

Tables 12 and 13 show the number of searches, the mean search times, and the standard deviations for both time and accuracy for each symbol group. Analysis of Variance shows that there are significant differences in the mean search times for the symbol groups, F (4, 620) = 34.27, $p < .001$. Further, there are significant differences in search accuracy among the symbol groups, F (4, 620) = 19.19, $p < .001$ (Table 14).

Table 14. Significant Differences of Symbol Groups on Irregular Linear Background

ANOVA[a]

		Sum of Squares	df	Mean Square	F	Sig.
Time	Between Groups	12068.148	4	3017.037	34.278	.000
	Within Groups	54571.013	620	88.018		
	Total	66639.162	624			
Percent Correct	Between Groups	14256.154	4	3564.039	19.195	.000
	Within Groups	115120.601	620	185.678		
	Total	129376.756	624			

The mean search times for individual symbol groups varied from 18.20 to 35.37 seconds, and the standard deviations varied from 7.22 to 10.84 (Table 12). The response time for SG5 (old complex geometric) ($\bar{x}$ = 18.20, s = 7.22) was significantly faster than for the four other symbol groups. *t* tests showed participants had a significantly faster search time for SG5 than for the other symbol groups. Additionally, response time of SG4 ($\bar{x}$ =35.37, s = 10.73) was significantly slower than the other symbol groups. (Table 15).

Table 15. *t* Tests for Equality of Means (Time) among Symbol Groups on the Irregular Linear Background

Independent Samples Test							
t-test for Equality of Means (Time)							
Symbol Group	t	df	Sig. (2-tailed)	Mean Difference	Std. Error Difference	95% Confidence Interval of the Difference	
						Lower	Upper
SG3 * SG2	5.103	310	.000	5.423	1.063	3.332	7.514
SG3 * SG1	3.352	313	.001	3.074	.917	1.270	4.878
SG3 * SG4	-9.712	298	.000	-10.426	1.073	-12.538	-8.313
SG2 * SG1	-2.079	293	.038	-2.350	1.130	-4.574	-.125
SG2 * SG4	-6.437	281	.000	-7.352	1.142	-9.601	-5.104
SG1 * SG4	-3.874	278	.000	-5.003	1.291	-7.545	-2.461
SG1 * SG5	5.944	177	.000	9.813	1.651	6.555	13.071
SG2 * SG5	5.872	174	.000	12.163	2.071	8.075	16.251
SG3 * SG5	4.385	194	.000	6.740	1.537	3.708	9.771
SG4 * SG5	8.334	162	.000	17.166	2.060	13.098	21.233

The mean search accuracy for individual symbol groups varied from 81.00 percent to 93.08 percent, and the standard deviation varied from 6.88 to 23.69 (Table 13). The *t* tests showed that there were no significant differences between SG1 ($\bar{x}$ = 93.08, *s* = 8.16), SG3 ($\bar{x}$= 92.37, *s* = 6.88), and SG5 ($\bar{x}$= 92.72, *s* = 8.17). Additionally, SG2 ($\bar{x}$ = 81.00, *s* = 23.69) was found to be significantly less accurate than the other symbol groups (Table 16).

Table 16. *t* Tests for Equality of Means (Accuracy) among Symbol Groups on the Irregular Linear Background

Independent Samples Test							
t-test for Equality of Means (Accuracy)							
Symbol Group	t	df	Sig. (2-tailed)	Mean Difference	Std. Error Difference	95% Confidence Interval of the Difference	
						Lower	Upper
SG3 * SG2	-5.903	310	.000	-11.3655	1.9253	-15.1538	-7.5772
SG3 * SG1	.839	313	.402	.7119	.8482	-.9570	2.3808
SG3 * SG4	4.417	298	.000	4.3957	.9951	2.4374	6.3540
SG2 * SG1	5.875	293	.000	12.0774	2.0556	8.0317	16.1231
SG2 * SG4	4.650	281	.000	5.1076	1.0984	2.9454	7.2698
SG1 * SG4	-3.143	278	.002	-6.9698	2.2173	-11.3347	-2.6049
SG1 * SG5	.222	177	.825	.3628	1.6339	-2.8616	3.5873
SG2 * SG5	-2.670	174	.008	-11.7145	4.3881	-20.3753	-3.0538
SG3 * SG5	-.248	194	.804	-.3490	1.4071	-3.1243	2.4262
SG4 * SG5	-2.364	162	.019	-4.7447	2.0072	-8.7084	-.7811

From the analyses it is clear that SG5 performed best for the search task, both in terms of time and accuracy. That was unexpected, since the characteristics of the symbol shapes are similar. There is, however, the consideration that the linear pattern of the background divided the background into areas, making the search process easier.

Moreover, the results found that SG4 had the slowest search time, a result that was expected, not only because of the complexity of the symbols in the SG4 group, but also because their similarity in appearance.

The results showed the highest mean search accuracy for SG3, SG5, and SG1. The reason for this is, as mentioned before, was that SG3 was simple in its characteristics; the symbols were distinctly different from each other in many ways, so high accuracy was expected. The high degree of accuracy for SG1 symbols could be, because each symbol is simple in its characteristics. The high degree of accuracy in the searches involving symbols in SG5 probably occurred, because SG5 was tested against a linear pattern that helped to divide the background into areas and made the visual search task easier. On the other hand, SG2 had the low degree of accuracy, because of the complex characteristics of the symbol design.

Results of the Symbol Groups on the New Imagery Background

Table 17. Descriptive Statistics for Symbol Groups in Search Time on the New Imagery Background

Descriptives									
		N	Mean	Std. Deviation	Std. Error	95% Confidence Interval for Mean		Minimum	Maximum
						Lower Bound	Upper Bound		
Time on the New Imagery BK	Simple Geometric	147	27.14	9.214	.760	25.64	28.64	7	57
	Complex Geometric	165	29.43	10.496	.817	27.82	31.04	15	80
	Simple Pictorial	136	26.98	7.885	.676	25.64	28.32	12	48
	Complex Pictorial	123	35.61	10.749	.969	33.69	37.53	13	67
	Old complex geometric	26	21.19	4.427	.868	19.40	22.98	14	33

Table 18. Descriptive Statistics of Symbol Groups in Accuracy on the New Imagery Background

Descriptives									
						95% Confidence Interval for Mean			
		N	Mean	Std. Deviation	Std. Error	Lower Bound	Upper Bound	Minimum	Maximum
Percent Correct on the New Imagery BK	Simple Geometric	147	89.940	11.8084	.9739	88.015	91.865	17.6	100.0
	Complex Geometric	165	79.574	27.1898	2.1167	75.395	83.754	.0	100.0
	Simple Pictorial	136	90.265	9.6619	.8285	88.626	91.904	52.4	100.0
	Complex Pictorial	123	83.174	13.7171	1.2368	80.726	85.622	40.0	100.0
	Old complex geometric	26	90.132	10.6806	2.0946	85.818	94.446	66.7	100.0

The symbols were analyzed using the two dependent variables: time and accuracy. Tables 17 and 18 show the number of searches, mean search times, and standard deviations for both time and accuracy for each symbol group. Analysis of Variance shows that there were significant differences in the mean search times, F (4, 592) = 22.21, $p < .001$. Further, there are significant differences in search accuracy among the symbol groups, F (4, 592) = 10.65, $p < .001$ (Table 19). The mean search times for individual symbol group varied from 21.19 to 35.61 seconds, and the standard deviations from 4.42 to 10.74 (Table 17).

Table 19. Significant Differences of Symbol Groups on the New Imagery Background

ANOVA[a]

		Sum of Squares	df	Mean Square	F	Sig.
Time	Between Groups	8022.681	4	2005.670	22.218	.000
	Within Groups	53440.689	592	90.271		
	Total	61463.370	596			
Percent Correct	Between Groups	12961.619	4	3240.405	10.657	.000
	Within Groups	180010.440	592	304.072		
	Total	192972.059	596			

The response time for SG5 (old complex geometric) ($\bar{x}$ = 21.19, s = 4.42) was significantly faster than the other four symbol groups. In contrast, the response time for SG4 ($\bar{x}$ = 35.61, s = 10.74) was significantly slower than for the other symbol groups, and the *t* tests showed that the participants had significantly slower search times for SG4 than the other symbol groups (Table 20).

Table 20. *t* Tests for Equality of Means (Time) among Symbol Groups on the New Imagery Background

Independent Samples Test							
t-test for Equality of Means (Time)							
Symbol Group	t	df	Sig. (2-tailed)	Mean Difference	Std. Error Difference	95% Confidence Interval of the Difference	
						Lower	Upper
SG3 * SG1	.161	281	.872	.165	1.023	-1.850	2.179
SG3 * SG2	2.251	299	.025	2.452	1.089	.308	4.596
SG3 * SG4	-7.416	257	.000	-8.632	1.164	-10.924	-6.340
SG2 * SG1	-2.035	310	.043	-2.287	1.124	-4.500	-.075
SG2 * SG4	-4.892	286	.000	-6.179	1.263	-8.666	-3.693
SG1 * SG4	-6.969	268	.000	-8.467	1.215	-10.859	-6.075
SG1 * SG5	3.222	171	.002	5.951	1.847	2.305	9.596
SG2 * SG5	3.940	189	.000	8.238	2.091	4.114	12.362
SG3 * SG5	3.628	160	.000	5.786	1.595	2.636	8.935
SG4 * SG5	6.706	147	.000	14.417	2.150	10.168	18.666

The mean search accuracy for individual symbol groups varied from 79.57 percent to 90.26 percent, and the standard deviations varied from 9.66 to 27.18 (Table 18). The *t* tests showed that there were no significant differences between SG1 ($\bar{x}$ = 89.94, s = 11.80), SG3 ($\bar{x}$= 90.26, s = 9.66), and SG5 ($\bar{x}$= 90.13, s = 10.68); they were found to be significantly more accurate than the other symbol groups. Further, SG2 ($\bar{x}$ = 79.57, s = 27.18) and SG4 ($\bar{x}$ =83.17, s = 13.71) were found significantly less accurate than the other symbol groups (Table 21).

Table 21. *t* Tests for Equality of Means (Accuracy) among Symbol Groups on the New Imagery Background

Independent Samples Test							
t-test for Equality of Means (Accuracy)							
Symbol Group	t	df	Sig. (2-tailed)	Mean Difference	Std. Error Difference	95% Confidence Interval of the Difference	
						Lower	Upper
SG3 * SG1	-.252	281	.801	-.3252	1.2886	-2.8616	2.2113
SG3 * SG2	-4.363	299	.000	-10.6909	2.4504	-15.5131	-5.8686
SG3 * SG4	4.845	257	.000	7.0910	1.4636	4.2088	9.9732
SG2 * SG1	4.276	310	.000	10.3657	2.4240	5.5962	15.1352
SG2 * SG4	-1.346	286	.179	-3.5999	2.6748	-8.8648	1.6650
SG1 * SG4	4.355	268	.000	6.7658	1.5535	3.7072	9.8245
SG1 * SG5	-.078	171	.938	-.1923	2.4787	-5.0849	4.7004
SG2 * SG5	-1.953	189	.052	-10.5580	5.4067	-21.2232	.1073
SG3 * SG5	.063	160	.950	.1329	2.1036	-4.0215	4.2873
SG4 * SG5	-2.433	147	.016	-6.9581	2.8600	-12.6101	-1.3061

It is clear from the analyses that SG5 performs best for the search task, both in terms of search time and accuracy. The design of the SG5 symbol seems to help the symbols pop out of the background.

The results show that the highest mean search accuracy was for SG3, SG5, and SG1. The SG3 symbols are simple in their characteristics, and distinctly different from each other. Each SG1 symbol is simple in its characteristics and different enough to promote an accurate search.

The SG4 symbols was the slowest symbol group in search time and lowest in accuracy, results expected because of the complexity of the symbols in the group. All of the symbols look similar to each other. Again, SG2 was low in search accuracy, because the characteristics of the symbols are very complex.

Results of the Symbol Groups on the Shaded Relief Background

Table 22. Descriptive Statistics for Symbol Groups in Search Time on the Shaded Relief Background

Descriptives									
		N	Mean	Std. Deviation	Std. Error	95% Confidence Interval for Mean		Minimum	Maximum
						Lower Bound	Upper Bound		
Time on the Shaded Relief BK	Simple Geometric	141	31.74	9.547	.804	30.15	33.33	17	57
	Complex Geometric	134	31.05	10.864	.938	29.20	32.91	11	62
	Simple Pictorial	147	32.77	11.210	.925	30.94	34.60	9	70
	Complex Pictorial	136	47.43	12.590	1.080	45.30	49.57	15	76
	Old complex geometric	30	25.63	9.118	1.665	22.23	29.04	10	58

Table 23. Descriptive Statistics for Symbol Groups in Accuracy on the Shaded Relief Background

Descriptives									
		N	Mean	Std. Deviation	Std. Error	95% Confidence Interval for Mean		Minimum	Maximum
						Lower Bound	Upper Bound		
Percent Correct on the Shaded Relief BK	Simple Geometric	141	86.243	12.0417	1.0141	84.238	88.248	30.4	100.0
	Complex Geometric	134	79.167	30.2673	2.6147	73.995	84.338	.0	100.0
	Simple Pictorial	147	88.512	10.6315	.8769	86.779	90.245	55.0	100.0
	Complex Pictorial	136	75.769	15.7009	1.3463	73.107	78.432	11.1	100.0
	Old complex geometric	30	94.361	6.5678	1.1991	91.909	96.814	75.0	100.0

The symbol system was analyzed using the two dependent variables: time and accuracy. Tables 22 and 23 show the number of searches, mean search times, and the standard deviations of both time and accuracy. Analysis of Variance shows that there were significant differences in the mean search times for the symbol groups, F (4, 583) = 57.72, $p < .001$. Further, there were significant differences in search accuracy among the symbol groups, F (4, 583) = 14.24, $p < .001$ (Table 24).

Table 24. Significant Differences of Symbol Group on Shaded Relief Background

ANOVA[a]

		Sum of Squares	df	Mean Square	F	Sig.
Time	Between Groups	27963.859	4	6990.965	57.720	.000
	Within Groups	70612.432	583	121.119		
	Total	98576.291	587			
Percent Correct	Between Groups	18880.119	4	4720.030	14.245	.000
	Within Groups	193175.565	583	331.347		
	Total	212055.684	587			

The mean search times for individual symbol groups varied from 25.63 to 47.43 seconds, and the standard deviations from 9.11 to 12.59 (Table 22). The response time for SG5 (old complex geometric) ($\bar{x}$ = 25.63, s = 9.11) was significantly faster than the other symbol groups. Additionally, the response time of SG4 ($\bar{x}$ = 47.43, s = 12.59) was significantly slower than that of the other symbol groups (Table 25).

Table 25. *t* Tests for Equality of Means (Time) among Symbol Groups on the Shaded Relief Background

Independent Samples Test							
t-test for Equality of Means (Time)							
Symbol Group	t	df	Sig. (2-tailed)	Mean Difference	Std. Error Difference	95% Confidence Interval of the Difference	
						Lower	Upper
SG3 * SG1	-.839	286	.402	-1.031	1.229	-3.451	1.389
SG3 * SG2	-1.301	279	.194	-1.716	1.319	-4.314	.881
SG3 * SG4	-10.364	281	.000	-14.665	1.415	-17.450	-11.880
SG2 * SG1	.556	273	.578	.685	1.232	-1.740	3.110
SG2 * SG4	-11.439	268	.000	-16.382	1.432	-19.201	-13.562
SG1 * SG4	-11.718	275	.000	-15.696	1.340	-18.333	-13.059
SG1 * SG5	3.204	169	.002	6.104	1.905	2.344	9.865
SG2 * SG5	2.538	162	.012	5.419	2.135	1.202	9.636
SG3 * SG5	3.270	175	.001	7.135	2.182	2.829	11.442
SG4 * SG5	8.970	164	.000	21.800	2.430	17.001	26.599

The mean search accuracy for individual symbol groups varied from 75.76 percent to 94.36 percent, and the standard deviations varied from 6.56 to 30.26 (Table 23). *t* tests showed that there were significant differences between SG5 ($\bar{x}$ = 94.36, s = 6.56) and the other symbol groups. Additionally, SG2 ($\bar{x}$ = 79.167, s = 30.26) and SG4 ($\bar{x}$ = 75.76, s = 15.70) were found significantly less accurate than the other symbol groups (Table 26).

Table 26. *t* Tests for Equality of Means (Accuracy) among Symbol Groups on the Shaded Relief Background

Independent Samples Test							
t-test for Equality of Means (Accuracy)							
Symbol Group	t	df	Sig. (2-tailed)	Mean Difference	Std. Error Difference	95% Confidence Interval of the Difference	
						Lower	Upper
SG3 * SG1	-1.697	286	.091	-2.2686	1.3372	-4.9005	.3633
SG3 * SG2	-3.514	279	.001	-9.3453	2.6596	-14.5808	-4.1098
SG3 * SG4	8.047	281	.000	12.7427	1.5836	9.6254	15.8599
SG2 * SG1	2.571	273	.011	7.0767	2.7529	1.6572	12.4963
SG2 * SG4	1.160	268	.247	3.3973	2.9284	-2.3682	9.1629
SG1 * SG4	6.243	275	.000	10.4741	1.6776	7.1714	13.7767
SG1 * SG5	-3.575	169	.000	-8.1178	2.2705	-12.6000	-3.6356
SG2 * SG5	-2.729	162	.007	-15.1945	5.5676	-26.1889	-4.2001
SG3 * SG5	-2.899	175	.004	-5.8492	2.0178	-9.8316	-1.8668
SG4 * SG5	-6.352	164	.000	-18.5919	2.9269	-24.3711	-12.8126

SG5 performed best for both search tasks, time and accuracy. Although the characteristics of the symbols seem similar to each other, the target symbol was found quickly and accurately against the shaded relief background.

The results point out that SG4 was the slowest symbol group in mean search time and the lowest in accuracy.

In addition, the results showed that SG2 was, statistically, lowest in mean search accuracy, a result of the complex characteristics of the symbol design.

Results of the Symbol Groups on the Old Imagery Background

Table 27. Descriptive Statistics of Symbol Groups in Search Time on the Old Imagery Background

Descriptives									
		N	Mean	Std. Deviation	Std. Error	95% Confidence Interval for Mean		Minimum	Maximum
						Lower Bound	Upper Bound		
Time on the Old Imagery BK	Simple Geometric	133	28.47	10.025	.869	26.75	30.19	9	60
	Complex Geometric	147	27.90	10.075	.831	26.26	29.55	8	59
	Simple Pictorial	134	25.31	8.257	.713	23.90	26.72	5	50
	Complex Pictorial	167	39.99	12.579	.973	38.07	41.92	11	68
	Old complex geometric	30	27.77	5.876	1.073	25.57	29.96	15	39

Table 28. Descriptive Statistics of Symbol Groups in Accuracy on the Old Imagery Background

Descriptives									
		N	Mean	Std. Deviation	Std. Error	95% Confidence Interval for Mean		Minimum	Maximum
						Lower Bound	Upper Bound		
Percent Correct on the Old Imagery BK	Simple Geometric	133	88.693	12.7044	1.1016	86.514	90.872	9.1	100.0
	Complex Geometric	147	78.082	27.0141	2.2281	73.678	82.485	.0	100.0
	Simple Pictorial	134	92.524	7.9418	.6861	91.167	93.881	63.2	100.0
	Complex Pictorial	167	81.731	13.2747	1.0272	79.703	83.759	22.2	100.0
	Old complex geometric	30	84.444	22.1925	4.0518	76.158	92.731	.0	100.0

The symbol groups were analyzed using the two dependent variables: time and accuracy. Tables 27 and 28 show the number of searches, mean search times, and standard deviations for both time and accuracy for each symbol group. Analysis of Variance shows that there were significant differences in mean search times for the symbol groups, F (4, 606) = 47.94, $p < .001$. Further, there were significant differences in search accuracy among the symbol groups, F (4, 606) = 15.35, $p < .001$ (Table 29).

Table 29. Significant Differences of Symbol Groups on the Old Imagery Background

ANOVA[a]

		Sum of Squares	df	Mean Square	F	Sig.
Time	Between Groups	20388.024	4	5097.006	47.944	.000
	Within Groups	64424.640	606	106.311		
	Total	84812.664	610			
Percent Correct	Between Groups	18217.898	4	4554.474	15.353	.000
	Within Groups	179773.419	606	296.656		
	Total	197991.316	610			

The mean search times for the individual symbol groups varied from 25.31 to 39.99 seconds, and the standard deviations varied from 5.87 to 12.57 (Table 27). There was no significant difference in the response times for SG3 (simple pictorial) ($\bar{x}$ = 25.31, s = 8.25) and SG5 (old complex geometric) ($\bar{x}$ = 27.77, s = 5.87). The response time for SG4 ($\bar{x}$ = 39.99, s = 12.57) was significantly slower than the other symbol groups (Table 30).

Table 30. *t* Tests for Equality of Means (Time) among Symbol Groups on the Old Imagery Background

Independent Samples Test							
t-test for Equality of Means (Time)							
Symbol Group	t	df	Sig. (2-tailed)	Mean Difference	Std. Error Difference	95% Confidence Interval of the Difference	
						Lower	Upper
SG3 * SG1	2.819	265	.005	3.168	1.124	.955	5.380
SG3 * SG2	2.351	279	.019	2.599	1.105	.423	4.774
SG3 * SG4	-11.650	299	.000	-14.688	1.261	-17.169	-12.207
SG2 * SG1	.473	278	.637	.569	1.203	-1.799	2.937
SG2 * SG4	-9.315	312	.000	-12.089	1.298	-14.643	-9.536
SG1 * SG4	-8.606	298	.000	-11.520	1.339	-14.155	-8.886
SG1 * SG5	.372	161	.711	.707	1.903	-3.051	4.465
SG2 * SG5	.072	175	.942	.138	1.905	-3.622	3.898
SG3 * SG5	-1.545	162	.124	-2.461	1.592	-5.605	.684
SG4 * SG5	5.214	195	.000	12.227	2.345	7.603	16.852

The mean search accuracy for individual symbol groups varied from 78.08 percent to 92.52 percent, and the standard deviations varied from 7.94 to 27.01 (Table 28). *t* tests showed that there were significant differences between SG3 ($\bar{x}$ = 92.52, s = 7.94) and the other groups; SG3 was significantly more accurate than the other groups. On the other hand, SG2 ($\bar{x}$ = 78.08, s = 27.01), SG4 ($\bar{x}$ = 81.73, s = 13.27), and SG5 ($\bar{x}$ = 84.44, s = 22.19) were found significantly less accurate than the other symbol groups (Table 31).

Table 31. *t* Tests for Equality of Means (Accuracy) among Symbol Groups on the Old Imagery Background

Independent Samples Test							
t-test for Equality of Means (Accuracy)							
Symbol Group	t	df	Sig. (2-tailed)	Mean Difference	Std. Error Difference	95% Confidence Interval of the Difference	
						Lower	Upper
SG3 * SG1	-2.956	265	.003	-3.8305	1.2956	-6.3816	-1.2795
SG3 * SG2	-5.957	279	.000	-14.4418	2.4242	-19.2138	-9.6698
SG3 * SG4	8.294	299	.000	10.7926	1.3013	8.2318	13.3534
SG2 * SG1	4.135	278	.000	10.6113	2.5664	5.5592	15.6633
SG2 * SG4	-1.547	312	.123	-3.6492	2.3595	-8.2918	.9933
SG1 * SG4	4.599	298	.000	6.9620	1.5138	3.9830	9.9410
SG1 * SG5	1.414	161	.159	4.2485	3.0050	-1.6858	10.1828
SG2 * SG5	-1.209	175	.228	-6.3627	5.2642	-16.7522	4.0267
SG3 * SG5	3.381	162	.001	8.0791	2.3894	3.3607	12.7975
SG4 * SG5	-.916	195	.361	-2.7135	2.9629	-8.5569	3.1300

According to the analyses SG3 was best for the search task, both in terms of time and accuracy. Although the characteristics of the symbols in SG5 look alike, SG5 worked best for search time but was low in accuracy.

Moreover, the results found that statistically, SG4 was the slowest symbol group in mean search time and lowest in accuracy, results expected because of the complexity of the symbols in the SG4 group. SG2 was also low in accuracy since symbol characteristics were complex, i.e., very similar to each other.

Results of the Symbol Groups on the Dense Linear Pattern Background

Table 32. Descriptive Statistics of Symbol Groups in Search Time on the Dense Linear Background

Descriptives									
		N	Mean	Std. Deviation	Std. Error	95% Confidence Interval for Mean Lower Bound	95% Confidence Interval for Mean Upper Bound	Minimum	Maximum
Time on the Dense Linear BK	Simple Geometric	134	27.01	10.371	.896	25.24	28.79	10	57
	Complex Geometric	150	28.71	11.565	.944	26.84	30.57	7	58
	Simple Pictorial	166	23.30	8.233	.639	22.04	24.56	7	57
	Complex Pictorial	124	32.88	9.141	.821	31.25	34.50	13	60
	Old complex geometric	26	18.81	5.543	1.087	16.57	21.05	11	31

Table. 33. Descriptive Statistics of Symbol Groups in Accuracy on the Dense Linear Background

Descriptives									
		N	Mean	Std. Deviation	Std. Error	95% Confidence Interval for Mean Lower Bound	95% Confidence Interval for Mean Upper Bound	Minimum	Maximum
Percent Correct on the Dense Linear BK	Simple Geometric	134	92.333	10.6858	.9231	90.507	94.159	4.3	100.0
	Complex Geometric	150	85.663	22.9834	1.8766	81.955	89.371	4.8	100.0
	Simple Pictorial	166	91.849	7.4414	.5776	90.709	92.990	50.0	100.0
	Complex Pictorial	124	84.693	13.6432	1.2252	82.268	87.118	45.0	100.0
	Old complex geometric	26	97.034	4.3761	.8582	95.267	98.802	85.0	100.0

The symbol groups were analyzed using the two dependent variables: time and accuracy. Tables 32 and 33 show the number of searches, mean search times, and standard deviations for both time and accuracy for each symbol group. Analysis of Variance shows that there were significant differences in the mean search times for the symbol groups, F (4, 595) = 22.91, $p < .001$. Further, there were significant differences in search accuracy among the backgrounds, F (4, 595) = 9.96, $p < .001$ (Table 34).

Table 34. Significant Differences of Symbol Group on the Dense Linear Background

ANOVA[a]

		Sum of Squares	df	Mean Square	F	Sig.
Time	Between Groups	8696.106	4	2174.027	22.910	.000
	Within Groups	56463.227	595	94.896		
	Total	65159.333	599			
Percent Correct	Between Groups	8470.529	4	2117.632	9.968	.000
	Within Groups	126404.197	595	212.444		
	Total	134874.726	599			

The mean search times for the individual symbol groups varied from 18.18 to 32.88 seconds, and the standard deviations varied from 5.54 to 11.56 (Table 32). The response time for SG5 (old complex geometric) ($\bar{x}$ = 18.81, s = 5.54) was significantly faster than the other four symbol groups. Additionally, the response time of SG4 ($\bar{x}$ = 32.88, s = 9.14) was significantly slower than the other symbol groups, and *t* tests showed that SG4 had a significantly slower search time than the other symbol groups (Table 35).

Table 35. *t* Tests for Equality of Means (Time) among Symbol Groups on the Dense Linear Background

Independent Samples Test							
t-test for Equality of Means (Time)							
Symbol Group	t	df	Sig. (2-tailed)	Mean Difference	Std. Error Difference	95% Confidence Interval of the Difference	
						Lower	Upper
SG3 * SG1	3.458	298	.001	3.714	1.074	1.600	5.827
SG3 * SG2	4.820	314	.000	5.405	1.121	3.199	7.612
SG3 * SG4	-9.347	288	.000	-9.578	1.025	-11.595	-7.561
SG2 * SG1	-1.292	282	.198	-1.692	1.310	-4.270	.886
SG2 * SG4	-3.262	272	.001	-4.172	1.279	-6.690	-1.654
SG1 * SG4	-4.803	256	.000	-5.864	1.221	-8.269	-3.460
SG1 * SG5	3.921	158	.000	8.207	2.093	4.073	12.341
SG2 * SG5	4.273	174	.000	9.899	2.317	5.326	14.472
SG3 * SG5	2.686	190	.008	4.494	1.673	1.194	7.793
SG4 * SG5	7.551	148	.000	14.071	1.863	10.389	17.754

The mean search accuracy for individual symbol groups varied from 84.69 percent to 97.03 percent, and the standard deviations from 4.37 to 22.98 (Table 33). *t* tests showed that there were significant differences between SG5 ($\bar{x}$= 97.03, s = 4.37) and the other symbol groups in search accuracy. Additionally, SG2 ($\bar{x}$ = 85.66, s = 22.98) and SG4 ($\bar{x}$ = 84.69, s = 13.64) were found significantly less accurate than the other symbol groups, and *t* tests showed that the two groups were less accurate than the other symbol groups (Table 36).

Table 36. *t* Tests for Equality of Means (Accuracy) among Symbol Groups on the Dense Linear Background

Independent Samples Test							
t-test for Equality of Means (Accuracy)							
Symbol Group	t	df	Sig. (2-tailed)	Mean Difference	Std. Error Difference	95% Confidence Interval of the Difference	
						Lower	Upper
SG3 * SG1	.461	298	.645	.4835	1.0492	-1.5813	2.5482
SG3 * SG2	-3.283	314	.001	-6.1863	1.8842	-9.8936	-2.4789
SG3 * SG4	5.717	288	.000	7.1566	1.2518	4.6928	9.6204
SG2 * SG1	3.075	282	.002	6.6697	2.1690	2.4003	10.9392
SG2 * SG4	.414	272	.679	.9704	2.3458	-3.6478	5.5885
SG1 * SG4	5.027	256	.000	7.6401	1.5198	4.6472	10.6330
SG1 * SG5	-2.203	158	.029	-4.7015	2.1338	-8.9161	-.4870
SG2 * SG5	-2.509	174	.013	-11.3712	4.5318	-20.3157	-2.4268
SG3 * SG5	-3.456	190	.001	-5.1850	1.5004	-8.1447	-2.2253
SG4 * SG5	-4.553	148	.000	-12.3416	2.7107	-17.6983	-6.9849

The analyses indicate that SG5 achieved best for the search task, both in terms of search time and accuracy. The reason might due to the golfing symbol that was tested against this background, and the golfing symbol seems distinctive.

Moreover, the results found that SG4 was the slowest symbol group in mean search time and accuracy, a result that was expected because of the complexity of the symbols in the SG4 group; additionally, all of the SG4 symbols look similar to each other. Further, SG2 was low in accuracy, since the characteristics of these symbols are complex and all appear similar to each other.

Results of the Symbol Groups on the Gray Background

Table 37. Descriptive Statistics for Symbol Groups in Search Time on the Gray Background

Descriptives						95% Confidence Interval for Mean			
		N	Mean	Std. Deviation	Std. Error	Lower Bound	Upper Bound	Minimum	Maximum
Time on the Gray BK	Simple Geometric	98	31.40	13.834	1.397	28.62	34.17	10	95
	Complex Geometric	98	36.38	13.633	1.377	33.64	39.11	8	74
	Simple Pictorial	98	25.76	9.630	.973	23.82	27.69	9	63
	Complex Pictorial	98	30.66	10.187	1.029	28.62	32.71	10	92
	Total	392	31.05	12.512	.632	29.81	32.29	8	95

Table 38. Descriptive Statistics for Symbol Groups in Accuracy on the Gray Background

Descriptives						95% Confidence Interval for Mean			
		N	Mean	Std. Deviation	Std. Error	Lower Bound	Upper Bound	Minimum	Maximum
Percent Correct on the Gray BK	Simple Geometric	98	92.857	14.4897	1.4637	89.952	95.762	16.7	100.0
	Complex Geometric	98	64.457	28.8651	2.9158	58.670	70.244	.0	95.5
	Simple Pictorial	98	96.778	6.7863	.6855	95.417	98.138	57.9	100.0
	Complex Pictorial	98	69.255	5.1577	.5210	68.221	70.289	56.5	91.3
	Total	392	80.837	21.8537	1.1038	78.667	83.007	.0	100.0

The symbol groups were analyzed using the two dependent variables: time and accuracy. Tables 37 and 38 show the number of searches, mean search times, and standard deviations forboth time and accuracy for each symbol group. Analysis of Variance shows that there were significant differences in the mean search times for the symbol groups, F (3, 388) = 12.91, $p < .001$. Further, there were significant differences in search accuracy among the symbol groups, F (3, 388) = 93.80, $p < .001$ (Table 39).

Table 39. Significant Differences of the Symbol Groups on the Gray Background

ANOVA[a]

		Sum of Squares	df	Mean Square	F	Sig.
Time	Between Groups	5555.559	3	1851.853	12.910	.000
	Within Groups	55654.520	388	143.439		
	Total	61210.079	391			
Percent Correct	Between Groups	78503.534	3	26167.845	93.809	.000
	Within Groups	108232.386	388	278.949		
	Total	186735.920	391			

The mean search times for individual symbol groups varied from 25.76 to 36.38 seconds, and standard deviations from 9.63 to 13.83 (Table 37). The response time for SG3 (simple pictorial) ($\bar{x}$ = 25.76, s = 9.63) was significantly different in mean search time than the other symbol groups. Additionally, the response time of SG2 ($\bar{x}$ = 36.38, s = 13.63) was significantly slower than the other symbol groups (Table 40).

Table 40. *t* Test for Equality of Means (Time) among Symbol Groups on the Gray Background

Independent Samples Test							
t-test for Equality of Means (Time)							
Symbol Group	t	df	Sig. (2-tailed)	Mean Difference	Std. Error Difference	95% Confidence Interval of the Difference	
						Lower	Upper
SG3 * SG1	3.314	194	.001	5.643	1.703	2.285	9.001
SG3 * SG2	6.300	194	.000	10.622	1.686	7.297	13.948
SG3 * SG4	-3.466	194	.001	-4.908	1.416	-7.701	-2.115
SG2 * SG1	-2.538	194	.012	-4.980	1.962	-8.849	-1.110
SG2 * SG4	3.324	194	.001	5.714	1.719	2.324	9.105
SG1 * SG4	.423	194	.673	.735	1.735	-2.688	4.157

The mean search accuracy for the individual symbol groups varied from 64.45 percent to 96.77 percent, and the standard deviations varied from 5.15 to 28.86 (Table 38). *t* tests showed that there were significant differences between SG3 ($\bar{x}$= 96.77, s = 6.78) and the other symbol groups in search accuracy. Additionally, SG2 ($\bar{x}$ = 64.45, s = 28.86) and SG4 ($\bar{x}$ = 69.25, s = 5.15) were found significantly less accurate than the other symbol groups (Table 41).

The analyses indicate that SG3 worked best for the search task, both in terms of search time and accuracy. This was due to the simple characteristics of the symbols, which meant that fast times with high accuracy were expected. SG4 was the slowest symbol group in mean search time and lowest in accuracy (like SG2), a result that was expected because of the complexity of the symbols in the SG4 group and

Table 41. *t* tests for Equality of Means (Accuracy) among Symbol Groups on the Gray Background

Independent Samples Test							
t-test for Equality of Means (Accuracy)							
Symbol Group	t	df	Sig. (2-tailed)	Mean Difference	Std. Error Difference	95% Confidence Interval of the Difference	
						Lower	Upper
SG3 * SG1	-2.425	194	.016	-3.9202	1.6163	-7.1079	-.7325
SG3 * SG2	-10.790	194	.000	-32.3208	2.9953	-38.2284	-26.4133
SG3 * SG4	31.965	194	.000	27.5230	.8610	25.8248	29.2212
SG2 * SG1	8.705	194	.000	28.4006	3.2626	21.9660	34.8353
SG2 * SG4	-1.620	194	.107	-4.7978	2.9620	-10.6396	1.0440
SG1 * SG4	15.192	194	.000	23.6028	1.5536	20.5386	26.6670

their similarity to each other. The SG2 group was low in accuracy, because the symbol characteristics were complex, and all the symbols were similar to each other.

After displaying the analysis of the five symbol groups against the eight backgrounds, and showing the effect of the backgrounds on the five symbol groups in mean search time and accuracy, it was found that the best performance in mean search time and accuracy was for the simple geometric symbol group, the simple pictorial symbol group, and the old complex geometric symbol group. The worst performance in mean search time and accuracy for the eight backgrounds was with the complex geometric symbol group and the complex pictorial symbol group.

The next section will move on to a consideration of the individual symbols tested. It will present analyses for each symbol tested on the eight backgrounds.

Chapter Eight

GEOG 104: All Symbols on All Backgrounds

The analysis of the relationships among the five symbol groups and the eight backgrounds, showing not only how the backgrounds interacted with the five symbol groups but also how the symbols within a group interacted with each other, in search time and accuracy, revealed that the best performances in search time and accuracy with the eight backgrounds was with the simple geometric symbol group, the simple pictorial symbol group, and the old complex geometric symbol group. The worst performances in search time and accuracy with the eight backgrounds was with the complex geometric symbol group and the complex pictorial symbol group.

The following pages will present an analysis of the performance of each symbol on the eight backgrounds. All 4568 responses to the symbols are shown in Figure 1. It is possible to make generalizations by examining Figure 1. The yellow dots representing the old complex geometric symbol group are concentrated in the shortest time and highest level of accuracy sector (lower right-hand). The (new) complex geometric responses are scattered across the graph, but clearly dominate the left-hand area of low accuracy responses. The simple geometric, the simple pictorial, and the complex pictorial are represented by areas of blue, orange, and magenta dots.

The situation is displayed in another level of detail by the five graphs in Figure 2. These five "dot maps" illustrate, as do conventional maps using this technique, the relationships among the five symbols in each group in the time-accuracy space.

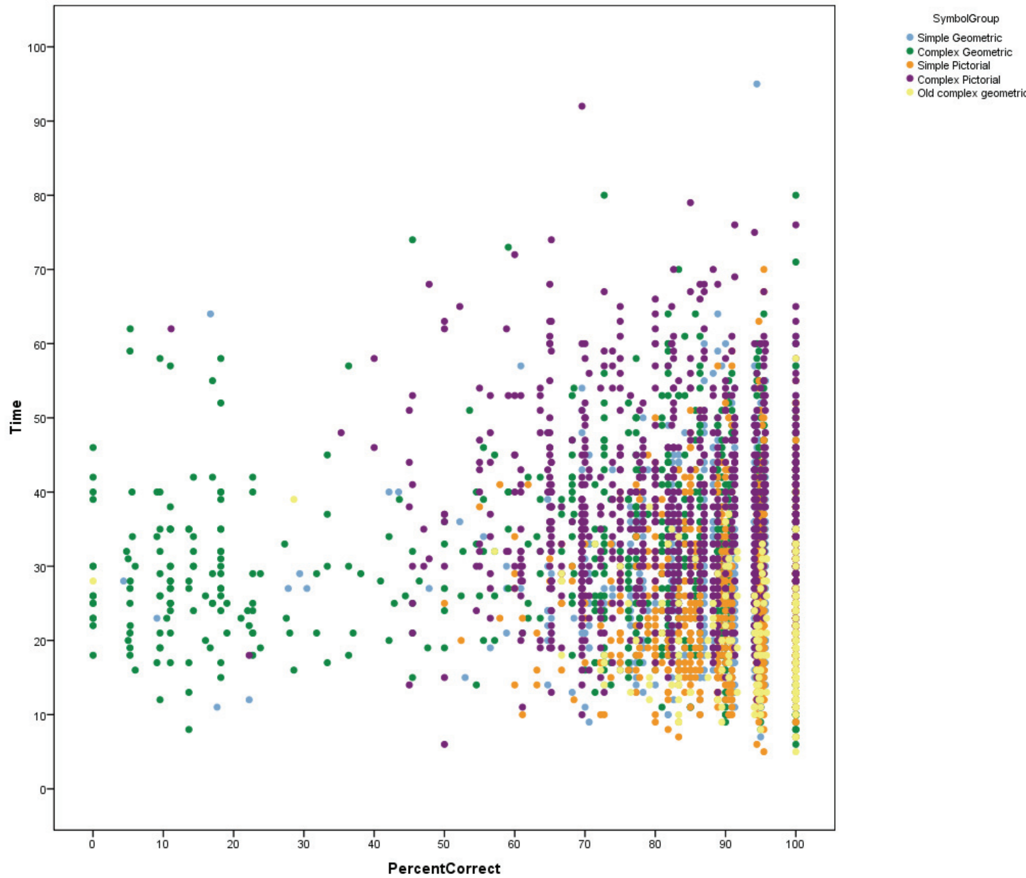


Figure 1. The 4568 responses to the series of tests administered in GEOG 104, all symbol groups.

Here the small number of responses for the old complex geometric symbols is highly concentrated in the fast time – high accuracy sector. The widespread responses to the (new) complex geometric group clearly stand apart from the other groups. For every group there is a wide range of time and accuracy; there are in some groups very few extreme responses, that is, few long search times and few low accuracies.

The complexity involved in this research promotes an extensive program of analysis. At this stage, there remains the necessity to look at how the individual

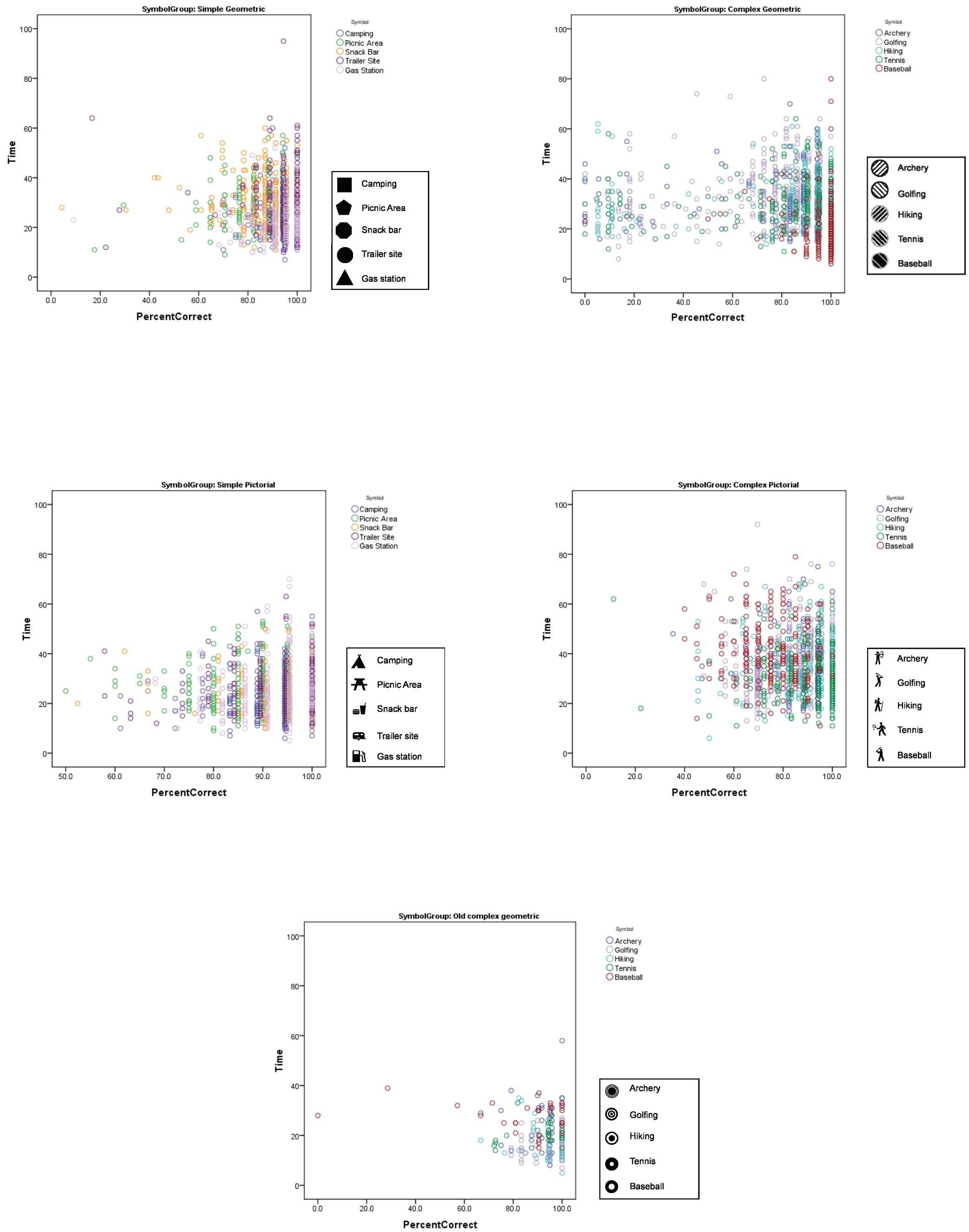


Figure 2. The five symbol groups that were tested against the eight backgrounds.

symbols in each group performed, and why. Although the symbols in each group share similarities, each is different and, as a result, it is necessary to analyze the time and accuracy data for the individual symbols and see how each compares to the other four members of the group. This will be handled in several stages. In the first stage, all five symbols in the simple geometric group will be analyzed in detail, looking at their performances in the context of the eight backgrounds. The goal is to determine which specific symbols required more search time and which were the most accurate (in the counting process), and what statistical significance can be attributed to the raw data values.

The examination of the simple geometric group will be followed by similar analyses of the other symbol groups.

After looking at all of the symbols in each of the groups, four pages of data tables will present, for the four principal symbol groups, a summary of the search times and accuracies for all of the symbols, with an indication of the statistically significant relationships.

The discussion will conclude with a graph that, like the earlier "dot maps," helps provide another element of perspective on the research.

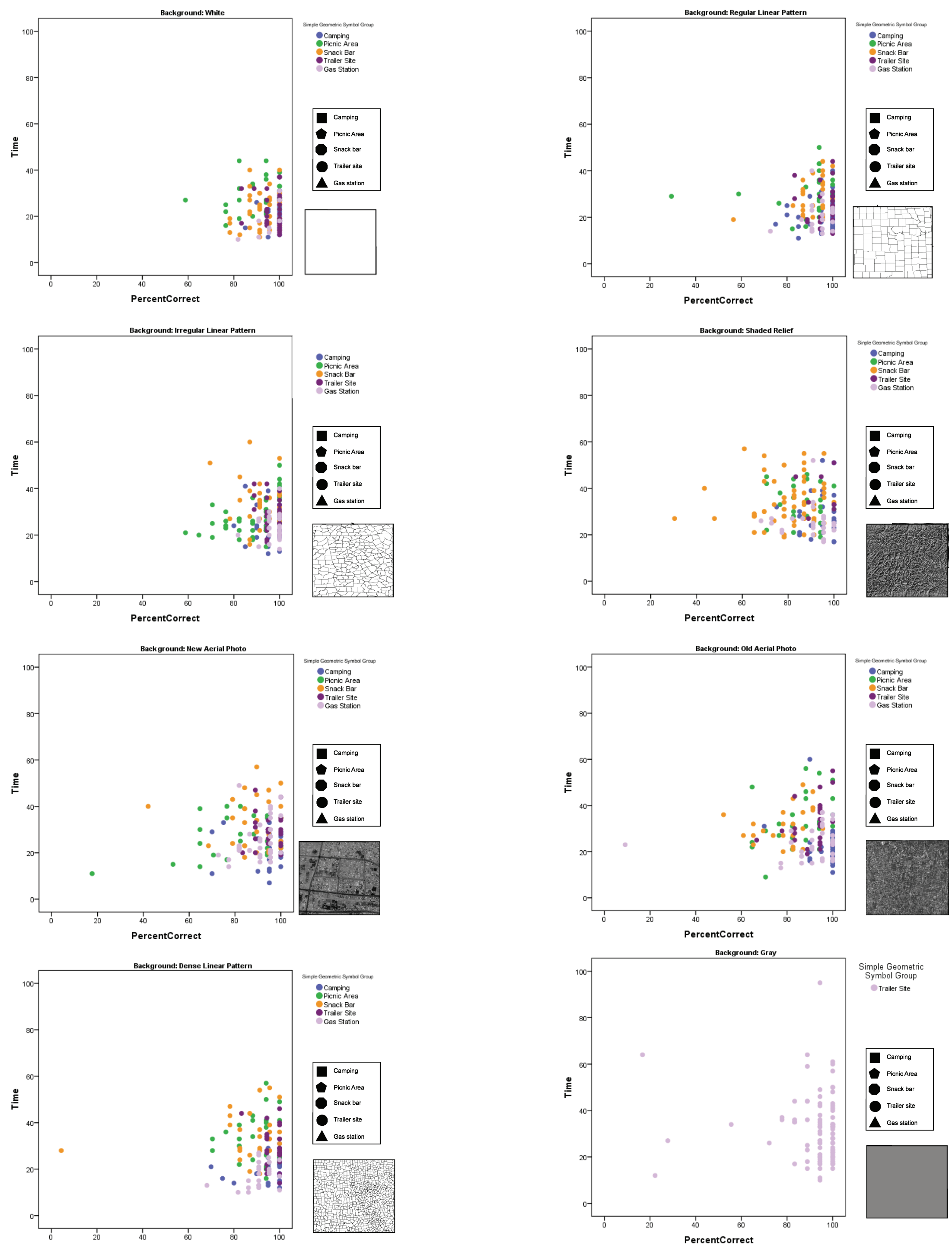


Figure 3. Simple geometric symbol group on the eight backgrounds.

Simple Geometric Symbols on the White Background

Table 1. Descriptive Statistics for the Simple Geometric Symbols in Search Time on the White background

Descriptives

		N	Mean	Std. Deviation	Std. Error	95% Confidence Interval for Mean Lower Bound	95% Confidence Interval for Mean Upper Bound	Minimum	Maximum
Time on the White BK	Camping	26	20.77	5.854	1.148	18.40	23.13	11	31
	Picnic Area	26	28.85	7.379	1.447	25.87	31.83	16	44
	Snack Bar	38	22.47	7.518	1.220	20.00	24.94	11	40
	Trailer Site	32	22.62	7.268	1.285	20.00	25.25	12	37
	Gas Station	8	17.88	7.530	2.662	11.58	24.17	10	31
	Total	130	23.16	7.667	.672	21.83	24.49	10	44

Table 2. Descriptive Statistics for the Simple Geometric Symbols in Accuracy on the White Background

Descriptives

		N	Mean	Std. Deviation	Std. Error	95% Confidence Interval for Mean Lower Bound	95% Confidence Interval for Mean Upper Bound	Minimum	Maximum
Percent Correct on the White BK	Camping	26	98.077	3.7622	.7378	96.557	99.596	85.0	100.0
	Picnic Area	26	89.819	10.1964	1.9997	85.701	93.937	58.8	100.0
	Snack Bar	38	92.449	6.5264	1.0587	90.303	94.594	78.3	100.0
	Trailer Site	32	96.701	4.6501	.8220	95.025	98.378	83.3	100.0
	Gas Station	8	94.318	6.3124	2.2318	89.041	99.595	81.8	100.0
	Total	130	94.210	7.1987	.6314	92.961	95.459	58.8	100.0

The symbol system was analyzed using the two dependent variables: time and accuracy. Tables 1 and 2 show the number of searches, the mean search times, and the standard deviations for both time and accuracy. Analysis of Variance shows that there are significant differences in the mean search times for the symbols, F (4, 125) = 6.10, $p < .001$. Further, there are significant differences in accuracy, F (4, 125) = 6.88, $p < .001$ (Table 3). Mean search times for individual symbols varied from 17.88 to 28.85 seconds, and the standard deviations varied from 5.85 to 7.53 (Table 1). The response time for the gas station ($\bar{x}$ = 17.88, s = 7.53), camping ($\bar{x}$ = 20.77, s = 5.85), snack bar ($\bar{x}$ = 22.47, s = 7.5), and trailer site ($\bar{x}$ = 22.62, s = 7.26) symbols were significantly faster than the picnic area symbol. Further, the response time of the picnic area ($\bar{x}$ =28.85, s = 7.37) was significantly slower than the other symbols (Table 4). The mean search accuracy for individual symbols varied from 89.81 percent to 98.07 percent, and the standard deviations from 3.76 to 10.19 (Table 2).

Table 3. Significant Differences of Symbols on the White Background.

ANOVA[a]

		Sum of Squares	df	Mean Square	F	Sig.
Time	Between Groups	1239.759	4	309.940	6.107	.000
	Within Groups	6343.849	125	50.751		
	Total	7583.608	129			
Percent Correct	Between Groups	1206.708	4	301.677	6.884	.000
	Within Groups	5478.214	125	43.826		
	Total	6684.923	129			

Table 4. *t* Tests for Equality of Means (Time) among Symbols on the White Background

Independent Samples Test							
t-test for Equality of Means (Time)							
Symbol	t	df	Sig. (2-tailed)	Mean Difference	Std. Error Difference	95% Confidence Interval of the Difference	
						Lower	Upper
Camping * Picnic	-4.372	50	.000	-8.077	1.847	-11.787	-4.367
Camping * Snack	-.971	62	.335	-1.704	1.755	-5.213	1.804
Camping * Trailer	-1.053	56	.297	-1.856	1.762	-5.386	1.674
Camping * Gas	1.144	32	.261	2.894	2.530	-2.260	8.049
Picnic * Snack	3.355	62	.001	6.372	1.899	2.576	10.169
Picnic * Trailer	3.220	56	.002	6.221	1.932	2.351	10.092
Picnic * Gas	3.661	32	.001	10.971	2.997	4.867	17.076
Snack * Trailer	-.085	68	.932	-.151	1.777	-3.697	3.394
Snack * Gas	1.572	44	.123	4.599	2.925	-1.297	10.494
Trailer * Gas	1.642	38	.109	4.750	2.892	-1.105	10.605

The *t* tests showed that there were no significant differences between the camping symbol and the trailer site symbol in search accuracy; however the camping ($\bar{x}$ = 98.07, s = 3.76) and trailer site ($\bar{x}$=96.70, s = 4.65) symbols were found to be significantly more accurate than the other symbols. On the other hand, the picnic area ($\bar{x}$ = 89.81, s = 10.19), snack bar ($\bar{x}$ =92.44, s = 6.52), and gas station ($\bar{x}$ = 94.31, s = 6.31) symbols (Table 5).

It appears from the analyses that the camping (square) and trailer site (circle) symbols were best for the search task, both in terms of search time and accuracy. The fastest search times were expected to be for the camping and trailer site symbols since they are different in design from the other symbols. All of their

Table 5. *t* Tests for Equality of Means (Accuracy) among Symbols on the White Background

Independent Samples Test							
t-test for Equality of Means (Accuracy)							
Symbol	t	df	Sig. (2-tailed)	Mean Difference	Std. Error Difference	95% Confidence Interval of the Difference	
						Lower	Upper
Camping * Picnic	3.874	50	.000	8.2579	2.1314	3.9768	12.5391
Camping * Snack	3.964	62	.000	5.6284	1.4199	2.7900	8.4668
Camping * Trailer	1.218	56	.228	1.3755	1.1291	-.8864	3.6375
Camping * Gas	2.091	32	.045	3.7587	1.7979	.0966	7.4209
Picnic * Snack	-1.259	62	.213	-2.6295	2.0886	-6.8045	1.5455
Picnic * Trailer	-3.411	56	.001	-6.8824	2.0174	-10.9238	-2.8410
Picnic * Gas	-1.173	32	.249	-4.4992	3.8343	-12.3093	3.3110
Snack * Trailer	-3.084	68	.003	-4.2529	1.3790	-7.0046	-1.5011
Snack * Gas	-.740	44	.463	-1.8697	2.5257	-6.9598	3.2205
Trailer * Gas	1.206	38	.235	2.3832	1.9757	-1.6163	6.3827

Characteristics enable them to be easy to search for, and this would produce fast and accurate searches. While, the gas station symbol (triangle) and snack bar (octagon) symbols were found to be fast in search time, they were low in accuracy. That perhaps could be because they were searched quickly, and that may have caused low accuracy.

Simple Geometric Symbols on the Regular Linear Background

Table 6. Descriptive Statistics for the Simple Geometric Symbols in Search Time on the Regular Linear Background

Descriptives									
						95% Confidence Interval for Mean			
		N	Mean	Std. Deviation	Std. Error	Lower Bound	Upper Bound	Minimum	Maximum
Time on the Regular Linear BK	Camping	45	21.53	6.700	.999	19.52	23.55	11	40
	Picnic Area	26	30.23	8.650	1.696	26.74	33.72	15	50
	Snack Bar	26	28.77	7.809	1.532	25.62	31.92	19	44
	Trailer Site	25	25.80	8.057	1.611	22.47	29.13	13	44
	Gas Station	24	20.58	6.317	1.289	17.92	23.25	13	40
	Total	146	24.95	8.284	.686	23.59	26.30	11	50

Table 7. Descriptive Statistics for the Simple Geometric Symbols in Accuracy on the Regular Linear Background

Descriptives									
						95% Confidence Interval for Mean			
		N	Mean	Std. Deviation	Std. Error	Lower Bound	Upper Bound	Minimum	Maximum
Percent Correct on the Regular Linear BK	Camping	45	95.556	6.3266	.9431	93.655	97.456	75.0	100.0
	Picnic Area	26	90.045	15.2278	2.9864	83.895	96.196	29.4	100.0
	Snack Bar	26	90.803	8.4600	1.6591	87.386	94.220	56.5	100.0
	Trailer Site	25	96.667	5.3190	1.0638	94.471	98.862	83.3	100.0
	Gas Station	24	93.939	5.9442	1.2134	91.429	96.449	72.7	100.0
	Total	146	93.652	9.0137	.7460	92.178	95.127	29.4	100.0

The symbol system was analyzed using the two dependent variables: time and accuracy. Tables 6 and 7 show the number of searches, mean search times, and standard deviations for both time and accuracy for each symbol. Analysis of Variance shows that there are significant differences in the mean search times for the symbols, F (4, 141) = 9.45, $p < .001$. There are significant differences in search accuracy among the symbols, F (4, 141) = 3.06, $p < .001$ (Table 8). The mean search times for individual symbols varied from 20.58 to 30.23 seconds, and the standard deviations varied from 6.31 to 8.65 (Table 6). The response time for the gas station ($\bar{x}$ = 20.58, s = 6.31) and camping ($\bar{x}$ = 21.53, s = 6.70) symbols was significantly faster than the other symbols. Response times for the trailer site ($\bar{x}$ = 25.80, s = 8.05), snack bar ($\bar{x}$ = 28.77, s = 7.80), and picnic area ($\bar{x}$ = 30.23, s = 8.65) symbols were significantly slower (Table 9).

Table 8. Significant Differences of Symbols on the Regular Linear Background

ANOVA[a]

		Sum of Squares	df	Mean Square	F	Sig.
Time	Between Groups	2105.298	4	526.324	9.458	.000
	Within Groups	7846.264	141	55.647		
	Total	9951.562	145			
Percent Correct	Between Groups	941.556	4	235.389	3.062	.019
	Within Groups	10839.272	141	76.874		
	Total	11780.828	145			

Table 9. *t* Tests for Equality of Means (Time) among Symbols on the Regular Linear Background

Independent Samples Test							
t-test for Equality of Means (Time)							
Symbol	t	df	Sig. (2-tailed)	Mean Difference	Std. Error Difference	95% Confidence Interval of the Difference	
						Lower	Upper
Camping * Picnic	-4.729	69	.000	-8.697	1.839	-12.366	-5.029
Camping * Snack	-4.124	69	.000	-7.236	1.754	-10.736	-3.736
Camping * Trailer	-2.373	68	.020	-4.267	1.798	-7.855	-.679
Camping * Gas	.572	67	.569	.950	1.661	-2.365	4.265
Picnic * Snack	.639	50	.525	1.462	2.285	-3.129	6.052
Picnic * Trailer	1.891	49	.065	4.431	2.343	-.278	9.139
Picnic * Gas	4.472	48	.000	9.647	2.158	5.309	13.985
Snack * Trailer	1.336	49	.188	2.969	2.222	-1.495	7.434
Snack * Gas	4.054	48	.000	8.186	2.019	4.126	12.246
Trailer * Gas	2.515	47	.015	5.217	2.074	1.044	9.389

The mean search accuracy varied from 90.04 percent to 96.66 percent, and the standard deviations varied from 5.31 to 15.22 (Table 7). *t* tests showed that there were no significant differences between the trailer site ($\bar{x}$ = 96.66, s = 5.31), camping ($\bar{x}$= 95.55, s = 6.32), and gas station ($\bar{x}$=93.93, s = 5.94) symbols in search accuracy. Snack bar ($\bar{x}$ =90.80, s = 8.46) and picnic area ($\bar{x}$ =90.04, s = 15.22) symbols were found to be significantly less accurate than the other symbols (Table 10).

From the analyses gas station (triangle) and camping (square) symbols seem to perform best for both search time and accuracy tasks. The fastest search time was expected to be for these symbols since they look different in their design from the others in the group. All of their characteristics enable them to be easy to search for with high accuracy. Furthermore, the results found that the trailer site (circle), snack bar (octagon), and picnic area (pentagon) symbols were the slowest symbols in mean search time, a result that was expected because these symbols look somewhat similar to each other. And while the snack bar and picnic area were slow in time with less accuracy, the trailer site symbol was slow in time but with high accuracy.

Table 10. *t* Tests for Equality of Means (Accuracy) among Symbols on the Regular Linear Background

Independent Samples Test							
t-test for Equality of Means (Accuracy)							
Symbol	t	df	Sig. (2-tailed)	Mean Difference	Std. Error Difference	95% Confidence Interval of the Difference	
						Lower	Upper
Camping * Picnic	2.137	69	.036	5.5103	2.5782	.3669	10.6538
Camping * Snack	2.690	69	.009	4.7529	1.7671	1.2277	8.2781
Camping * Trailer	-.744	68	.460	-1.1111	1.4943	-4.0928	1.8706
Camping * Gas	1.032	67	.306	1.6162	1.5666	-1.5108	4.7431
Picnic * Snack	-.222	50	.825	-.7574	3.4164	-7.6194	6.1045
Picnic * Trailer	-2.056	49	.045	-6.6214	3.2203	-13.0928	-.1501
Picnic * Gas	-1.172	48	.247	-3.8941	3.3218	-10.5730	2.7847
Snack * Trailer	-2.950	49	.005	-5.8640	1.9881	-9.8592	-1.8688
Snack * Gas	-1.505	48	.139	-3.1367	2.0841	-7.3271	1.0537
Trailer * Gas	1.694	47	.097	2.7273	1.6099	-.5115	5.9661

Simple Geometric Symbols on the Irregular Linear Background

Table 11. Descriptive Statistics for the Simple Geometric Symbols in Search Time on the Irregular Linear Background

Descriptives									
						95% Confidence Interval for Mean			
		N	Mean	Std. Deviation	Std. Error	Lower Bound	Upper Bound	Minimum	Maximum
Time on the Irregular Linear BK	Camping	24	24.83	7.705	1.573	21.58	28.09	12	41
	Picnic Area	47	28.32	7.757	1.132	26.04	30.60	15	50
	Snack Bar	26	34.27	10.185	1.997	30.16	38.38	16	60
	Trailer Site	26	28.54	7.106	1.394	25.67	31.41	17	42
	Gas Station	26	23.62	5.543	1.087	21.38	25.85	14	40
	Total	149	28.01	8.436	.691	26.65	29.38	12	60

Table 12. Descriptive Statistics for the Simple Geometric Symbols in Accuracy on the Irregular Linear Background

Descriptives									
						95% Confidence Interval for Mean			
		N	Mean	Std. Deviation	Std. Error	Lower Bound	Upper Bound	Minimum	Maximum
Percent Correct on the Irregular Linear BK	Camping	24	94.792	5.8009	1.1841	92.342	97.241	80.0	100.0
	Picnic Area	47	89.487	10.8282	1.5795	86.308	92.666	58.8	100.0
	Snack Bar	26	90.970	7.4725	1.4655	87.952	93.988	69.6	100.0
	Trailer Site	26	96.368	3.8305	.7512	94.820	97.915	88.9	100.0
	Gas Station	26	96.853	4.4106	.8650	95.072	98.635	81.8	100.0
	Total	149	93.086	8.1625	.6687	91.765	94.408	58.8	100.0

The symbol system was analyzed using the two dependent variables: time and accuracy. Tables 11 and 12 show the number of searches, mean search times, and standard deviations for both time and accuracy for each symbol. Analysis of Variance shows that there are significant differences in the mean search times for the symbols, F (4, 144) = 7.29, $p < .001$. Further, there are significant differences in search accuracy among the symbols, F (4, 144) = 6.17, $p < .001$ (Table 13).

The mean search times for individual symbols varied from 23.62 to 34.27 seconds, and the standard deviations varied from 5.54 to 10.18 (Table 14). The response time for gas station symbol ($\bar{x}$ = 23.62, s = 5.54) was significantly faster than the other symbol, except the camping symbol ($\bar{x}$ = 24.83, s = 7.70). t tests showed participants had a significantly faster search times for the gas station and camping symbols than the other symbols. The response time for the snack bar symbol

Table 13. Significant Differences of Symbols on the Irregular Linear Background

ANOVA[a]

		Sum of Squares	df	Mean Square	F	Sig.
Time	Between Groups	1774.696	4	443.674	7.296	.000
	Within Groups	8757.277	144	60.814		
	Total	10531.973	148			
Percent Correct	Between Groups	1444.032	4	361.008	6.177	.000
	Within Groups	8416.563	144	58.448		
	Total	9860.595	148			

Table 14. *t* Tests for Equality of Means (Time) among Symbols on the Irregular Linear Background

Independent Samples Test							
t-test for Equality of Means (Time)							
Symbol	t	df	Sig. (2-tailed)	Mean Difference	Std. Error Difference	95% Confidence Interval of the Difference	
						Lower	Upper
Camping * Picnic	-1.795	69	.077	-3.486	1.942	-7.360	.388
Camping * Snack	-3.671	48	.001	-9.436	2.571	-14.604	-4.267
Camping * Trailer	-1.769	48	.083	-3.705	2.094	-7.916	.506
Camping * Gas	.645	48	.522	1.218	1.887	-2.577	5.012
Picnic * Snack	-2.801	71	.007	-5.950	2.124	-10.185	-1.715
Picnic * Trailer	-.119	71	.906	-.219	1.842	-3.891	3.453
Picnic * Gas	2.727	71	.008	4.704	1.725	1.264	8.143
Snack * Trailer	2.353	50	.023	5.731	2.435	.839	10.623
Snack * Gas	4.685	50	.000	10.654	2.274	6.086	15.221
Trailer * Gas	2.785	50	.008	4.923	1.767	1.373	8.473

($\bar{x}$ = 34.27, s = 10.18) was significantly slower than the other symbols (Table 14).

The mean search accuracy for individual symbols varied from 89.48 to 96.85 percent, and the standard deviations from 3.83 to 10.82 (Table 12). The *t* tests showed that there were no significant differences between the trailer site, gas station and camping symbols in search accuracy; however, the gas station ($\bar{x}$ = 96.85, s = 4.41), and camping ($\bar{x}$= 96.36, s = 3.83) symbols were found to be more accurate than the other symbols. The snack bar ($\bar{x}$ =90.97, s = 7.47) and picnic area ($\bar{x}$ = 89.48, s =

10.82) symbols were found significantly less accurate than the other symbols (Table 15).

Table 15. *t* Tests for Equality of Means (Accuracy) among Symbols on the Irregular Linear Background

Independent Samples Test							
t-test for Equality of Means (Accuracy)							
Symbol	t	df	Sig. (2-tailed)	Mean Difference	Std. Error Difference	95% Confidence Interval of the Difference	
						Lower	Upper
Camping * Picnic	2.236	69	.029	5.3048	2.3719	.5729	10.0367
Camping * Snack	2.008	48	.050	3.8218	1.9032	-.0050	7.6485
Camping * Trailer	-1.142	48	.259	-1.5759	1.3800	-4.3505	1.1988
Camping * Gas	-1.421	48	.162	-2.0615	1.4505	-4.9778	.8549
Picnic * Snack	-.620	71	.537	-1.4830	2.3901	-6.2487	3.2827
Picnic * Trailer	-3.125	71	.003	-6.8807	2.2015	-11.2703	-2.4910
Picnic * Gas	-3.312	71	.001	-7.3663	2.2242	-11.8013	-2.9313
Snack * Trailer	-3.278	50	.002	-5.3976	1.6468	-8.7053	-2.0899
Snack * Gas	-3.457	50	.001	-5.8832	1.7017	-9.3012	-2.4653
Trailer * Gas	-.424	50	.673	-.4856	1.1457	-2.7867	1.8155

The gas station symbol works best for the search task. This was expected: its triangular characteristics are distinctive. The trailer site and camping symbols, also high in search accuracy, are also distinctive (circle, square). The snack bar was the slowest in time and lowest in accuracy, an expected result: it looks similar to other symbols (octagon compared to the circle and pentagon).

Simple Geometric Symbols on the New Imagery Background

Table 16. Descriptive Statistics for the Simple Geometric Symbols in Search Time on the New Imagery background

Descriptives									
		N	Mean	Std. Deviation	Std. Error	95% Confidence Interval for Mean		Minimum	Maximum
						Lower Bound	Upper Bound		
Time on the New Imagery BK	Camping	25	21.76	7.595	1.519	18.62	24.90	7	35
	Picnic Area	25	26.32	8.693	1.739	22.73	29.91	11	40
	Snack Bar	32	32.84	10.195	1.802	29.17	36.52	18	57
	Trailer Site	26	29.35	6.887	1.351	26.56	32.13	19	47
	Gas Station	39	24.97	8.428	1.350	22.24	27.71	14	49
	Total	147	27.14	9.214	.760	25.64	28.64	7	57

Table 17. Descriptive Statistics for the Simple Geometric Symbols in Search Accuracy on the New Imagery background

Descriptives									
		N	Mean	Std. Deviation	Std. Error	95% Confidence Interval for Mean		Minimum	Maximum
						Lower Bound	Upper Bound		
Percent Correct on the New Imagery BK	Camping	25	94.000	9.0139	1.8028	90.279	97.721	70.0	100.0
	Picnic Area	25	80.706	18.9487	3.7897	72.884	88.528	17.6	100.0
	Snack Bar	32	88.651	11.5085	2.0344	84.502	92.801	42.1	100.0
	Trailer Site	26	94.872	4.9499	.9708	92.872	96.871	83.3	100.0
	Gas Station	39	91.026	6.8767	1.1012	88.796	93.255	72.7	100.0
	Total	147	89.940	11.8084	.9739	88.015	91.865	17.6	100.0

The symbol system was analyzed using the two dependent variables: time and accuracy. Tables 16 and 17 show the number of searches, the mean search times, and the standard deviations of both time and accuracy for each symbol. Analysis of Variance shows that there are significant differences in mean search times for the symbols, $F\,(4, 142) = 7.20$, $p < .001$. Further, there are significant differences in search accuracy among the symbols, $F\,(4, 142) = 6.80$, $p < .001$ (Table 18). The mean search times for individual symbols varied from 21.76 to 32.84 seconds, and the standard deviations varied from 6.88 to 10.19 (Table 16). The response time for the camping symbol ($\bar{x} = 21.76$, $s = 7.59$) was significantly faster than the other symbols except for the gas station symbol ($\bar{x} = 24.97$, $s = 8.42$). A t test showed a significantly faster search time for the camping symbol than the other symbols. Response times for the snack bar ($\bar{x} = 32.84$, $s = 10.19$) and trailer site ($\bar{x} = 29.35$, $s = 6.88$) symbols were significantly slower than the other symbols, and the t test showed

Table 18. Significant Differences of Symbols on the New Imagery Background

ANOVA[a]

		Sum of Squares	df	Mean Square	F	Sig.
Time	Between Groups	2090.922	4	522.731	7.203	.000
	Within Groups	10305.078	142	72.571		
	Total	12396.000	146			
Percent Correct	Between Groups	3275.309	4	818.827	6.807	.000
	Within Groups	17082.610	142	120.300		
	Total	20357.920	146			

Table 19. *t* Tests for Equality of Means (Time) among Symbols on the New Imagery Background

Independent Samples Test							
t-test for Equality of Means (Time)							
Symbol	t	df	Sig. (2-tailed)	Mean Difference	Std. Error Difference	95% Confidence Interval of the Difference	
						Lower	Upper
Camping * Picnic	-1.975	48	.054	-4.560	2.309	-9.202	.082
Camping * Snack	-4.537	55	.000	-11.084	2.443	-15.979	-6.188
Camping * Trailer	-3.739	49	.000	-7.586	2.029	-11.663	-3.509
Camping * Gas	-1.546	62	.127	-3.214	2.079	-7.371	.942
Picnic * Snack	-2.554	55	.013	-6.524	2.554	-11.642	-1.405
Picnic * Trailer	-1.381	49	.174	-3.026	2.192	-7.430	1.378
Picnic * Gas	.616	62	.540	1.346	2.186	-3.024	5.715
Snack * Trailer	1.493	56	.141	3.498	2.343	-1.195	8.190
Snack * Gas	3.562	69	.001	7.869	2.210	3.461	12.277
Trailer * Gas	2.199	63	.032	4.372	1.988	.399	8.345

that there was a significantly slower search time for the snack bar and trailer site than for the other symbols (Table 19). The mean search accuracy for individual symbols varied from 80.70 percent to 94.87 percent, and the standard deviations varied from to 18.94 (Table 17).

The *t* tests showed that there were no significant differences between the camping ($\bar{x}$ = 94.00, s = 9.01) and the trailer site ($\bar{x}$=94.87, s = 4.94) symbols in search accuracy; both were found to be significantly more accurate than the other symbols. Additionally, the picnic area symbol ($\bar{x}$ =80.70, s = 18.94) was found significantly less accurate than the other symbols (Table 20).

It would appear from the analyses that the camping symbol works on this background best for the search task, both in terms of search time and accuracy. The fastest search time was expected for the camping symbol (a square), and the reason to be fast was because the symbol distinctive in its design. Its characteristics enable it to

Table 20. *t* Tests for Equality of Means (Accuracy) among Symbols on the New Imagery Background

Independent Samples Test							
t-test for Equality of Means (Accuracy)							
Symbol	t	df	Sig. (2-tailed)	Mean Difference	Std. Error Difference	95% Confidence Interval of the Difference	
						Lower	Upper
Camping * Picnic	3.168	48	.003	13.2941	4.1967	4.8561	21.7321
Camping * Snack	1.910	55	.061	5.3487	2.8009	-.2644	10.9618
Camping * Trailer	-.430	49	.669	-.8718	2.0257	-4.9425	3.1989
Camping * Gas	1.493	62	.140	2.9744	1.9917	-1.0071	6.9558
Picnic * Snack	-1.957	55	.055	-7.9454	4.0598	-16.0815	.1906
Picnic * Trailer	-3.685	49	.001	-14.1659	3.8444	-21.8915	-6.4403
Picnic * Gas	-3.108	62	.003	-10.3198	3.3205	-16.9574	-3.6821
Snack * Trailer	-2.567	56	.013	-6.2205	2.4235	-11.0754	-1.3655
Snack * Gas	-1.076	69	.286	-2.3743	2.2061	-6.7754	2.0267
Trailer * Gas	2.456	63	.017	3.8462	1.5658	.7172	6.9751

be easy to search with high accuracy. In addition, the results found that snack bar was the slowest symbol in mean search time, a result that was expected because of this symbol looks similar to other symbols (an octagon, contrasted to a circle).

Also, the highest mean search accuracy (other than the camping symbol) is the trailer site symbol (circle). The reason for this: again, the characteristics of these symbols are distinctly different from the others.

Simple Geometric Symbols on the Shaded Relief Background

Table 21. Descriptive Statistics for the Simple Geometric Symbols in Search Time on the Shaded Relief Background

Descriptives									
		N	Mean	Std. Deviation	Std. Error	95% Confidence Interval for Mean		Minimum	Maximum
						Lower Bound	Upper Bound		
Time on the Shaded Relief Background	Camping	26	28.81	9.381	1.840	25.02	32.60	17	52
	Picnic Area	25	33.76	8.253	1.651	30.35	37.17	19	46
	Snack Bar	56	34.30	9.877	1.320	31.66	36.95	19	57
	Trailer Site	8	37.38	8.450	2.988	30.31	44.44	27	51
	Gas Station	26	25.46	6.592	1.293	22.80	28.12	17	52
	Total	141	31.74	9.547	.804	30.15	33.33	17	57

Table 22. Descriptive Statistics for the Simple Geometric Symbols in Accuracy on the Shaded Relief Background

Descriptives									
		N	Mean	Std. Deviation	Std. Error	95% Confidence Interval for Mean		Minimum	Maximum
						Lower Bound	Upper Bound		
Percent Correct on the Shaded Relief Background	Camping	26	93.84	6.9725	1.3674	91.030	96.662	75.0	100.0
	Picnic Area	25	86.35	8.7777	1.7555	82.730	89.976	70.6	100.0
	Snack Bar	56	79.81	13.5584	1.8118	76.183	83.445	30.4	100.0
	Trailer Site	8	94.44	6.6402	2.3477	88.893	99.996	83.3	100.0
	Gas Station	26	89.86	9.2090	1.8060	86.141	93.580	68.2	100.0
	Total	141	86.24	12.0417	1.0141	84.238	88.248	30.4	100.0

The symbol system was analyzed using the two dependent variables: time and accuracy. Tables 21 and 22 show the number of searches, the mean search times, and the standard deviations of both time and accuracy for each symbol. Analysis of Variance shows that there are significant differences in the mean search times for the symbols, F (4, 136) = 6.21, $p < .001$. Further, there are significant differences in search accuracy among the symbols, F (4, 136) = 10.23, $p < .001$ (Table 23). The mean search times for individual symbols varied from 25.46 to 37.38 seconds, and the standard deviations varied from 6.59 to 9.87 (Table 21). The response times for the gas station ($\bar{x}$ = 25.46, s = 6.59) and camping ($\bar{x}$ = 28.81, s = 9.38) symbols were significantly faster than the other symbols. Additionally, response times for the picnic area ($\bar{x}$ =33.76, s = 8.25), snack bar ($\bar{x}$ = 34.30, s = 9.87), and trailer site ($\bar{x}$ = 37.38, s = 8.45) symbols were significantly slower than the other symbols (Table 24).

Table 23. Significant Differences of Symbols on the Shaded Relief Background

ANOVA[a]

		Sum of Squares	df	Mean Square	F	Sig.
Time	Between Groups	1972.516	4	493.129	6.217	.000
	Within Groups	10786.774	136	79.315		
	Total	12759.291	140			
Percent Correct	Between Groups	4696.430	4	1174.108	10.233	.000
	Within Groups	15604.035	136	114.736		
	Total	20300.466	140			

Table 24. *t* Tests for Equality of Means (Time) among Symbols on the Shaded Relief Background

Independent Samples Test							
t-test for Equality of Means (Time)							
Symbol	t	df	Sig. (2-tailed)	Mean Difference	Std. Error Difference	95% Confidence Interval of the Difference	
						Lower	Upper
Camping * Picnic	-1.999	49	.051	-4.952	2.478	-9.932	.027
Camping * Snack	-2.381	80	.020	-5.496	2.308	-10.089	-.903
Camping * Trailer	-2.307	32	.028	-8.567	3.714	-16.132	-1.003
Camping * Gas	1.488	50	.143	3.346	2.249	-1.170	7.863
Picnic * Snack	-.240	79	.811	-.544	2.264	-5.050	3.963
Picnic * Trailer	-1.073	31	.292	-3.615	3.371	-10.489	3.259
Picnic * Gas	3.976	49	.000	8.298	2.087	4.104	12.493
Snack * Trailer	-.835	62	.407	-3.071	3.676	-10.420	4.277
Snack * Gas	4.149	80	.000	8.842	2.131	4.601	13.083
Trailer * Gas	4.185	32	.000	11.913	2.847	6.115	17.712

The mean search accuracy for individual symbols varied from 79.81 percent to 94.44 percent, and the standard deviations varied from 6.64 to 13.55 (Table 22). The *t* tests showed that there were no significant differences between the trailer site ($\bar{x}$ = 94.44, s = 4.41), camping ($\bar{x}$=93.84, s = 6.97), and gas station ($\bar{x}$=89.86, s = 9.20) symbols in search accuracy; these were significantly more accurate than the other symbols. On the other hand, the snack bar symbol ($\bar{x}$ =79.81, s = 13.55) was found to be significantly less accurate than the other symbols (Table 25). It appears from the analyses that the gas station and camping symbols work best for the search task, both in terms of search time and accuracy. The fastest search time was expected to be for the gas station and camping symbols since these (triangle and square) are distinctive in shape.

Table 25. *t* Tests for Equality of Means (Accuracy) among Symbols on the Shaded Relief Background

Independent Samples Test							
t-test for Equality of Means (Accuracy)							
Symbol	t	df	Sig. (2-tailed)	Mean Difference	Std. Error Difference	95% Confidence Interval of the Difference	
						Lower	Upper
Camping * Picnic	3.383	49	.001	7.4932	2.2152	3.0416	11.9448
Camping * Snack	4.970	80	.000	14.0325	2.8237	8.4131	19.6519
Camping * Trailer	-.214	32	.832	-.5983	2.7902	-6.2817	5.0851
Camping * Gas	1.760	50	.085	3.9860	2.2653	-.5640	8.5360
Picnic * Snack	2.210	79	.030	6.5393	2.9596	.6484	12.4301
Picnic * Trailer	-2.388	31	.023	-8.0915	3.3889	-15.0033	-1.1797
Picnic * Gas	-1.391	49	.170	-3.5072	2.5211	-8.5735	1.5591
Snack * Trailer	-2.986	62	.004	-14.6308	4.8998	-24.4253	-4.8363
Snack * Gas	-3.424	80	.001	-10.0465	2.9343	-15.8860	-4.2070
Trailer * Gas	1.302	32	.202	4.5843	3.5223	-2.5904	11.7590

On the other hand, the picnic area, snack bar, and trailer site symbols were the slowest symbols in search time, an expected result because these symbols look similar to each other. And the same was with the picnic symbol which was also had a low accuracy since it similar to the other symbols which caused the low accuracy.

Simple Geometric Symbols on the Old Imagery Background

Table 26. Descriptive Statistics for the Simple Geometric Symbols in Search Time on the Old Imagery Background

Descriptives									
		N	Mean	Std. Deviation	Std. Error	95% Confidence Interval for Mean Lower Bound	95% Confidence Interval for Mean Upper Bound	Minimum	Maximum
Time on the Old Imagery BK	Camping	26	22.88	9.061	1.777	19.22	26.54	11	60
	Picnic Area	26	33.15	11.355	2.227	28.57	37.74	9	56
	Snack Bar	25	31.64	7.937	1.587	28.36	34.92	20	49
	Trailer Site	24	32.29	9.849	2.010	28.13	36.45	19	55
	Gas Station	32	23.88	7.161	1.266	21.29	26.46	13	37
	Total	133	28.47	10.025	.869	26.75	30.19	9	60

Table 27. Descriptive Statistics for the Simple Geometric Symbols in Accuracy on the Old Imagery Background

Descriptives									
		N	Mean	Std. Deviation	Std. Error	95% Confidence Interval for Mean Lower Bound	95% Confidence Interval for Mean Upper Bound	Minimum	Maximum
Percent Correct on the Old Imagery BK	Camping	26	96.154	6.8275	1.3390	93.396	98.912	70.0	100.0
	Picnic Area	26	85.747	11.6670	2.2881	81.034	90.459	64.7	100.0
	Snack Bar	25	79.478	11.0507	2.2101	74.917	84.040	52.2	95.7
	Trailer Site	24	91.204	8.0118	1.6354	87.821	94.587	66.7	100.0
	Gas Station	32	90.341	16.3583	2.8918	84.443	96.239	9.1	100.0
	Total	133	88.693	12.7044	1.1016	86.514	90.872	9.1	100.0

The symbol system was analyzed using the two dependent variables: time and accuracy. Tables 26 and 27 show the number of searches, mean search times, and the standard deviations of both time and accuracy for each symbol. Analysis of Variance shows that there are significant differences in the search times for the symbols, F (4, 128) = 8.02, $p < .001$. Further, there are significant differences in search accuracy among the symbols, F (4, 128) = 7.47, $p < .001$ (Table 28). The mean search times for individual symbols varied from 22.88 to 33.15 seconds, and the standard deviations varied from 7.16 to 11.35 (Table 26). The response time for the camping ($\bar{x}$ = 22.88, s = 9.06) and gas station ($\bar{x}$ = 23.88, s = 7.16) symbols were significantly faster than the other symbols. On the other hand, response times for the snack bar ($\bar{x}$ =31.64, s = 7.93), trailer site ($\bar{x}$ = 32.29, s = 9.84), and picnic area ($\bar{x}$ = 33.15, s = 11.15) symbols were significantly slower than the other symbols in the group (Table 29).

Table 28. Significant Differences of Symbols on the Old Imagery Background

ANOVA[a]

		Sum of Squares	df	Mean Square	F	Sig.
Time	Between Groups	2658.901	4	664.725	8.021	.000
	Within Groups	10608.257	128	82.877		
	Total	13267.158	132			
Percent Correct	Between Groups	4033.954	4	1008.488	7.474	.000
	Within Groups	17270.971	128	134.929		
	Total	21304.925	132			

Table 29. *t* Tests for Equality of Means (Time) among Symbols on the Old Imagery Background

Independent Samples Test							
t-test for Equality of Means (Time)							
Symbol	t	df	Sig. (2-tailed)	Mean Difference	Std. Error Difference	95% Confidence Interval of the Difference	
						Lower	Upper
Camping * Picnic	-3.604	50	.001	-10.269	2.849	-15.992	-4.547
Camping * Snack	-3.665	49	.001	-8.755	2.389	-13.556	-3.954
Camping * Trailer	-3.518	48	.001	-9.407	2.674	-14.784	-4.030
Camping * Gas	-.465	56	.644	-.990	2.129	-5.256	3.275
Picnic * Snack	.550	49	.585	1.514	2.754	-4.020	7.047
Picnic * Trailer	.286	48	.776	.862	3.017	-5.205	6.929
Picnic * Gas	3.791	56	.000	9.279	2.448	4.375	14.182
Snack * Trailer	-.256	47	.799	-.652	2.550	-5.782	4.479
Snack * Gas	3.874	55	.000	7.765	2.004	3.748	11.782
Trailer * Gas	3.706	54	.000	8.417	2.271	3.863	12.970

The mean search accuracy for individual symbols varied from 79.47 percent to 96.15 percent, and the standard deviations from 6.82 to 16.35 (Table 27). *t* tests showed that there were no significant differences between the camping ($\bar{x}$= 96.15, s = 6.82) and gas station ($\bar{x}$= 90.34, s = 16.35) symbols; both were found to be significantly more accurate than the other symbols. Finally, the snack bar symbol ($\bar{x}$ = 79.47, s = 11.05) was found significantly less accurate than the other symbols (Table 30). It would appear from the analyses camping symbol and gas station symbols work best for this search task, both in terms of time and accuracy. The

Table 30. *t* Tests for Equality of Means (Accuracy) among Symbols on the Old Imagery Background

Independent Samples Test							
t-test for Equality of Means (Accuracy)							
Symbol	t	df	Sig. (2-tailed)	Mean Difference	Std. Error Difference	95% Confidence Interval of the Difference	
						Lower	Upper
Camping * Picnic	3.926	50	.000	10.4072	2.6511	5.0824	15.7321
Camping * Snack	6.511	49	.000	16.6756	2.5611	11.5289	21.8222
Camping * Trailer	2.357	48	.023	4.9501	2.1000	.7278	9.1724
Camping * Gas	1.694	56	.096	5.8129	3.4318	-1.0618	12.6877
Picnic * Snack	1.968	49	.055	6.2683	3.1847	-.1315	12.6681
Picnic * Trailer	-1.912	48	.062	-5.4571	2.8540	-11.1954	.2812
Picnic * Gas	-1.204	56	.234	-4.5943	3.8161	-12.2389	3.0503
Snack * Trailer	-4.237	47	.000	-11.7254	2.7673	-17.2925	-6.1584
Snack * Gas	-2.848	55	.006	-10.8626	3.8135	-18.5052	-3.2201
Trailer * Gas	.238	54	.813	.8628	3.6325	-6.4199	8.1455

fastest search times was expected to be for the camping and gas station symbols.

On the other hand, the results found that the snack bar, trailer site, and picnic area symbols were the slowest symbols in search time; again, expected results.. And the same was with the snack bar symbol which was also had a low accuracy since it similar to the other symbols which caused the low accuracy.

Simple Geometric Symbols on the Dense Linear Background

Table 31. Descriptive Statistics for the Simple Geometric Symbols in Search Time on the Dense Linear Background

Descriptives									
						95% Confidence Interval for Mean			
		N	Mean	Std. Deviation	Std. Error	Lower Bound	Upper Bound	Minimum	Maximum
Time on the Dense Linear BK	Camping	32	20.88	5.511	.974	18.89	22.86	12	33
	Picnic Area	26	33.04	10.448	2.049	28.82	37.26	16	57
	Snack Bar	26	34.62	9.888	1.939	30.62	38.61	18	55
	Trailer Site	26	29.42	8.242	1.616	26.09	32.75	14	46
	Gas Station	24	17.83	5.378	1.098	15.56	20.10	10	27
	Total	134	27.01	10.371	.896	25.24	28.79	10	57

Table 32. Descriptive Statistics for the Simple Geometric Symbols in Accuracy on the Dense Linear Background

Descriptives									
						95% Confidence Interval for Mean			
		N	Mean	Std. Deviation	Std. Error	Lower Bound	Upper Bound	Minimum	Maximum
Percent Correct Against The Dense Linear BK	Camping	32	95.156	7.3489	1.2991	92.507	97.806	70.0	100.0
	Picnic Area	26	90.271	8.7948	1.7248	86.719	93.824	70.6	100.0
	Snack Bar	26	86.789	18.2186	3.5730	79.431	94.148	4.3	100.0
	Trailer Site	26	97.436	3.9223	.7692	95.852	99.020	83.3	100.0
	Gas Station	24	91.279	6.6850	1.3646	88.456	94.102	68.2	100.0
	Total	134	92.333	10.6858	.9231	90.507	94.159	4.3	100.0

The symbols were analyzed using the two dependent variables: time and accuracy. Tables 31 and 32 show the number of searches, mean search times, and standard deviations for both time and accuracy. Analysis of Variance shows that there are significant differences for both search times ($F(4, 129) = 22.16$, $p < .001$) and search accuracy ($F(4, 129) = 4.52$, $p < .001$) (Table 33). The mean search times for the individual symbols varied from 17.83 to 34.62 seconds, and the standard deviations varied from 5.37 to 10.44 (Table 72). The response time for the gas station symbol ($\bar{x} = 17.83$, $s = 5.37$) and the camping symbol ($\bar{x} = 20.88$, $s = 5.51$) were significantly faster than the other symbols. On the other hand, response times of the trailer site ($\bar{x} = 29.42$, $s = 8.24$), picnic area ($\bar{x} = 33.04$, $s = 10.44$), and snack bar ($\bar{x} = 34.62$, $s = 9.88$) symbols were significantly slower than the other symbols (Table 34).

The mean search accuracy for individual symbol varied from 86.78 percent to 97.43 percent, and the standard deviation varied from 3.92 to 18.21 (Table 32). The *t*

Table 33. Significant Differences of Symbols on the Dense Linear Background

ANOVA

		Sum of Squares	df	Mean Square	F	Sig.
Time	Between Groups	5825.675	4	1465.419	22.160	.000
	Within Groups	8478.295	129	65.723		
	Total	14303.970	133			
Percent Correct	Between Groups	1868.305	4	467.076	4.524	.002
	Within Groups	13318.363	129	103.243		
	Total	15186.668	133			

Table 34. *t* Tests for Equality of Means (Time) among Symbols on the Dense Linear Background

Independent Samples Test							
t-test for Equality of Means (Time)							
Symbol	t	df	Sig. (2-tailed)	Mean Difference	Std. Error Difference	95% Confidence Interval of the Difference	
						Lower	Upper
Camping * Picnic	-5.690	56	.000	-12.163	2.138	-16.446	-7.881
Camping * Snack	-6.693	56	.000	-13.740	2.053	-17.853	-9.628
Camping * Trailer	-4.715	56	.000	-8.548	1.813	-12.180	-4.917
Camping * Gas	2.065	54	.044	3.042	1.473	.088	5.995
Picnic * Snack	-.559	50	.579	-1.577	2.821	-7.243	4.089
Picnic * Trailer	1.385	50	.172	3.615	2.610	-1.627	8.857
Picnic * Gas	6.388	48	.000	15.205	2.380	10.419	19.991
Snack * Trailer	2.057	50	.045	5.192	2.524	.122	10.263
Snack * Gas	7.366	48	.000	16.782	2.278	12.201	21.363
Trailer * Gas	5.835	48	.000	11.590	1.986	7.596	15.584

test showed that there were no significant differences between the trailer site and camping symbols in search accuracy, however trailer site ($\bar{x}$= 97.43, s = 3.92), and camping ($\bar{x}$= 95.15, s = 7.34) were found to be significantly more accurate than the other symbols. Furthermore, the snack bar ($\bar{x}$ =86.78, s = 18.21), picnic area ($\bar{x}$ =90.27, s = 8.79), and gas station ($\bar{x}$ = 91.27, s = 6.68) symbols were found significantly less accurate than the other symbols (Table 35).

From the analyses, it is clear that the gas station symbol (triangle) and the camping symbol (square) work best for search time. The fastest search time was expected to be for the gas station symbol and camping symbol since these symbols are distinctive in design. The attributes of these symbols compared to the other symbols in the group promote a fast and accurate search. On the other hand, the trailer site, picnic area, and snack bar symbols were the slowest symbols; the snack bar and picnic area symbols had low accuracies.

Table 35. *t* Tests for Equality of Means (Accuracy) among Symbols on the Dense Linear Background

Independent Samples Test							
t-test for Equality of Means (Accuracy)							
Symbol	t	df	Sig. (2-tailed)	Mean Difference	Std. Error Difference	95% Confidence Interval of the Difference	
						Lower	Upper
Camping * Picnic	2.305	56	.025	4.8848	2.1193	.6393	9.1302
Camping * Snack	2.375	56	.021	8.3670	3.5233	1.3089	15.4250
Camping * Trailer	-1.424	56	.160	-2.2796	1.6009	-5.4867	.9274
Camping * Gas	2.030	54	.047	3.8774	1.9101	.0478	7.7070
Picnic * Snack	.878	50	.384	3.4822	3.9675	-4.4868	11.4511
Picnic * Trailer	-3.794	50	.000	-7.1644	1.8886	-10.9577	-3.3711
Picnic * Gas	-.453	48	.653	-1.0074	2.2235	-5.4780	3.4632
Snack * Trailer	-2.913	50	.005	-10.6466	3.6548	-17.9875	-3.3057
Snack * Gas	-1.138	48	.261	-4.4896	3.9456	-12.4228	3.4436
Trailer * Gas	4.010	48	.000	6.1570	1.5355	3.0696	9.2445

Simple Geometric Symbols on the Gray Background

The symbol system was analyzed using the two dependent variables: time and accuracy. Table 36 shows the number of searches, mean search times, and standard deviations for both time and accuracy for the trailer site symbol (a circle).

Table 36. Descriptive Statistics for the Trailer Site Symbol in Mean Search Time and Accuracy on the Gray Background

Background	Symbol		Time	Percent Correct
Gray	Trailer Site	N	98	98
		Mean	31.4	92.857
		Std. Deviation	13.834	14.4897

The response time for trailer site symbol ($\bar{x}$ = 31.4, s = 13.83), and the mean search accuracy was ($\bar{x}$ = 92.85, s = 14.48) (Table 36).

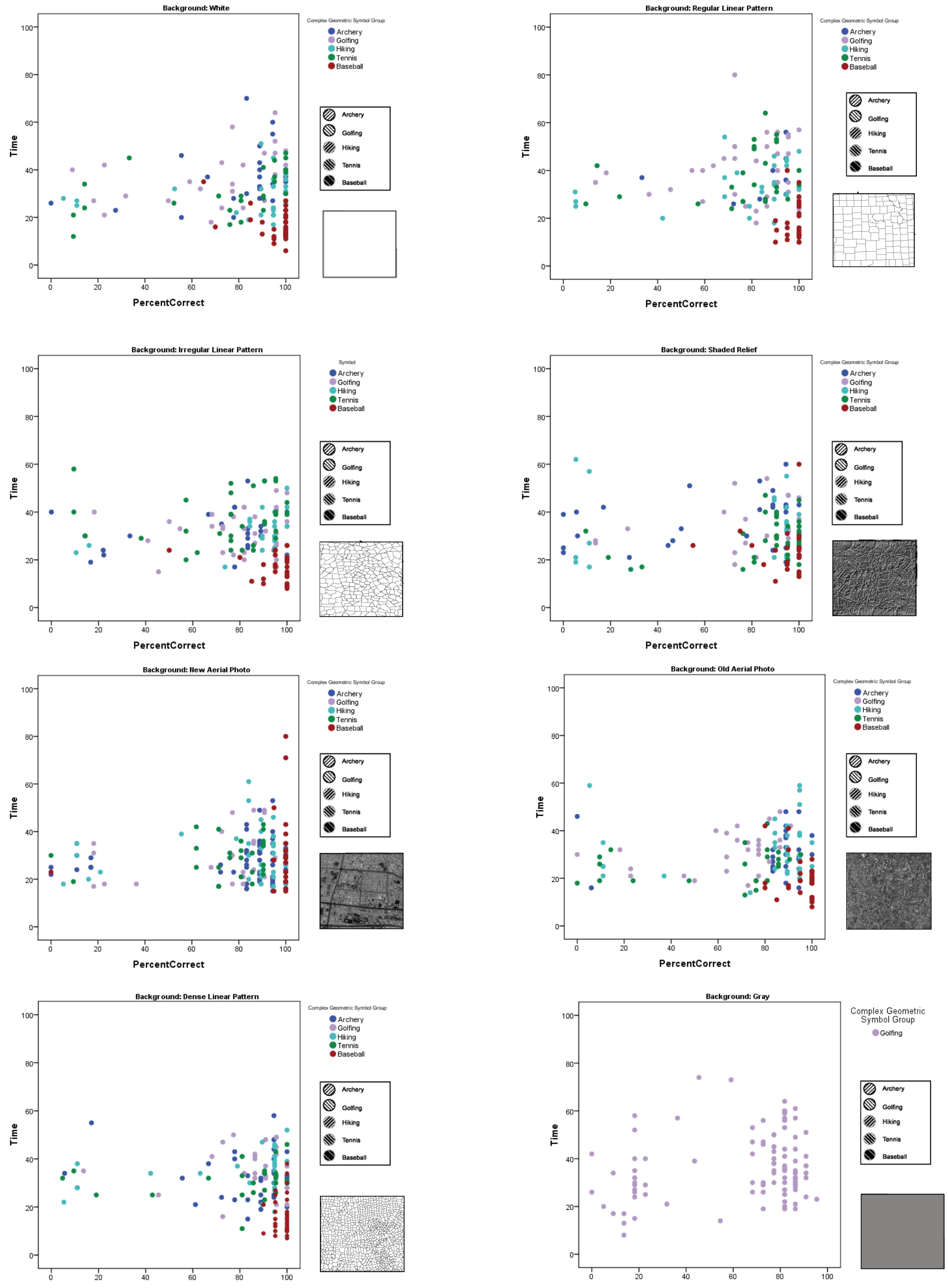


Figure 4. Complex geometric symbol group on the eight backgrounds.

Complex Geometric Symbols on the White Background

Table 37. Descriptive Statistics for the Complex Geometric Symbols in Search Time on the White Background

Descriptives									
		N	Mean	Std. Deviation	Std. Error	95% Confidence Interval for Mean Lower Bound	95% Confidence Interval for Mean Upper Bound	Minimum	Maximum
Time on the White BK	Archery	26	36.19	12.387	2.429	31.19	41.20	20	70
	Golfing	26	37.23	11.382	2.232	32.63	41.83	18	64
	Hiking	25	28.84	8.229	1.646	25.44	32.24	17	51
	Tennis	24	30.96	9.756	1.991	26.84	35.08	12	47
	Baseball	32	16.69	5.997	1.060	14.53	18.85	6	35
	Total	133	29.38	12.320	1.068	27.26	31.49	6	70

Table 38. Descriptive Statistics for the Complex Geometric Symbols in Accuracy on the White Background

Descriptives									
		N	Mean	Std. Deviation	Std. Error	95% Confidence Interval for Mean Lower Bound	95% Confidence Interval for Mean Upper Bound	Minimum	Maximum
Percent Correct on the White BK	Archery	26	81.827	23.8848	4.6842	72.180	91.474	.0	100.0
	Golfing	26	71.154	28.5444	5.5980	59.625	82.683	9.1	100.0
	Hiking	25	82.355	29.2776	5.8555	70.270	94.440	5.3	100.0
	Tennis	24	72.817	31.9740	6.5267	59.316	86.319	9.5	100.0
	Baseball	32	95.781	8.6238	1.5245	92.672	98.890	65.0	100.0
	Total	133	81.571	26.4235	2.2912	77.039	86.104	.0	100.0

The symbol system was analyzed using the two dependent variables: time and accuracy. Tables 37 and 38 show the number of searches, the mean search times, and standard deviations of both time and accuracy for each symbol. Analysis of Variance shows that there are significant differences in the mean search times for the symbol, F (4, 128) = 21.41, $p < .001$. Further, there are significant differences in search accuracy among the symbols, F (4, 128) = 4.39, $p < .001$ (Table 39). The mean search times for individual symbols varied from 16.69 to 37.23 seconds, and the standard deviations varied from 5.99 to 12.38 (Table 37). The response time for baseball ($\bar{x}$ = 16.69, s = 5.99) was found significantly faster than the other complex geometric symbols. On the other hand, t tests showed that there was no significant difference between the archery ($\bar{x}$ =36.19, s = 12.38) and golfing ($\bar{x}$ =37.23, s = 11.38) symbols, both significantly slower search times than the other symbols (Table 40).

Table 39. Significant Differences of Symbols on the White Background

ANOVA[a]

		Sum of Squares	df	Mean Square	F	Sig.
Time	Between Groups	8031.356	4	2007.839	21.410	.000
	Within Groups	12003.847	128	93.780		
	Total	20035.203	132			
Percent Correct	Between Groups	11139.305	4	2784.826	4.399	.002
	Within Groups	81023.129	128	632.993		
	Total	92162.434	132			

Table 40. *t* Tests for Equality of Means (Time) among Symbols on the White Background

Independent Samples Test							
t-test for Equality of Means (Time)							
Symbol	t	df	Sig. (2-tailed)	Mean Difference	Std. Error Difference	95% Confidence Interval of the Difference	
						Lower	Upper
Archery * Golfing	-.315	50	.754	-1.038	3.299	-7.665	5.588
Archery * Hiking	2.486	49	.016	7.352	2.957	1.410	13.295
Archery * Tennis	1.650	48	.105	5.234	3.171	-1.143	11.610
Archery * Baseball	7.857	56	.000	19.505	2.483	14.532	24.478
Golfing * Hiking	3.007	49	.004	8.391	2.791	2.782	13.999
Golfing * Tennis	2.084	48	.043	6.272	3.010	.220	12.325
Golfing * Baseball	8.825	56	.000	20.543	2.328	15.880	25.207
Hiking * Tennis	-.823	47	.415	-2.118	2.574	-7.297	3.061
Hiking * Baseball	6.450	55	.000	12.152	1.884	8.377	15.928
Tennis * Baseball	6.757	54	.000	14.271	2.112	10.036	18.505

The mean search accuracy for individual symbols varied from 71.15 percent to 95.78 percent, and the standard deviations from 8.62 to 31.97 (Table 38). *t* tests showed that there were significant differences between the baseball symbol and all other symbols in search accuracy; however, the baseball symbol ($\bar{x}$ = 95.78, s = 8.62) was found to be significantly more accurate than the other symbols. The golfing ($\bar{x}$ =71.15, s = 28.54), tennis ($\bar{x}$ =72.81, s = 31.97), archery ($\bar{x}$ =81.82, s = 23.88), and hiking ($\bar{x}$ =82.35, s = 29.27) symbols were found significantly less accurate than the baseball symbol, and *t* tests showed that there were no significant difference between these symbols (Table 41).

Table 41. *t* Tests for Equality of Means (Accuracy) among Symbols on the White Background

Independent Samples Test							
t-test for Equality of Means (Accuracy)							
Symbol	t	df	Sig. (2-tailed)	Mean Difference	Std. Error Difference	95% Confidence Interval of the Difference	
						Lower	Upper
Archery * Golfing	1.462	50	.150	10.6731	7.2993	-3.9879	25.3341
Archery * Hiking	-.071	49	.944	-.5282	7.4685	-15.5368	14.4803
Archery * Tennis	1.135	48	.262	9.0095	7.9411	-6.9571	24.9761
Archery * Baseball	-3.073	56	.003	-13.9543	4.5414	-23.0518	-4.8569
Golfing * Hiking	-1.383	49	.173	-11.2013	8.0968	-27.4725	5.0698
Golfing * Tennis	-.194	48	.847	-1.6636	8.5590	-18.8726	15.5454
Golfing * Baseball	-4.635	56	.000	-24.6274	5.3129	-35.2704	13.9844
Hiking * Tennis	1.090	47	.281	9.5377	8.7523	-8.0697	27.1451
Hiking * Baseball	-2.466	55	.017	-13.4261	5.4440	-24.3361	-2.5161
Tennis * Baseball	-3.889	54	.000	14.271	2.112	10.036	18.505

From these analyses, the baseball symbol was best for the task, both in time and accuracy. A fast and accurate search was expected; the baseball symbol is clearly different from the other symbols. There was a high contrast between all symbols and the white background. The other symbols, however, were slow in time and low in accuracy, which was expected since these symbols were similar to each other in their design characteristics.

Complex Geometric Symbols on the Regular Linear Background

Table 42. Descriptive Statistics for the Complex Geometric Symbols in Search Time on the Regular Linear Background

Descriptives									
		N	Mean	Std. Deviation	Std. Error	95% Confidence Interval for Mean Lower Bound	95% Confidence Interval for Mean Upper Bound	Minimum	Maximum
Time on the Regular Linear BK	Archery	8	37.25	9.896	3.499	28.98	45.52	26	56
	Golfing	35	39.49	12.821	2.167	35.08	43.89	18	80
	Hiking	26	33.92	9.130	1.791	30.24	37.61	18	54
	Tennis	25	37.88	11.512	2.302	33.13	42.63	24	64
	Baseball	24	18.46	8.151	1.664	15.02	21.90	10	40
	Total	118	33.49	13.188	1.214	31.09	35.90	10	80

Table 43. Descriptive Statistics for the Complex Geometric Symbols in Search Accuracy on the Regular Linear Background

Descriptives									
		N	Mean	Std. Deviation	Std. Error	95% Confidence Interval for Mean Lower Bound	95% Confidence Interval for Mean Upper Bound	Minimum	Maximum
Percent Correct on the Regular Linear BK	Archery	8	81.944	21.1549	7.4794	64.258	99.630	33.3	94.4
	Golfing	35	77.403	22.2267	3.7570	69.767	85.038	13.6	100.0
	Hiking	26	75.698	28.9329	5.6742	64.012	87.385	5.0	100.0
	Tennis	25	75.619	24.4872	4.8974	65.511	85.727	9.5	100.0
	Baseball	24	97.728	3.5621	.7271	96.224	99.232	90.0	100.0
	Total	118	81.091	23.4192	2.1559	76.821	85.361	5.0	100.0

The symbol system was analyzed using the two dependent variables: time and accuracy. Tables 42 and 43 show the number of searches, mean search times, and standard deviations for both time and accuracy. Analysis of Variance shows that there are significant differences in mean search times for the symbols, $F(4, 113) = 15.74$, $p < .001$. Further, there are significant differences in search accuracy, $F(4, 113) = 4.38$, $p < .001$ (Table 44). The mean search times for individual symbol varied from 18.46 to 39.49 seconds, and standard deviations varied from 8.15 to 12.82 (Table 42). The response time for baseball ($\bar{x} = 18.46$, $s = 8.15$) was significantly faster than the other symbols. t tests showed that the participants had a significantly slower search time for the other four symbols than the baseball symbol (Table 45). The mean search accuracy for individual symbols varied from 75.61 to 97.72 percent, and the standard deviations from 3.56 to 28.93 (Table 43). t tests showed that there were significant

Table 44. Significant Differences of Symbols in Search Time and Accuracy on the Regular Linear Background

ANOVA[a]

		Sum of Squares	df	Mean Square	F	Sig.
Time	Between Groups	7280.804	4	1820.201	15.741	.000
	Within Groups	13066.687	113	115.634		
	Total	20347.492	117			
Percent Correct	Between Groups	8629.717	4	2157.429	4.389	.002
	Within Groups	55540.242	113	491.507		
	Total	64169.959	117			

Table 45. *t* Tests for Equality of Means (Time) among Symbols on the Regular Linear Background

Independent Samples Test							
t-test for Equality of Means (Time)							
Symbol	t	df	Sig. (2-tailed)	Mean Difference	Std. Error Difference	95% Confidence Interval of the Difference	
						Lower	Upper
Archery * Golfing	-.461	41	.647	-2.236	4.848	-12.026	7.555
Archery * Hiking	.885	32	.383	3.327	3.761	-4.334	10.988
Archery * Tennis	-.139	31	.890	-.630	4.536	-9.882	8.622
Archery * Baseball	5.359	30	.000	18.792	3.507	11.630	25.953
Golfing * Hiking	1.884	59	.064	5.563	2.952	-.345	11.471
Golfing * Tennis	.499	58	.620	1.606	3.220	-4.840	8.051
Golfing * Baseball	7.101	57	.000	21.027	2.961	15.097	26.957
Hiking * Tennis	-1.363	49	.179	-3.957	2.903	-9.792	1.878
Hiking * Baseball	6.298	48	.000	15.465	2.455	10.528	20.402
Tennis * Baseball	6.790	47	.000	19.422	2.860	13.667	25.176

differences between the baseball symbol ($\bar{x}$ = 97.72, s = 3.56) and the other symbols, therefore baseball was found to be significantly more accurate (Table 46).

It would appear from the analyses the baseball symbol performs best for the search task, both in terms of search time and accuracy. The fastest search time was expected to be for this symbol since it looks different in design characteristic than the others in the group. Its characteristics enable it to pop out in fast time with a high accuracy. Furthermore, the results found that the archery, golfing, hiking, and tennis symbols were the slowest symbols in search time, as well as low in accuracy. These

Table 46. *t* Tests for Equality of Means (Accuracy) among Symbols on the Regular Linear Background

Independent Samples Test							
t-test for Equality of Means (Accuracy)							
Symbol	t	df	Sig. (2-tailed)	Mean Difference	Std. Error Difference	95% Confidence Interval of the Difference	
						Lower	Upper
Archery * Golfing	.526	41	.602	4.5418	8.6400	-12.9070	21.9907
Archery * Hiking	.563	32	.577	6.2461	11.0863	-16.3359	28.8281
Archery * Tennis	.655	31	.517	6.3254	9.6577	-13.3716	26.0224
Archery * Baseball	-3.619	30	.001	-15.7837	4.3618	-24.6917	-6.8758
Golfing * Hiking	.260	59	.796	1.7042	6.5468	-11.3960	14.8044
Golfing * Tennis	.294	58	.770	1.7835	6.0723	-10.3714	13.9385
Golfing * Baseball	-4.429	57	.000	-20.3256	4.5889	-29.5146	-11.1366
Hiking * Tennis	.011	49	.992	.0793	7.5203	-15.0332	15.1919
Hiking * Baseball	-3.701	48	.001	-22.0298	5.9517	-33.9965	-10.0631
Tennis * Baseball	-4.377	47	.000	-22.1091	5.0510	-32.2704	-11.9478

results were expected because of these symbols look similar to each other. As target symbols they did not pop out from among the non target symbols in most cases.

Complex Geometric Symbols on the Irregular Linear Background

Table 47. Descriptive Statistics for the Complex Geometric Symbols in Search Time on the Irregular Linear Background

Descriptives

		N	Mean	Std. Deviation	Std. Error	95% Confidence Interval for Mean		Minimum	Maximum
						Lower Bound	Upper Bound		
Time on the Irregular Linear BK	Archery	22	31.00	8.652	1.845	27.16	34.84	17	53
	Golfing	34	32.03	8.840	1.516	28.94	35.11	15	49
	Hiking	26	31.31	7.693	1.509	28.20	34.41	17	50
	Tennis	39	36.87	10.350	1.657	33.52	40.23	20	58
	Baseball	25	16.40	5.431	1.086	14.16	18.64	8	26
	Total	146	30.36	10.847	.898	28.59	32.14	8	58

Table 48. Descriptive Statistics for the Complex Geometric Symbols in Search Accuracy on the Irregular Linear Background

Descriptives

		N	Mean	Std. Deviation	Std. Error	95% Confidence Interval for Mean		Minimum	Maximum
						Lower Bound	Upper Bound		
Percent Correct on the Irregular Linear BK	Archery	22	68.677	28.9885	6.1804	55.824	81.530	.0	100.0
	Golfing	34	80.615	19.6166	3.3642	73.770	87.460	18.2	100.0
	Hiking	26	87.052	22.6628	4.4445	77.898	96.205	10.5	100.0
	Tennis	39	75.824	26.0679	4.1742	67.374	84.274	9.5	100.0
	Baseball	25	94.200	10.6732	2.1346	89.794	98.606	50.0	100.0
	Total	146	81.009	23.6994	1.9614	77.132	84.885	.0	100.0

The set of symbols was analyzed using the two dependent variables: time and accuracy. Tables 47 and 48 show the number of searches, mean search times, and standard deviations for both time and accuracy for each symbol. Analysis of Variance shows that there are significant differences in the mean search times for the symbols, $F\ (4, 141) = 22.53$, $p < .001$. Further, there are significant differences in search accuracy among the symbols, $F\ (4, 141) = 4.76$, $p < .001$ (Table 49). The mean search times for individual symbols varied from 16.40 to 36.87 seconds, and the standard deviations varied from 5.43 to 10.35 (Table 47). The response time for the baseball symbol ($\bar{x}$ = 16.40, s = 5.43) was significantly faster than the other symbols. Response time for the tennis symbol ($\bar{x}$=36.87, s = 10.35) was significantly slower than the other symbols (Table 50).

Table 49. Significant Differences of Symbols in Search Time and Accuracy on the Irregular Linear Background

ANOVA[a]

		Sum of Squares	df	Mean Square	F	Sig.
Time	Between Groups	6652.892	4	1663.223	22.530	.000
	Within Groups	10408.868	141	73.822		
	Total	17061.760	145			
Percent Correct	Between Groups	9698.946	4	2424.736	4.766	.001
	Within Groups	71742.143	141	508.810		
	Total	81441.089	145			

Table 50. *t* Tests for Equality of Means (Time) among Symbols on the Irregular Linear Background

Independent Samples Test							
t-test for Equality of Means (Time)							
Symbol	t	df	Sig. (2-tailed)	Mean Difference	Std. Error Difference	95% Confidence Interval of the Difference	
						Lower	Upper
Archery * Golfing	-.429	54	.670	-1.029	2.399	-5.839	3.780
Archery * Hiking	-.130	46	.897	-.308	2.359	-5.057	4.442
Archery * Tennis	-2.252	59	.028	-5.872	2.608	-11.089	-.654
Archery * Baseball	7.017	45	.000	14.600	2.081	10.409	18.791
Golfing * Hiking	.331	58	.742	.722	2.179	-3.641	5.084
Golfing * Tennis	-2.133	71	.036	-4.842	2.271	-9.370	-.315
Golfing * Baseball	7.812	57	.000	15.629	2.001	11.623	19.636
Hiking * Tennis	-2.341	63	.022	-5.564	2.376	-10.313	-.815
Hiking * Baseball	7.965	49	.000	14.908	1.872	11.147	18.669
Tennis * Baseball	9.102	62	.000	20.472	2.249	15.976	24.968

The mean search accuracy for individual symbol groups varied from 68.67 to 94.20, and the standard deviations varied from 10.67 to 28.98 (Table 48). *t* tests showed that there was significant difference between the baseball symbol and the other symbols in accuracy, except for the hiking symbol; however, the baseball symbol ($\bar{x}$ = 94.20, s = 10.67) was found to be significantly more accurate than the other symbols. Additionally, *t* tests showed that there was no significant difference between the archery and tennis symbols, and between the archery and golfing symbols; further, the archery ($\bar{x}$ =68.67, s = 28.98), tennis ($\bar{x}$ =75.82, s = 26.06), and golfing ($\bar{x}$ =80.61, s = 19.61) symbols were found to be significantly less accurate than the other symbols (Table 51).

Table 51. *t* Tests for Equality of Means (Accuracy) among Symbols on the Irregular Linear Background

Independent Samples Test							
t-test for Equality of Means (Accuracy)							
Symbol	t	df	Sig. (2-tailed)	Mean Difference	Std. Error Difference	95% Confidence Interval of the Difference	
						Lower	Upper
Archery * Golfing	-1.841	54	.071	-11.9382	6.4863	-24.9424	1.0660
Archery * Hiking	-2.464	46	.018	-18.3749	7.4576	-33.3863	-3.3634
Archery * Tennis	-.988	59	.327	-7.1474	7.2375	-21.6296	7.3347
Archery * Baseball	-4.103	45	.000	-25.5232	6.2212	-38.0534	-12.993
Golfing * Hiking	-1.177	58	.244	-6.4366	5.4668	-17.3797	4.5064
Golfing * Tennis	.877	71	.384	4.7908	5.4653	-6.1066	15.6882
Golfing * Baseball	-3.134	57	.003	-13.5850	4.3351	-22.2659	-4.9041
Hiking * Tennis	1.790	63	.078	11.2274	6.2721	-1.3063	23.7612
Hiking * Baseball	-1.431	49	.159	-7.1484	4.9938	-17.1838	2.8870
Tennis * Baseball	-3.342	62	.001	-18.3758	5.4985	-29.3672	-7.3845

From the analyses, the baseball symbol is best both in terms of time and accuracy. These results were expected since this symbol has a distinctive design, different from the other four which have similar characteristics.

Complex Geometric Symbol Group on the New Imagery Background

Table 52. Descriptive Statistics for the Complex Geometric Symbols in Search Time on the New Imagery Background

Descriptives

		N	Mean	Std. Deviation	Std. Error	95% Confidence Interval for Mean Lower Bound	95% Confidence Interval for Mean Upper Bound	Minimum	Maximum
Time on the New Imagery BK	Archery	57	27.44	8.248	1.093	25.25	29.63	15	53
	Golfing	21	30.14	11.346	2.476	24.98	35.31	17	49
	Hiking	35	30.86	10.460	1.768	27.26	34.45	17	61
	Tennis	26	29.23	7.921	1.553	26.03	32.43	17	43
	Baseball	26	31.50	15.456	3.031	25.26	37.74	15	80
	Total	165	29.43	10.496	.817	27.82	31.04	15	80

Table 53. Descriptive Statistics for the Complex Geometric Symbols in Search Accuracy on the New Imagery Background

Descriptives

		N	Mean	Std. Deviation	Std. Error	95% Confidence Interval for Mean Lower Bound	95% Confidence Interval for Mean Upper Bound	Minimum	Maximum
Percent Correct on the New Imagery BK	Archery	57	80.033	27.1620	3.5977	72.826	87.240	.0	100.0
	Golfing	21	68.831	27.3969	5.9785	56.360	81.302	18.2	95.5
	Hiking	35	77.123	30.9219	5.2267	66.501	87.745	5.3	100.0
	Tennis	26	74.542	22.6956	4.4510	65.375	83.709	.0	90.5
	Baseball	26	95.577	19.5615	3.8363	87.676	103.47	.0	100.0
	Total	165	79.574	27.1898	2.1167	75.395	83.754	.0	100.0

The symbol system was analyzed using the two dependent variables: time and accuracy. Tables 52 and 53 show the number of searches, mean search times, and standard deviations for both time and accuracy for each symbol. Analysis of Variance shows that there are no significant differences in the mean search times for the symbols, F (4, 160) = .95, p = .435. On the other hand, there are significant differences in search accuracy among the symbols, F (4, 160) = 3.58, p < .001 (Table 54). Search times for symbols varied from 27.44 to 31.50 seconds, and the standard deviations varied from 7.92 to 15.45 (Table 52). *t* tests showed that there were no significant differences among the symbols in the mean search time (Table 55).

Accuracy varied from 68.83 to 95.57 percent, and standard deviations from 19.56 to 30.92 (Table 53). *t*-tests showed that the baseball symbol ($\bar{x}$ = 95.57, s = 19.56) was significantly more accurate than the other four. symbols (Table 56).

Table 54. Significant Differences of Symbols in Search Time and Accuracy on the New Imagery Background

ANOVA[a]

		Sum of Squares	df	Mean Square	F	Sig.
Time	Between Groups	420.441	4	105.110	.953	.435
	Within Groups	17646.008	160	110.288		
	Total	18066.448	164			
Percent Correct	Between Groups	9962.660	4	2490.665	3.581	.008
	Within Groups	111280.185	160	695.501		
	Total	121242.845	164			

Table 55. *t* Tests for Equality of Means (Time) among the Complex Geometric Symbols on the New Imagery Background

Independent Samples Test							
t-test for Equality of Means (Time)							
Symbol	t	df	Sig. (2-tailed)	Mean Difference	Std. Error Difference	95% Confidence Interval of the Difference	
						Lower	Upper
Archery * Golfing	-1.156	76	.251	-2.704	2.340	-7.364	1.956
Archery * Hiking	-1.740	90	.085	-3.419	1.964	-7.321	.484
Archery * Tennis	-.929	81	.355	-1.792	1.928	-5.629	2.045
Archery * Baseball	-1.562	81	.122	-4.061	2.601	-9.236	1.113
Golfing * Hiking	-.240	54	.811	-.714	2.980	-6.689	5.261
Golfing * Tennis	.324	45	.747	.912	2.815	-4.758	6.582
Golfing * Baseball	-.336	45	.739	-1.357	4.043	-9.501	6.787
Hiking * Tennis	.663	59	.510	1.626	2.451	-3.279	6.531
Hiking * Baseball	-.194	59	.847	-.643	3.319	-7.283	5.997
Tennis * Baseball	-.666	50	.508	-2.269	3.406	-9.111	4.572

The five symbols had no significant differences from each other in the search time on the new imagery background. The reason: the effect of the background. Since these symbols were complex in their characteristics and the background was complex, all of the symbols had the same level of performance. For example, while the baseball would pop out among the other symbols in some backgrounds, it did not pop out this time because this background is similar to these symbols.

Moreover, while there were no significant differences among the symbols in the search time, there was a difference between the baseball symbol and the rest of the symbols in search accuracy. The reason for this could be due to the time that the participants spent in searching for the baseball; although there were no significant differences among the symbols against this background, the mean time searching for the baseball was the slowest one, and that probably made the accuracy of the baseball to be the highest.

Table 56. *t* Tests for Equality of Means (Accuracy) among the Complex Geometric Symbols on the New Imagery Background

Independent Samples Test							
t-test for Equality of Means (Accuracy)							
Symbol	t	df	Sig. (2-tailed)	Mean Difference	Std. Error Difference	95% Confidence Interval of the Difference	
						Lower	Upper
Archery * Golfing	1.612	76	.111	11.2020	6.9495	-2.6391	25.0431
Archery * Hiking	.473	90	.637	2.9105	6.1504	-9.3083	15.1293
Archery * Tennis	.897	81	.372	5.4910	6.1213	-6.6884	17.6704
Archery * Baseball	-2.621	81	.010	-15.5438	5.9313	-27.3453	-3.7423
Golfing * Hiking	-1.013	54	.316	-8.2915	8.1884	-24.7082	8.1252
Golfing * Tennis	-.782	45	.438	-5.7110	7.3040	-20.4220	9.0001
Golfing * Baseball	-3.901	45	.000	-26.7458	6.8568	-40.5560	-12.9355
Hiking * Tennis	.359	59	.721	2.5805	7.1810	-11.7885	16.9496
Hiking * Baseball	-2.669	59	.010	-18.4543	6.9141	-32.2893	-4.6192
Tennis * Baseball	-3.580	50	.001	-21.0348	5.8761	-32.8373	-9.2323

Complex Geometric Symbol Group on the Shaded Relief Background

Table 57. Descriptive Statistics for the Complex Geometric Symbols in Search Time on the Shaded Relief Background

Descriptives									
						95% Confidence Interval for Mean			
		N	Mean	Std. Deviation	Std. Error	Lower Bound	Upper Bound	Minimum	Maximum
Time on the Shaded Relief BK	Archery	26	36.38	10.759	2.110	32.04	40.73	19	60
	Golfing	25	34.24	9.189	1.838	30.45	38.03	18	54
	Hiking	22	33.36	13.233	2.821	27.50	39.23	17	62
	Tennis	35	28.89	8.127	1.374	26.09	31.68	16	47
	Baseball	26	23.62	9.252	1.815	19.88	27.35	11	60
	Total	134	31.05	10.864	.938	29.20	32.91	11	62

Table 58. Descriptive Statistics for the Complex Geometric Symbols in Search Accuracy on the Shaded Relief Background

Descriptives									
						95% Confidence Interval for Mean			
		N	Mean	Std. Deviation	Std. Error	Lower Bound	Upper Bound	Minimum	Maximum
Percent Correct on the Shaded Relief BK	Archery	26	62.218	37.4457	7.3437	47.093	77.343	.0	100.0
	Golfing	25	80.545	25.7304	5.1461	69.924	91.166	13.6	100.0
	Hiking	22	71.358	39.7702	8.4790	53.725	88.991	5.3	100.0
	Tennis	35	84.490	23.7631	4.0167	76.327	92.653	9.5	100.0
	Baseball	26	94.231	10.4587	2.0511	90.006	98.455	55.0	100.0
	Total	134	79.167	30.2673	2.6147	73.995	84.338	.0	100.0

The symbols were analyzed using the two dependent variables: time and accuracy. Tables 57 and 58 show the number of searches, mean search times, and standard deviations for both time and accuracy. Analysis of Variance shows that there are significant differences in search times for the symbols, F (4, 129) = 6.73, $p < .001$. Further, there are significant differences in search accuracy among the symbols, F (4, 129) = 4.78, $p < .001$ (Table 59). The mean search times varied from 23.62 to 36.38 seconds, and the standard deviations from 8.12 to 13.23 (Table 58). t tests showed that the response time for the baseball symbol ($\bar{x}$ = 23.62, s = 9.25) was significantly faster than times for the other symbols. Response times for the archery ($\bar{x}$ =36.38, s = 10.75), golfing ($\bar{x}$ = 34.24, s = 9.18), and hiking ($\bar{x}$ = 33.36, s = 13.23) symbols were significantly slower than the other symbols (Table 60).

Table 59. Significant Differences of Symbols in Search Time and Accuracy on the Shaded Relief Background.

ANOVA[a]

		Sum of Squares	df	Mean Square	F	Sig.
Time	Between Groups	2713.133	4	678.283	6.739	.000
	Within Groups	12983.501	129	100.647		
	Total	15696.634	133			
Percent Correct	Between Groups	15749.528	4	3937.382	4.788	.001
	Within Groups	106092.707	129	822.424		
	Total	121842.235	133			

Table 60. *t* Tests for Equality of Means (Time) among Symbols on the Shaded Relief Background

Independent Samples Test							
t-test for Equality of Means (Time)							
Symbol	t	df	Sig. (2-tailed)	Mean Difference	Std. Error Difference	95% Confidence Interval of the Difference	
						Lower	Upper
Archery * Golfing	.764	49	.449	2.145	2.807	-3.496	7.786
Archery * Hiking	.873	46	.387	3.021	3.462	-3.948	9.990
Archery * Tennis	3.103	59	.003	7.499	2.417	2.663	12.334
Archery * Baseball	4.588	50	.000	12.769	2.783	7.179	18.359
Golfing * Hiking	.266	45	.791	.876	3.291	-5.752	7.505
Golfing * Tennis	2.382	58	.020	5.354	2.247	.856	9.853
Golfing * Baseball	4.113	49	.000	10.625	2.583	5.434	15.815
Hiking * Tennis	1.586	55	.118	4.478	2.823	-1.180	10.136
Hiking * Baseball	2.992	46	.004	9.748	3.258	3.191	16.306
Tennis * Baseball	2.361	59	.022	5.270	2.232	.804	9.737

Search accuracy for individual symbols varied from 62.21 to 94.23 percent, and standard deviations varied from 10.45 to 39.77 (Table 58). *t*-tests showed that there were significant differences between the baseball symbol and the other symbols except for the tennis symbol; however, baseball symbol ($\bar{x}$ = 94.23, s = 10.45), was found to be significantly more accurate than the other symbols. Additionally, the archery symbol ($\bar{x}$ = 62.21, s = 37.44) was found significantly less accurate than the other symbols (Table 61).

Table 61. *t* Tests for Equality of Means (Accuracy) among Symbols on the Shaded Relief Background

Independent Samples Test							
t-test for Equality of Means (Accuracy)							
Symbol	t	df	Sig. (2-tailed)	Mean Difference	Std. Error Difference	95% Confidence Interval of the Difference	
						Lower	Upper
Archery * Golfing	-2.029	49	.048	-18.3275	9.0318	-36.4777	-.1774
Archery * Hiking	-.819	46	.417	-9.1402	11.1598	-31.6037	13.3234
Archery * Tennis	-2.837	59	.006	-22.2718	7.8511	-37.9820	-6.5617
Archery * Baseball	-4.199	50	.000	-32.0128	7.6248	-47.3276	16.6980
Golfing * Hiking	.951	45	.346	9.1873	9.6565	-10.2619	28.6366
Golfing * Tennis	-.612	58	.543	-3.9443	6.4408	-16.8370	8.9483
Golfing * Baseball	-2.506	49	.016	-13.6853	5.4609	-24.6594	-2.7112
Hiking * Tennis	-1.563	55	.124	-13.1317	8.3992	-29.9639	3.7006
Hiking * Baseball	-2.824	46	.007	-22.8726	8.0983	-39.1736	-6.5717
Tennis * Baseball	-1.951	59	.056	-9.7410	4.9920	-19.7300	.2480

It appears from the analyses that the baseball symbol works best for the search task, in terms of both time and accuracy. Although the shaded relief background is complex, the baseball symbol still pops out from the background and among the other symbols. On the other hand, the archery, golfing, and hiking symbols were the slowest symbols, a result expected because of their similarity in design. In addition, the lowest search accuracy was found with both the archery symbol and the hiking symbol which both had the same orientation design.

Complex Geometric Symbol Group on the Old Imagery Background

Table 62. Descriptive Statistics for the Complex Geometric Symbols in Search Time on the Old Imagery Background

Descriptives									
		N	Mean	Std. Deviation	Std. Error	95% Confidence Interval for Mean Lower Bound	95% Confidence Interval for Mean Upper Bound	Minimum	Maximum
Time on the Old Imagery BK	Archery	26	31.00	9.038	1.772	27.35	34.65	16	48
	Golfing	26	31.69	8.346	1.637	28.32	35.06	17	48
	Hiking	39	31.67	10.991	1.760	28.10	35.23	14	59
	Tennis	24	24.96	7.166	1.463	21.93	27.98	13	43
	Baseball	32	19.94	7.729	1.366	17.15	22.72	8	42
	Total	147	27.90	10.075	.831	26.26	29.55	8	59

Table 63. Descriptive Statistics for the Complex Geometric Symbols in Search Accuracy on the Old Imagery Background

Descriptives									
		N	Mean	Std. Deviation	Std. Error	95% Confidence Interval for Mean Lower Bound	95% Confidence Interval for Mean Upper Bound	Minimum	Maximum
Percent Correct on the Old Imagery BK	Archery	26	83.350	24.1846	4.7430	73.582	93.119	.0	100.0
	Golfing	26	63.986	23.8079	4.6691	54.370	73.602	.0	90.9
	Hiking	39	79.405	28.8389	4.6179	70.056	88.753	5.3	100.0
	Tennis	24	62.103	31.5394	6.4380	48.785	75.421	.0	95.2
	Baseball	32	95.625	6.5685	1.1612	93.257	97.993	80.0	100.0
	Total	147	78.082	27.0141	2.2281	73.678	82.485	.0	100.0

The symbols were analyzed using the two dependent variables: time and accuracy. Tables 62 and 63 show the number of searches, mean search times, and standard deviations for both time and accuracy for each symbol. Analysis of Variance shows that there are significant differences in the mean search times, $F(4, 142) = 10.62$, $p < .001$. Further, there are significant differences in search accuracy, $F(4, 142) = 9.20$, $p < .001$ (Table 64). The search times for symbols varied from 19.94 to 31.69 seconds, and the standard deviations varied from 7.16 to 10.99 (Table 62). The response time for the baseball symbol ($\bar{x}$ = 19.94, s = 7.16) was significantly faster than the other symbols. And the *t* test showed participants had a significantly faster search time in baseball symbol than the other symbols. Also, the *t* test showed that there were no significant differences among the archery ($\bar{x}$ =31.00, s = 9.03), hiking ($\bar{x}$ = 31.67, s = 10.99), and golfing ($\bar{x}$ = 31.69, s = 8.34) symbols, these significantly slower than the baseball and tennis symbols (Table 65).

Table 64. Significant Differences of Symbols in Search Time and Accuracy on the Old Imagery Background

ANOVA[a]

		Sum of Squares	df	Mean Square	F	Sig.
Time	Between Groups	3413.628	4	853.407	10.624	.000
	Within Groups	11407.038	142	80.331		
	Total	14820.667	146			
Percent Correct	Between Groups	21931.998	4	5482.999	9.202	.000
	Within Groups	84613.001	142	595.866		
	Total	106544.999	146			

Table 65. *t* Tests for Equality of Means (Time) among Symbols on the Old Imagery Background

Independent Samples Test							
t-test for Equality of Means (Time)							
Symbol	t	df	Sig. (2-tailed)	Mean Difference	Std. Error Difference	95% Confidence Interval of the Difference	
						Lower	Upper
Archery * Golfing	-.287	50	.775	-.692	2.413	-5.538	4.154
Archery * Hiking	-.257	63	.798	-.667	2.598	-5.858	4.525
Archery * Tennis	2.605	48	.012	6.042	2.320	1.378	10.705
Archery * Baseball	5.025	56	.000	11.062	2.202	6.652	15.473
Golfing * Hiking	.010	63	.992	.026	2.538	-5.047	5.098
Golfing * Tennis	3.049	48	.004	6.734	2.209	2.293	11.175
Golfing * Baseball	5.558	56	.000	11.755	2.115	7.518	15.992
Hiking * Tennis	2.658	61	.010	6.708	2.524	1.662	11.755
Hiking * Baseball	5.089	69	.000	11.729	2.305	7.131	16.327
Tennis * Baseball	2.481	54	.016	5.021	2.024	.964	9.078

The mean search accuracy for individual symbols varied from 62.10 to 95.62 percent, and the standard deviations from 6.56 to 31.53 (Table 63). *t* tests showed that there were significant differences between the baseball symbol ($\bar{x}$ = 95.62, s = 6.56) and the other symbols in search accuracy. Additionally, *t* tests showed that there was no significant difference between the tennis ($\bar{x}$ = 62.10, s = 31.53) and golfing ($\bar{x}$ = 63.98, s = 23.80) symbols in accuracy; the tennis and golfing symbols were found significantly less accurate than the other symbols (Table 66).

Table 66. *t* Tests for Equality of Means (Accuracy) among Symbols on the Old Imagery Background

Independent Samples Test							
t-test for Equality of Means (Accuracy)							
Symbol	t	df	Sig. (2-tailed)	Mean Difference	Std. Error Difference	95% Confidence Interval of the Difference	
						Lower	Upper
Archery * Golfing	2.910	50	.005	19.3644	6.6556	5.9963	32.7325
Archery * Hiking	.575	63	.567	3.9456	6.8582	-9.7595	17.6506
Archery * Tennis	2.685	48	.010	21.2473	7.9122	5.3388	37.1557
Archery * Baseball	-2.754	56	.008	-12.2746	4.4573	-21.2037	-3.3455
Golfing * Hiking	-2.259	63	.027	-15.4188	6.8246	-29.0567	-1.7809
Golfing * Tennis	.239	48	.812	1.8828	7.8643	-13.9295	17.6951
Golfing * Baseball	-7.201	56	.000	-31.6390	4.3937	-40.4407	-22.837
Hiking * Tennis	2.231	61	.029	17.3017	7.7535	1.7976	32.8057
Hiking * Baseball	-3.112	69	.003	-16.2201	5.2116	-26.6169	-5.8234
Tennis * Baseball	-5.862	54	.000	-33.5218	5.7184	-44.9864	-22.057

It would appear from the analyses that the baseball symbol works best for the search task, both in terms of search time and accuracy. While there were no significant differences among the symbols against the new imagery background in mean search time, the old imagery background showed that there were significant differences among the symbols; the baseball symbol had the fastest time with the highest accuracy. The reason for that could due to the characteristics of the old imagery background. Therefore, the baseball symbol popped out against the background and among the other symbols.

Also, while the results found that there were no significant differences in mean search time against the new imagery background, this background showed that the archery symbol, hiking symbol, and golfing symbol were the slowest symbols in mean search time; this result was expected because these symbols look similar in their shape design to each other.

In addition, the baseball symbol was found to be the highest in the mean search accuracy whether on the new imagery or the old imagery. That could be due to the difference in the design of the baseball symbol compared to the other symbols. Also, while the results of the new imagery background showed that there were no significant differences among the archery, golfing, hiking, and tennis symbols in mean search accuracy and all of them had the lowest mean search accuracy, the results of the old imagery indicated no significant difference between the tennis and golfing symbols in the accuracy, and both had the lowest mean search accuracy.

Complex Geometric Symbol Group on the Dense Linear Background

Table 67. Descriptive Statistics for the Complex Geometric Symbols in Search Time on the Dense Linear Background

Descriptives

		N	Mean	Std. Deviation	Std. Error	95% Confidence Interval for Mean Lower Bound	95% Confidence Interval for Mean Upper Bound	Minimum	Maximum
Time on the Dense Linear BK	Archery	32	32.12	10.395	1.838	28.38	35.87	15	58
	Golfing	26	36.15	9.332	1.830	32.38	39.92	16	50
	Hiking	26	34.42	8.348	1.637	31.05	37.80	18	52
	Tennis	26	31.00	6.882	1.350	28.22	33.78	11	46
	Baseball	40	15.92	7.405	1.171	13.56	18.29	7	38
	Total	150	28.71	11.565	.944	26.84	30.57	7	58

Table 68. Descriptive Statistics for the Complex Geometric Symbols in Search Accuracy on the Dense Linear Background

Descriptives

		N	Mean	Std. Deviation	Std. Error	95% Confidence Interval for Mean Lower Bound	95% Confidence Interval for Mean Upper Bound	Minimum	Maximum
Percent Correct on the Dense Linear BK	Archery	32	82.651	21.9031	3.8720	74.754	90.548	5.6	100.0
	Golfing	26	84.615	18.9857	3.7234	76.947	92.284	13.6	100.0
	Hiking	26	77.789	32.1621	6.3075	64.798	90.779	5.3	100.0
	Tennis	26	79.121	27.8016	5.4523	67.892	90.350	4.8	100.0
	Baseball	40	98.125	3.1394	.4964	97.121	99.129	90.0	100.0
	Total	150	85.663	22.9834	1.8766	81.955	89.371	4.8	100.0

The five symbols were analyzed using the two dependent variables: time and accuracy. Tables 67 and 68 show the number of searches, mean search times, and standard deviations for both time and accuracy for each symbol Analysis of Variance shows that there are significant differences in the mean search times for the symbols, F (4, 145) = 31.95, $p < .001$. Further, there are significant differences in search accuracy among the symbols, F (4, 145) = 4.83, $p < .001$ (Table 69). The mean search times for individual symbol varied from 15.92 to 36.15 seconds, and the standard deviations varied from 6.88 to 10.39 (Table 67). The response time for the baseball symbol ($\bar{x}$ = 15.92, s = 7.40) was significantly faster than the other symbols. Also, the t test showed that there were no significant differences among the archery ($\bar{x}$ = 32.12, s = 10.39), hiking ($\bar{x}$ = 34.42, s = 8.34), and golfing ($\bar{x}$ = 36.15, s = 9.33) symbols, which were significantly slower than the other symbols (Table 70).

Table 69. Significant Differences of Symbols in Search Time and Accuracy on the Dense Linear Background

ANOVA[a]

		Sum of Squares	df	Mean Square	F	Sig.
Time	Between Groups	9337.088	4	2334.272	31.955	.000
	Within Groups	10592.006	145	73.048		
	Total	19929.093	149			
Percent Correct	Between Groups	9255.795	4	2313.949	4.831	.001
	Within Groups	69451.222	145	478.974		
	Total	78707.017	149			

Table 70. *t* Tests for Equality of Means (Time) among Symbols on the Dense Linear Background

Independent Samples Test							
t-test for Equality of Means (Time)							
Symbol	t	df	Sig. (2-tailed)	Mean Difference	Std. Error Difference	95% Confidence Interval of the Difference	
						Lower	Upper
Archery * Golfing	-1.536	56	.130	-4.029	2.623	-9.283	1.226
Archery * Hiking	-.913	56	.365	-2.298	2.518	-7.342	2.745
Archery * Tennis	.474	56	.638	1.125	2.376	-3.634	5.884
Archery * Baseball	7.714	70	.000	16.200	2.100	12.012	20.388
Golfing * Hiking	.705	50	.484	1.731	2.456	-3.202	6.663
Golfing * Tennis	2.266	50	.028	5.154	2.274	.586	9.721
Golfing * Baseball	9.778	64	.000	20.229	2.069	16.096	24.362
Hiking * Tennis	1.613	50	.113	3.423	2.122	-.839	7.685
Hiking * Baseball	9.429	64	.000	18.498	1.962	14.579	22.417
Tennis * Baseball	8.305	64	.000	15.075	1.815	11.449	18.701

The mean search accuracy for individual symbols varied from 77.78 to 98.12 percent, and the standard deviations from 3.13 to 32.16 (Table 68). *t* tests showed that the baseball symbol ($\bar{x}$ = 98.12, s = 3.13) was significantly more accurate than the other symbols. Additionally, *t* tests showed that there was no significant difference between the hiking ($\bar{x}$ =77.78, s = 32.16), tennis ($\bar{x}$ =79.12, s = 27.80), archery ($\bar{x}$ =82.65, s =21.90), and the golfing ($\bar{x}$ =84.61, s = 18.98) symbols in search accuracy. These four were found significantly less accurate than the baseball symbol (Table 71).

Table 71. *t* Tests for Equality of Means (Accuracy) among Symbols on the Dense Linear Background

Independent Samples Test							
t-test for Equality of Means (Accuracy)							
Symbol	t	df	Sig. (2-tailed)	Mean Difference	Std. Error Difference	95% Confidence Interval of the Difference	
						Lower	Upper
Archery * Golfing	-.360	56	.720	-1.9647	5.4527	-12.8877	8.9583
Archery * Hiking	.683	56	.498	4.8618	7.1208	-9.4028	19.1265
Archery * Tennis	.541	56	.591	3.5298	6.5244	-9.5402	16.5998
Archery * Baseball	-4.419	70	.000	-15.4743	3.5014	-22.4576	-8.4910
Golfing * Hiking	.932	50	.356	6.8265	7.3245	-7.8852	21.5382
Golfing * Tennis	.832	50	.409	5.4945	6.6024	-7.7668	18.7558
Golfing * Baseball	-4.426	64	.000	-13.5096	3.0523	-19.6074	-7.4119
Hiking * Tennis	-.160	50	.874	-1.3320	8.3374	-18.0782	15.4142
Hiking * Baseball	-3.986	64	.000	-20.3361	5.1013	-30.5272	10.1450
Tennis * Baseball	-4.299	64	.000	-19.0041	4.4206	-27.8353	-10.172

From the analyses it is clear that the baseball symbol does best search task, both in time and accuracy. The characteristics of the baseball symbol design distinguishes it from the other symbols; therefore, it pops out from the background and among the other symbols.

The archery, hiking, and golfing symbols were slow in search time, and these and hiking had the lowest search accuracy. The reason? Their similarity in the pattern of orientation.

Complex Geometric Symbol Group on the Gray Background

The symbol system was analyzed using the two dependent variables: time and accuracy. Table 72 shows the number of searches, mean search times, and the standard deviations for both time and accuracy for the golfing symbol. The golfing symbol was the only one tested on the gray background.

Table 72. Descriptive Statistics for the Golfing Symbol in Search Time and Accuracy on the Gray Background

Background	Symbol		Time	Percent Correct
Gray	Golfing	N	98	98
		Mean	36.38	64.457
		Std. Deviation	13.633	28.8651

The response time for the golfing symbol was long ($\bar{x}$ = 36.38, s = 13.63), and the mean search accuracy was low ($\bar{x}$ = 64.45, s = 28.86) (Table 72). These values are similar to values for this symbol on other backgrounds.

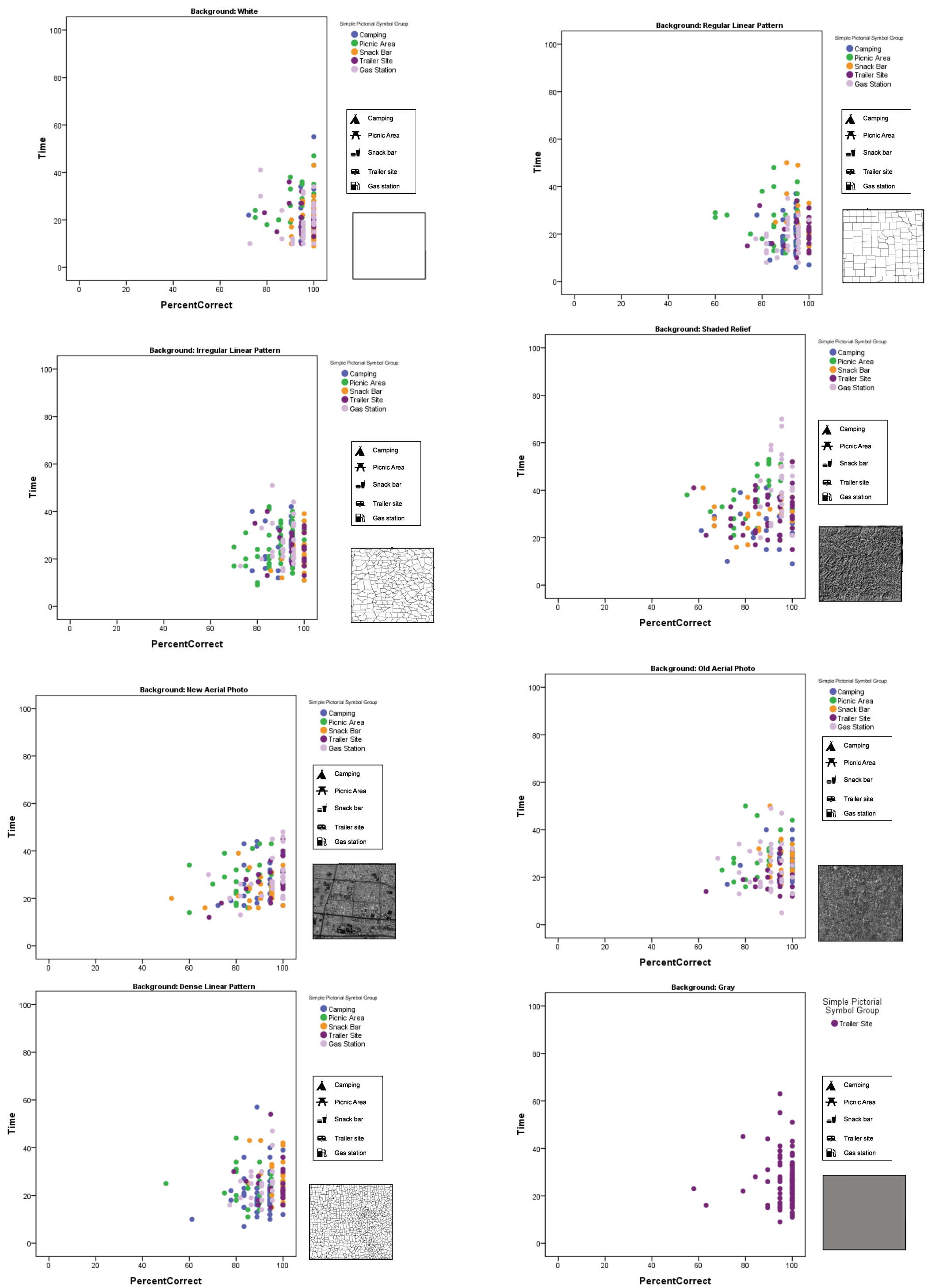


Figure 5. Simple pictorial symbol group on the eight backgrounds.

Simple Pictorial Symbol Group on the White Background

Table 73. Descriptive Statistics for the Simple Pictorial Symbols in Search Time on the White Background

Descriptives									
						95% Confidence Interval for Mean			
		N	Mean	Std. Deviation	Std. Error	Lower Bound	Upper Bound	Minimum	Maximum
Time on the White BK	Camping	26	21.65	9.068	1.778	17.99	25.32	11	55
	Picnic Area	26	26.38	8.603	1.687	22.91	29.86	13	47
	Snack Bar	41	18.41	6.797	1.062	16.27	20.56	9	43
	Trailer Site	23	19.74	6.129	1.278	17.09	22.39	10	36
	Gas Station	32	19.47	8.000	1.414	16.58	22.35	10	41
	Total	148	20.82	8.127	.668	19.50	22.14	9	55

Table 74. Descriptive Statistics for the Simple Pictorial Symbols in Search Accuracy on the White Background

Descriptives									
						95% Confidence Interval for Mean			
		N	Mean	Std. Deviation	Std. Error	Lower Bound	Upper Bound	Minimum	Maximum
Percent Correct on the White BK	Camping	26	97.436	5.7156	1.1209	95.127	99.744	72.2	100.0
	Picnic Area	26	93.077	7.6259	1.4956	89.997	96.157	75.0	100.0
	Snack Bar	41	97.793	3.3836	.5284	96.725	98.861	90.5	100.0
	Trailer Site	23	95.195	5.4772	1.1421	92.826	97.563	78.9	100.0
	Gas Station	32	94.318	7.2101	1.2746	91.719	96.918	72.7	100.0
	Total	148	95.747	6.1188	.5030	94.753	96.741	72.2	100.0

The five symbols in this group were analyzed using the two dependent variables: time and accuracy. Tables 73 and 74 show the number of searches, mean search times, and standard deviations for both time and accuracy for each symbol. Analysis of Variance shows that there are significant differences in the mean search times for the symbols, F (4, 143) = 4.78, p < .001. Further, there are significant differences in search accuracy among the symbols, F (4, 143) = 3.600, p < .001 (Table 75). The mean search times for individual symbols varied from 18.41 to 26.38 seconds, and the standard deviations varied from 6.12 to 9.06 (Table 73). The response times for the snack bar ($\bar{x}$ = 18.41, s = 6.79), gas station ($\bar{x}$ = 19.47, s = 8.00), trailer site ($\bar{x}$ = 19.74, s = 6.12), and camping ($\bar{x}$ = 21.65, s = 9.06) symbols were found to be significantly faster than the picnic area symbol. Additionally, the response time of the picnic area symbol ($\bar{x}$ = 26.38, s = 8.60) was significantly slower than the other symbols (Table 76).

Table 75. Significant Differences of Symbols on the White Background

ANOVA[a]

		Sum of Squares	df	Mean Square	F	Sig.
Time	Between Groups	1145.681	4	286.420	4.782	.001
	Within Groups	8564.393	143	59.891		
	Total	9710.074	147			
Percent Correct	Between Groups	503.548	4	125.887	3.600	.008
	Within Groups	5000.072	143	34.966		
	Total	5503.620	147			

Table 76. *t* Tests for Equality of Means (Time) among Symbols on the White Background

Independent Samples Test							
t-test for Equality of Means (Time)							
Symbol	t	df	Sig. (2-tailed)	Mean Difference	Std. Error Difference	95% Confidence Interval of the Difference	
						Lower	Upper
Camping * Picnic	-1.930	50	.059	-4.731	2.451	-9.655	.193
Camping * Snack	1.667	65	.100	3.239	1.943	-.641	7.119
Camping * Trailer	.854	47	.397	1.915	2.242	-2.595	6.424
Camping * Gas	.974	56	.334	2.185	2.243	-2.307	6.677
Picnic * Snack	4.215	65	.000	7.970	1.891	4.193	11.747
Picnic * Trailer	3.076	47	0.003	6.645	2.16	2.3	10.991
Picnic * Gas	3.166	56	.003	6.916	2.185	2.539	11.292
Snack * Trailer	-.774	62	.442	-1.324	1.711	-4.745	2.096
Snack * Gas	-.608	71	.545	-1.054	1.733	-4.509	2.401
Trailer * Gas	.136	53	.892	.270	1.991	-3.722	4.263

The mean search accuracy for the individual symbols varied from 93.07 to 97.79 percent, and the standard deviations varied from 3.38 to 7.62 (Table 74). *t* tests showed that there were significant differences between the snack bar symbol ($\bar{x}$ = 97.79, s = 3.38) and other symbols in accuracy. While *t* tests showed that there was no significant difference between picnic area symbol and other symbols in search accuracy, the picnic area ($\bar{x}$ = 93.07, s = 7.62), gas station ($\bar{x}$ =94.31, s = 7.21), and trailer site ($\bar{x}$ =95.19, s = 5.47) symbols were found to be significantly less accurate than the other two symbols in the group (Table 77).

Table 77. *t* Tests for Equality of Means (Accuracy) among Symbols on the White Background

Independent Samples Test							
t-test for Equality of Means (Accuracy)							
Symbol Group	t	df	Sig. (2-tailed)	Mean Difference	Std. Error Difference	95% Confidence Interval of the Difference	
						Lower	Upper
Camping * Picnic	2.332	50	.024	4.3590	1.8690	.6050	8.1130
Camping * Snack	-.322	65	.749	-.3574	1.1102	-2.5746	1.8598
Camping * Trailer	1.397	47	.169	2.2414	1.6045	-.9865	5.4693
Camping * Gas	1.793	56	.078	3.1177	1.7386	-.3652	6.6006
Picnic * Snack	-3.469	65	.001	-4.7163	1.3596	-7.4317	-2.0010
Picnic * Trailer	-1.103	47	0.276	-2.1176	1.9197	-5.9795	1.7444
Picnic * Gas	-.635	56	.528	-1.2413	1.9535	-5.1545	2.6720
Snack * Trailer	2.349	62	.022	2.5988	1.1062	.3874	4.8101
Snack * Gas	2.729	71	.008	3.4751	1.2735	.9358	6.0144
Trailer * Gas	.490	53	.626	.8763	1.7896	-2.7133	4.4659

From the analyses snack bar symbol emerged as the best for the search task, both in terms of search time and accuracy. The fastest search time was expected to be for the snack bar symbol since it is different in its design from the other symbols. Its characteristics make it easy to search for, and this produced the fastest search times and the level of accuracy. The picnic area symbol was slow in search time and low in accuracy. This is probably because the picnic area symbol did not have enough unique characteristics to make it distinctive.

Simple Pictorial Symbol Group on the Regular Linear Background

Table 78. Descriptive Statistics for the Simple Pictorial Symbols in Search Time on the Regular Linear Background

Descriptives									
						95% Confidence Interval for Mean			
		N	Mean	Std. Deviation	Std. Error	Lower Bound	Upper Bound	Minimum	Maximum
Time on the Regular Linear Pattern BK	Camping	45	19.04	7.074	1.055	16.92	21.17	6	37
	Picnic Area	26	25.85	9.439	1.851	22.03	29.66	12	48
	Snack Bar	26	24.81	9.440	1.851	20.99	28.62	12	50
	Trailer Site	26	20.81	6.274	1.230	18.27	23.34	10	34
	Gas Station	39	18.18	5.703	.913	16.33	20.03	8	35
	Total	162	21.14	8.016	.630	19.89	22.38	6	50

Table 79. Descriptive Statistics for the Simple Pictorial Symbols in Search Accuracy on the Regular Linear Background

Descriptives									
						95% Confidence Interval for Mean			
		N	Mean	Std. Deviation	Std. Error	Lower Bound	Upper Bound	Minimum	Maximum
Percent Correct on the Regular Linear Pattern BK	Camping	45	92.222	4.6481	.6929	90.826	93.619	77.8	100.0
	Picnic Area	26	85.962	10.7721	2.1126	81.611	90.312	60.0	100.0
	Snack Bar	26	95.604	4.4514	.8730	93.806	97.402	85.7	100.0
	Trailer Site	26	95.547	7.0914	1.3907	92.682	98.411	73.7	100.0
	Gas Station	39	90.793	5.9437	.9518	88.866	92.719	77.3	100.0
	Total	162	91.950	7.3163	.5748	90.814	93.085	60.0	100.0

The group of simple pictorial symbols was analyzed using the two dependent variables: time and accuracy. Tables 78 and 79 show the number of searches, mean search times, and standard deviations for both time and accuracy for each symbol. Analysis of Variance shows that there are significant differences in both search times, F (4, 157) = 6.49, $p < .001$, and search accuracy, F (4, 157) = 9.44, $p < .001$ (Table 80). The mean search times for individual symbols varied from 18.18 to 25.85 seconds, and the standard deviations from 5.70 to 9.44 (Table 78). The response times for the gas station ($\bar{x}$ = 18.18, s = 5.70), camping ($\bar{x}$ = 19.04, s = 7.07), and trailer site ($\bar{x}$ = 20.81, s = 6.27) symbols were found to be significantly faster than the other symbols. Response time for the picnic area symbol ($\bar{x}$ = 25.85, s = 9.43) was significantly slower than the other symbols (Table 81).

Table 80. Significant Differences of Symbols in Search Time and Accuracy on the Regular Linear Background

ANOVA[a]

		Sum of Squares	df	Mean Square	F	Sig.
Time	Between Groups	1467.896	4	366.974	6.490	.000
	Within Groups	8877.116	157	56.542		
	Total	10345.012	161			
Percent Correct	Between Groups	1671.523	4	417.881	9.445	.000
	Within Groups	6946.593	157	44.246		
	Total	8618.116	161			

Table 81. *t* Tests for Equality of Means (Time) among Symbols on the Regular Linear Background

Independent Samples Test							
t-test for Equality of Means (Time)							
Symbol	t	df	Sig. (2-tailed)	Mean Difference	Std. Error Difference	95% Confidence Interval of the Difference	
						Lower	Upper
Camping * Picnic	-3.446	69	.001	-6.802	1.974	-10.739	-2.864
Camping * Snack	-2.920	69	.005	-5.763	1.974	-9.701	-1.826
Camping * Trailer	-1.053	69	.296	-1.763	1.674	-5.103	1.576
Camping * Gas	.611	82	.543	.865	1.417	-1.953	3.683
Picnic * Snack	.397	50	.693	1.038	2.618	-4.220	6.297
Picnic * Trailer	2.267	50	.028	5.038	2.223	.574	9.503
Picnic * Gas	4.084	63	.000	7.667	1.877	3.915	11.418
Snack * Trailer	1.799	50	.078	4.000	2.223	-.465	8.465
Snack * Gas	3.531	63	.001	6.628	1.877	2.877	10.380
Trailer * Gas	1.749	63	.085	2.628	1.503	-.375	5.631

The mean search accuracy for the symbols ranged from 85.96 percent to 95.60, and the standard deviations varied from 4.45 to 10.77 (Table 79). *t* tests showed that there were no significant differences between the snack bar ($\bar{x}$ = 95.60, s = 4.45) and trailer site ($\bar{x}$=95.54, s = 7.09) symbols in search accuracy, and these were significantly more accurate than the other symbols. On the other hand, picnic area symbol ($\bar{x}$ =85.96, s = 10.77), was found significantly less accurate than the other symbols (Table 82).

Table 82. *t* Tests for Equality of Means (Accuracy) among Symbols on the Regular Linear Background

Independent Samples Test							
t-test for Equality of Means (Accuracy)							
Symbol	t	df	Sig. (2-tailed)	Mean Difference	Std. Error Difference	95% Confidence Interval of the Difference	
						Lower	Upper
Camping * Picnic	3.402	69	.001	6.2607	1.8405	2.5890	9.9323
Camping * Snack	-2.999	69	.004	-3.3822	1.1277	-5.6319	-1.1325
Camping * Trailer	-2.386	69	.020	-3.3243	1.3935	-6.1042	-.5445
Camping * Gas	1.236	82	.220	1.4297	1.1569	-.8718	3.7312
Picnic * Snack	-4.218	50	.000	-9.6429	2.2859	-14.2341	-5.0516
Picnic * Trailer	-3.790	50	.000	-9.5850	2.5293	-14.6652	-4.5049
Picnic * Gas	-2.325	63	.023	-4.8310	2.0779	-8.9834	-.6786
Snack * Trailer	.035	50	.972	.0578	1.6420	-3.2403	3.3559
Snack * Gas	3.519	63	.001	4.8119	1.3675	2.0792	7.5445
Trailer * Gas	2.923	63	.005	4.7540	1.6264	1.5039	8.0041

From the analyses the gas station, camping, and trailer site symbols achieved best for the search task, in term of search time. These symbols in their design have unique characteristics that enable them to be easy to search for, and this helped produce the fastest search times.

The picnic area symbol was the slowest symbol in mean search time and the lowest in accuracy, this perhaps because the picnic area symbol does not have enough distinctive characteristics as the other symbols to help in the visual search process.

Simple Pictorial Symbol Group on the Irregular Linear Background

Table 83. Descriptive Statistics for the Simple Pictorial Symbols in Search Time on the Irregular Linear Background

Descriptives

		N	Mean	Std. Deviation	Std. Error	95% Confidence Interval for Mean Lower Bound	95% Confidence Interval for Mean Upper Bound	Minimum	Maximum
Time on the Irregular Linear BK	Camping	24	26.08	8.607	1.757	22.45	29.72	12	42
	Picnic Area	64	24.62	7.835	.979	22.67	26.58	9	42
	Snack Bar	26	22.50	6.807	1.335	19.75	25.25	11	39
	Trailer Site	26	25.50	6.872	1.348	22.72	28.28	13	40
	Gas Station	26	26.54	8.842	1.734	22.97	30.11	15	51
	Total	166	24.94	7.836	.608	23.74	26.14	9	51

Table 84. Descriptive Statistics for the Simple Pictorial Symbols in Search Accuracy on the Irregular Linear Background

Descriptives

		N	Mean	Std. Deviation	Std. Error	95% Confidence Interval for Mean Lower Bound	95% Confidence Interval for Mean Upper Bound	Minimum	Maximum
Percent Correct on the Irregular Linear BK	Camping	24	90.741	6.2740	1.2807	88.091	93.390	77.8	100.0
	Picnic Area	64	90.312	7.4469	.9309	88.452	92.173	70.0	100.0
	Snack Bar	26	97.802	3.8641	.7578	96.241	99.363	85.7	100.0
	Trailer Site	26	95.344	5.8280	1.1430	92.990	97.698	78.9	100.0
	Gas Station	26	90.559	5.5927	1.0968	88.301	92.818	72.7	95.5
	Total	166	92.374	6.8846	.5343	91.319	93.429	70.0	100.0

Tables 83 and 84 show the number of searches, the mean search times, and the standard deviations for both time and accuracy, the two dependent variables in the analysis of each symbol. Analysis of Variance shows that there are no significant differences in the mean search times for the symbol, F (4, 161) = 1.09, p = .363. In contrast, there are significant differences in search accuracy for the symbols, F (4, 161) = 8.90, p < .001 (Table 85). The mean search times for the individual symbols varied from 22.50 to 26.54 seconds, and the standard deviations from 6.80 to 18.84 (Table 83). The response times for all of the symbols were found to be not significantly different from each other (Table 86). The mean search accuracy for the symbols varied from 90.31 to 97.80 percent, and the standard deviations from 3.86 to 7.44 (Table 84). t tests showed that there were no significant differences between the snack bar ($\bar{x}$ = 97.80, s = 3.86) and the trailer site ($\bar{x}$= 95.34, s = 5.82) symbols,

Table 85. Significant Differences of Symbols on the Irregular Linear Background

ANOVA[a]

		Sum of Squares	df	Mean Square	F	Sig.
Time	Between Groups	267.103	4	66.776	1.090	.363
	Within Groups	9864.295	161	61.269		
	Total	10131.398	165			
Percent Correct	Between Groups	1417.077	4	354.269	8.907	.000
	Within Groups	6403.460	161	39.773		
	Total	7820.537	165			

Table 86. *t* Tests for Equality of Means (Time) among Symbols in Search Time on the Irregular Linear Background

Independent Samples Test							
t-test for Equality of Means (Time)							
Symbol	t	df	Sig. (2-tailed)	Mean Difference	Std. Error Difference	95% Confidence Interval of the Difference	
						Lower	Upper
Camping * Picnic	.757	86	.451	1.458	1.926	-2.371	5.288
Camping * Snack	1.639	48	.108	3.583	2.186	-.812	7.978
Camping * Trailer	.266	48	.792	.583	2.194	-3.829	4.995
Camping * Gas	-.184	48	.855	-.455	2.471	-5.424	4.514
Picnic * Snack	1.209	88	.230	2.125	1.757	-1.368	5.618
Picnic * Trailer	-.497	88	.621	-.875	1.761	-4.375	2.625
Picnic * Gas	-1.012	88	.315	-1.913	1.892	-5.673	1.846
Snack * Trailer	-1.581	50	.120	-3.000	1.897	-6.810	.810
Snack * Gas	-1.845	50	.071	-4.038	2.188	-8.434	.357
Trailer * Gas	-.473	50	.638	-1.038	2.196	-5.450	3.373

these two symbols significantly more accurate than the other symbols. The picnic area ($\bar{x}$ = 90.31, s = 7.44), gas station ($\bar{x}$ = 90.55, s = 5.59), and camping ($\bar{x}$ = 90.74, s = 6.27) symbols were found significantly less accurate than the other two symbols, and the *t* tests showed that there were no significant differences among these symbols, (Table 87).

The analyses of search time found that there were no significant differences among the five symbols; all had similar search times. However, in terms of search accuracy, the snack bar and trailer site symbol had the highest accuracy levels in the

Table 87. ***t*** **Tests for Equality of Means (Accuracy) among Symbols in Search Accuracy on the Irregular Linear Background**

Independent Samples Test							
t-test for Equality of Means (Accuracy)							
Symbol	t	df	Sig. (2-tailed)	Mean Difference	Std. Error Difference	95% Confidence Interval of the Difference	
						Lower	Upper
Camping * Picnic	.250	86	.803	.4282	1.7119	-2.9749	3.8314
Camping * Snack	-4.833	48	.000	-7.0615	1.4610	-9.9990	-4.1240
Camping * Trailer	-2.690	48	.010	-4.6034	1.7114	-8.0444	-1.1624
Camping * Gas	.108	48	.914	.1813	1.6783	-3.1931	3.5557
Picnic * Snack	-4.858	88	.000	-7.4897	1.5417	-10.5534	-4.4259
Picnic * Trailer	-3.080	88	.003	-5.0316	1.6338	-8.2784	-1.7848
Picnic * Gas	-.152	88	.879	-.2469	1.6211	-3.4685	2.9746
Snack * Trailer	1.792	50	.079	2.4581	1.3714	-.2964	5.2125
Snack * Gas	5.433	50	.000	7.2428	1.3331	4.5651	9.9205
Trailer * Gas	3.020	50	.004	4.7847	1.5841	1.6029	7.9664

group, and the reason could be because these symbols are more distinctive than the other symbols against the irregular linear pattern background. On the other hand, since the *t* tests showed that there were no significant differences among the picnic area, gas station, and camping symbols in search accuracy, they must have interacted with the background characteristics in some common manner.

Simple Pictorial Symbol Group on the New Imagery Background

Table 88. Descriptive Statistics for the Simple Pictorial Symbols in Search Time on the New Imagery Background

Descriptives						95% Confidence Interval for Mean			
		N	Mean	Std. Deviation	Std. Error	Lower Bound	Upper Bound	Minimum	Maximum
Time on the New Imagery BK	Camping	26	27.96	8.789	1.724	24.41	31.51	17	44
	Picnic Area	25	27.88	8.177	1.635	24.50	31.26	14	43
	Snack Bar	33	23.48	5.292	.921	21.61	25.36	16	39
	Trailer Site	26	28.12	7.458	1.463	25.10	31.13	12	45
	Gas Station	26	28.42	9.021	1.769	24.78	32.07	13	48
	Total	136	26.98	7.885	.676	25.64	28.32	12	48

Table 89. Descriptive Statistics for the Simple Pictorial Symbols in Search Accuracy on the New Imagery Background

Descriptives						95% Confidence Interval for Mean			
		N	Mean	Std. Deviation	Std. Error	Lower Bound	Upper Bound	Minimum	Maximum
Percent Correct on the New Imagery BK	Camping	26	91.239	7.5642	1.4835	88.184	94.295	72.2	100.0
	Picnic Area	25	83.478	9.9915	1.9983	79.354	87.603	60.0	95.0
	Snack Bar	33	89.869	9.6534	1.6804	86.446	93.292	52.4	100.0
	Trailer Site	26	93.927	8.7682	1.7196	90.386	97.469	68.4	100.0
	Gas Station	26	92.657	9.3665	1.8369	88.874	96.441	68.2	100.0
	Total	136	90.265	9.6619	.8285	88.626	91.904	52.4	100.0

Using the two dependent variables, time and accuracy, the five symbols were analyzed. Tables 88 and 89 show the number of searches, mean search times, and standard deviations for both time and accuracy. Analysis of Variance shows that there are significant differences in the mean search times for the symbols, F (4, 131) = 2.23, p = .069. There are significant differences in search accuracy among the symbols, F (4, 131) = 5.03, $p < .001$ (Table 90). The mean search times for individual symbols varied from 23.48 to 28.42 seconds, and the standard deviations varied from 5.29 to 9.02 (Table 88). The response time for the snack bar symbol ($\bar{x}$ = 23.48, s = 5.29) was found significantly faster than the other symbols. Additionally, response times for the picnic area ($\bar{x}$ =27.88, s = 8.17), camping ($\bar{x}$ =27.96, s = 8.78), trailer site ($\bar{x}$ =28.12, s = 7.45), and gas station symbols ($\bar{x}$ =28.42, s = 9.02) were significantly slower than the snack bar symbol, and the t test showed that the

Table 90. Significant Differences of Symbols on the New Imagery Background

ANOVA[a]

		Sum of Squares	df	Mean Square	F	Sig.
Time	Between Groups	536.090	4	134.022	2.235	.069
	Within Groups	7856.844	131	59.976		
	Total	8392.934	135			
Percent Correct	Between Groups	1678.859	4	419.715	5.033	.001
	Within Groups	10923.666	131	83.387		
	Total	12602.524	135			

participants had a significantly slower search time for the picnic area symbol than the snack bar symbol (Table 91).

Table 91. *t* Tests for Equality of Means (Time) among Symbols in Search Time on the New Imagery Background

Independent Samples Test							
t-test for Equality of Means (Time)							
Symbol	t	df	Sig. (2-tailed)	Mean Difference	Std. Error Difference	95% Confidence Interval of the Difference	
						Lower	Upper
Camping * Picnic	.034	49	.973	.082	2.379	-4.700	4.863
Camping * Snack	2.424	57	.019	4.477	1.847	.779	8.175
Camping * Trailer	-.068	50	.946	-.154	2.261	-4.694	4.387
Camping * Gas	-.187	50	.853	-.462	2.470	-5.423	4.499
Picnic * Snack	2.480	56	.016	4.395	1.772	.846	7.945
Picnic * Trailer	-.107	49	.915	-.235	2.190	-4.636	4.166
Picnic * Gas	-.225	49	.823	-.543	2.414	-5.394	4.308
Snack * Trailer	-2.788	57	.007	-4.631	1.661	-7.957	-1.304
Snack * Gas	-2.626	57	.011	-4.938	1.880	-8.703	-1.173
Trailer * Gas	-.134	50	.894	-.308	2.295	-4.918	4.303

The mean search accuracy for individual symbol varied from 83.47 percent to 93.92 percent, and the standard deviation varied from 8.76 to 9.99 (Table 89). The *t* tests showed that there were no significant differences among the snack bar, camping, gas station, and trailer site symbols in search accuracy; however, the snack bar ($\bar{x}$ = 89.86, s = 9.65), camping ($\bar{x}$ = 91.23, s = 7.56), gas station ($\bar{x}$=92.65, s = 9.36), and trailer site ($\bar{x}$ = 93.92, s = 8.76) symbols were found to be significantly more accurate than the picnic area symbol. Additionally, the picnic area symbol ($\bar{x}$ = 83.47, s = 9.99) was found significantly less accurate than the other symbols, and the t test showed that there was significant difference between this symbol and the other symbols (Table 92).

Table 92. *t* Tests for Equality of Means (Accuracy) among Symbols in Search Accuracy on the New Imagery Background

Independent Samples Test							
t-test for Equality of Means (Accuracy)							
Symbol	t	df	Sig. (2-tailed)	Mean Difference	Std. Error Difference	95% Confidence Interval of the Difference	
						Lower	Upper
Camping * Picnic	3.135	49	.003	7.7611	2.4753	2.7868	12.7353
Camping * Snack	.594	57	.555	1.3707	2.3072	-3.2494	5.9908
Camping * Trailer	-1.184	50	.242	-2.6878	2.2710	-7.2493	1.8737
Camping * Gas	-.601	50	.551	-1.4180	2.3611	-6.1605	3.3244
Picnic * Snack	-2.459	56	.017	-6.3904	2.5984	-11.5955	-1.1852
Picnic * Trailer	-3.974	49	.000	-10.4489	2.6295	-15.7330	-5.1647
Picnic * Gas	-3.386	49	.001	-9.1791	2.7108	-14.6267	-3.7315
Snack * Trailer	-1.669	57	.101	-4.0585	2.4323	-8.9292	.8121
Snack * Gas	-1.116	57	.269	-2.7887	2.4987	-7.7923	2.2148
Trailer * Gas	.505	50	.616	1.2698	2.5162	-3.7841	6.3237

It would appear from the analyses that the snack bar symbol handled the search task best, both in terms of search time and accuracy. The fastest search time was expected to be the snack bar symbol on this background since it is distinctly different in its design compared to the other symbols, although all of the symbols look different from each other. While the camping symbol, trailer site symbol, and gas station symbol were found to be slow in search time, they were all high in accuracy. That could be because they were searched very slowly.

Furthermore, the results found that picnic area symbol was the slowest symbol in the group in mean search time and accuracy, and the reason could be due to the characteristics of the background and the nature of this symbol. Although the mean search time for the picnic area symbol was slow, it was also low in the accuracy, and that indicates that background characteristics probably played a role in yielding this result.

Simple Pictorial Symbol Group on the Shaded Relief Background

Table 93. Descriptive Statistics for the Simple Pictorial Symbols in Search Time on the Shaded Relief Background

Descriptives

		N	Mean	Std. Deviation	Std. Error	95% Confidence Interval for Mean Lower Bound	95% Confidence Interval for Mean Upper Bound	Minimum	Maximum
Time on the Shaded Relief BK	Camping	26	26.50	9.458	1.855	22.68	30.32	9	52
	Picnic Area	26	37.73	9.481	1.859	33.90	41.56	21	53
	Snack Bar	24	31.08	8.732	1.782	27.40	34.77	16	52
	Trailer Site	45	28.96	8.339	1.243	26.45	31.46	15	52
	Gas Station	26	42.23	13.171	2.583	36.91	47.55	20	70
	Total	147	32.77	11.210	.925	30.94	34.60	9	70

Table 94. Descriptive Statistics for the Simple Pictorial Symbols in Search Accuracy on the Shaded Relief Background

Descriptives

		N	Mean	Std. Deviation	Std. Error	95% Confidence Interval for Mean Lower Bound	95% Confidence Interval for Mean Upper Bound	Minimum	Maximum
Percent Correct on the Shaded Relief BK	Camping	26	88.248	11.7932	2.3128	83.484	93.011	61.1	100.0
	Picnic Area	26	83.462	10.3701	2.0337	79.273	87.650	55.0	100.0
	Snack Bar	24	86.111	12.0727	2.4643	81.013	91.209	61.9	100.0
	Trailer Site	45	89.357	10.3750	1.5466	86.240	92.474	57.9	100.0
	Gas Station	26	94.580	4.2677	.8370	92.857	96.304	86.4	100.0
	Total	147	88.512	10.6315	.8769	86.779	90.245	55.0	100.0

The five symbols in the group were analyzed using the dependent variables: time and accuracy. Tables 93 and 94 show the number of searches, mean search times, and the standard deviations for both time and accuracy for each symbol. Analysis of Variance shows that there are significant differences in the mean search times for the symbol, F (4, 142) = 12.26, $p < .001$. Further, there are significant differences in search accuracy among the symbols, F (4, 142) = 4.32, $p < .001$ (Table 95). The mean search times for individual symbols varied from 26.50 to 42.23 seconds, and the standard deviations varied from 8.33 to 13.17 (Table 93). The response time for the camping ($\bar{x}$ = 26.50, s = 9.45), snack bar ($\bar{x}$ = 31.08, s = 8.73), and trailer site ($\bar{x}$ = 28.96, s = 8.33) symbol were found significantly faster than the other symbols since the t test indicated that there were no significant differences between these symbols.

Table 95. Significant Differences of Symbols on the Shaded Relief Background

ANOVA[a]

		Sum of Squares	df	Mean Square	F	Sig.
Time	Between Groups	4712.161	4	1178.040	12.269	.000
	Within Groups	13633.975	142	96.014		
	Total	18346.136	146			
Percent Correct	Between Groups	1792.921	4	448.230	4.327	.002
	Within Groups	14709.229	142	103.586		
	Total	16502.150	146			

Additionally, the response time for the gas station symbol ($\bar{x}$ = 42.23, s = 13.17) was significantly slower than the other symbols (Table 96).

Table 96. *t* Tests for Equality of Means (Time) among Symbols in Search Time on the Shaded Relief Background

Independent Samples Test							
t-test for Equality of Means (Time)							
Symbol	t	df	Sig. (2-tailed)	Mean Difference	Std. Error Difference	95% Confidence Interval of the Difference	
						Lower	Upper
Camping * Picnic	-4.276	50	.000	-11.231	2.626	-16.506	-5.956
Camping * Snack	-1.776	48	.082	-4.583	2.581	-9.773	.606
Camping * Trailer	-1.138	69	.259	-2.456	2.158	-6.761	1.850
Camping * Gas	-4.947	50	.000	-15.731	3.180	-22.118	-9.344
Picnic * Snack	2.572	48	.013	6.647	2.584	1.451	11.844
Picnic * Trailer	3.076	47	.003	6.645	2.160	2.300	10.991
Picnic * Gas	4.062	69	.000	8.775	2.160	4.465	13.085
Snack * Trailer	.993	67	.324	2.128	2.142	-2.149	6.404
Snack * Gas	-3.496	48	.001	-11.147	3.189	-17.558	-4.736
Trailer * Gas	-5.205	69	.000	-13.275	2.551	-18.363	-8.187

The mean search accuracy for the individual symbols varied from 83.46 to 94.58 percent, and the standard deviations varied from 4.26 to 12.07 (Table 94). *t* tests showed that there were significant differences between the gas station symbol ($\bar{x}$ = 94.58, s = 4.26) and the other symbols in search accuracy. On the other hand, the picnic area ($\bar{x}$ =83.46, s = 10.37), snack bar ($\bar{x}$ =86.11, s = 12.07), camping ($\bar{x}$ =88.24, s = 11.79), and trailer site ($\bar{x}$ = 89.35, s = 10.37) symbols were found significantly less accurate than the gas station symbol, and the *t* test showed that there were no significant differences among the four symbols (Table 97).

Table 97. *t* Tests for Equality of Means (Accuracy) among Symbols in Search Accuracy on the Shaded Relief Background

Independent Samples Test							
t-test for Equality of Means (Accuracy)							
Symbol	t	df	Sig. (2-tailed)	Mean Difference	Std. Error Difference	95% Confidence Interval of the Difference	
						Lower	Upper
Camping * Picnic	1.554	50	.126	4.7863	3.0798	-1.3997	10.9723
Camping * Snack	.633	48	.530	2.1368	3.3764	-4.6520	8.9255
Camping * Trailer	-.413	69	.681	-1.1089	2.6876	-6.4705	4.2528
Camping * Gas	-2.575	50	.013	-6.3326	2.4596	-11.2728	-1.3923
Picnic * Snack	-.834	48	.408	-2.6496	3.1755	-9.0344	3.7352
Picnic * Trailer	-1.103	47	.276	-2.1176	1.9197	-5.9795	1.7444
Picnic * Gas	-5.056	50	.000	-11.1189	2.1992	-15.5362	-6.7016
Snack * Trailer	-1.169	67	.247	-3.2456	2.7772	-8.7889	2.2977
Snack * Gas	-3.359	48	.002	-8.4693	2.5211	-13.5384	-3.4002
Trailer * Gas	-2.445	69	.017	-5.2237	2.1368	-9.4865	-.9609

From the analyses the symbols that were best for the search task against this background, camping, snack bar, and trailer site, had low performances in search accuracy. And the reason for that is because of the complexity of the background. While the searchers found these symbols in a short search time, the accuracy for these symbols was low. Besides, the results found that gas station symbol was the slowest symbol in the group in search time, but this was with high accuracy. This accuracy came with a lot of time searching for the gas station symbol.

Simple Pictorial Symbol Group on the Old Imagery Background

Table 98. Descriptive Statistics for the Simple Pictorial Symbols in Search Time on the Old Imagery Background

Descriptives									
		N	Mean	Std. Deviation	Std. Error	95% Confidence Interval for Mean Lower Bound	95% Confidence Interval for Mean Upper Bound	Minimum	Maximum
Time on the Old Imagery BK	Camping	26	25.42	6.580	1.290	22.77	28.08	16	40
	Picnic Area	26	28.73	8.702	1.707	25.22	32.25	16	50
	Snack Bar	26	27.62	7.161	1.404	24.72	30.51	17	50
	Trailer Site	24	19.71	5.361	1.094	17.44	21.97	12	32
	Gas Station	32	24.75	9.745	1.723	21.24	28.26	5	49
	Total	134	25.31	8.257	.713	23.90	26.72	5	50

Table 99. Descriptive Statistics for the Simple Pictorial Symbols in Search Accuracy on the Old Imagery Background

Descriptives									
		N	Mean	Std. Deviation	Std. Error	95% Confidence Interval for Mean Lower Bound	95% Confidence Interval for Mean Upper Bound	Minimum	Maximum
Percent Correct on the Old Imagery BK	Camping	26	95.940	6.9491	1.3628	93.133	98.747	72.2	100.0
	Picnic Area	26	89.423	9.5212	1.8673	85.577	93.269	70.0	100.0
	Snack Bar	26	96.154	4.0449	.7933	94.520	97.788	85.7	100.0
	Trailer Site	24	92.105	8.2125	1.6764	88.637	95.573	63.2	100.0
	Gas Station	32	89.631	7.5915	1.3420	86.894	92.368	68.2	100.0
	Total	134	92.524	7.9418	.6861	91.167	93.881	63.2	100.0

The symbols were analyzed using the two dependent variables: time and accuracy. Tables 98 and 99 show the number of searches, mean search times, and standard deviations for both time and accuracy for each symbol. Analysis of Variance shows that there are significant differences in the mean search times for these symbol, F (4, 129) = 4.94, $p < .001$. Further, there are significant differences in search accuracy, F (4, 129) = 5.21, $p < .001$ (Table 100). The mean search times for individual symbols varied from 19.71 to 28.73 seconds, and the standard deviations varied from 5.36 to 9.74 (Table 98). The response time for trailer site symbol ($\bar{x}$ = 19.71, s = 5.36) was significantly faster than the other symbols. Also, the response times for the gas station ($\bar{x}$ =24.75, s = 9.74), camping ($\bar{x}$ =25.42, s = 6.58), snack bar ($\bar{x}$ =27.62, s = 7.16), and picnic area ($\bar{x}$ =28.73, s = 8.70) symbols were significantly slower than the trailer site symbol (Table 101).

Table 100. Significant Differences of Symbols on the Old Imagery Background

ANOVA[a]

		Sum of Squares	df	Mean Square	F	Sig.
Time	Between Groups	1205.882	4	301.470	4.946	.001
	Within Groups	7862.574	129	60.950		
	Total	9068.455	133			
Percent Correct	Between Groups	1168.094	4	292.024	5.217	.001
	Within Groups	7220.437	129	55.972		
	Total	8388.532	133			

Table 101. *t* Tests for Equality of Means (Time) among Symbols in Search Time on the Old Imagery Background

Independent Samples Test							
t-test for Equality of Means (Time)							
Symbol	t	df	Sig. (2-tailed)	Mean Difference	Std. Error Difference	95% Confidence Interval of the Difference	
						Lower	Upper
Camping * Picnic	-1.546	50	.128	-3.308	2.140	-7.605	.990
Camping * Snack	-1.149	50	.256	-2.192	1.907	-6.023	1.639
Camping * Trailer	3.350	48	.002	5.715	1.706	2.285	9.145
Camping * Gas	.301	56	.765	.673	2.239	-3.812	5.158
Picnic * Snack	.505	50	.616	1.115	2.210	-3.324	5.555
Picnic * Trailer	4.370	48	.000	9.022	2.065	4.871	13.174
Picnic * Gas	1.622	56	.110	3.981	2.454	-.935	8.896
Snack * Trailer	4.390	48	.000	7.907	1.801	4.286	11.528
Snack * Gas	1.249	56	.217	2.865	2.294	-1.729	7.460
Trailer * Gas	-2.285	54	.026	-5.042	2.206	-9.465	-.618

The mean search accuracy for the individual symbols varied from 89.42 to 96.15 percent, and the standard deviations from 4.04 to 9.52 (Table 99). *t* tests showed that there were significant differences between the snack bar symbol and the other symbols in search accuracy; the snack bar symbol ($\bar{x}$ = 96.15, s = 4.04) was found to be significantly more accurate than the other symbols. The picnic area ($\bar{x}$ = 89.42, s = 9.52), gas station ($\bar{x}$ = 89.63, s = 7.59), and trailer site ($\bar{x}$ = 92.10, s = 8.21) symbols were found too be significantly less accurate than the other symbols; were no significant differences among these symbols (Table 102).

Table 102. *t* Tests for Equality of Means (Accuracy) among Symbols in Search Accuracy the Old Imagery Background

Independent Samples Test							
t-test for Equality of Means (Accuracy)							
Symbol	t	df	Sig. (2-tailed)	Mean Difference	Std. Error Difference	95% Confidence Interval of the Difference	
						Lower	Upper
Camping * Picnic	2.819	50	.007	6.5171	2.3117	1.8739	11.1603
Camping * Snack	-.136	50	.893	-.2137	1.5769	-3.3810	2.9536
Camping * Trailer	1.787	48	.080	3.8349	2.1459	-.4797	8.1495
Camping * Gas	3.268	56	.002	6.3095	1.9305	2.4422	10.1768
Picnic * Snack	-3.318	50	.002	-6.7308	2.0288	-10.8057	-2.6558
Picnic * Trailer	-1.062	48	.293	-2.6822	2.5245	-7.7579	2.3936
Picnic * Gas	-.092	56	.927	-.2076	2.2462	-4.7072	4.2920
Snack * Trailer	2.238	48	.030	4.0486	1.8090	.4114	7.6858
Snack * Gas	3.946	56	.000	6.5232	1.6532	3.2113	9.8350
Trailer * Gas	1.166	54	.249	2.4746	2.1230	-1.7817	6.7309

From the analyses, it is clear that the trailer site symbol was best for the search time task. The reason for this is probably the characteristics of the background. In contrast, the gas station, camping, snack bar, and picnic area symbols were all slower in search time. And that could be because of the effect of the background which did not allow these symbols to pop out and to be find in a fast time.

In addition, the results found that the best symbol in the search accuracy was the snack bar symbol, and that could result to the amount of time that the searchers spent searching for this symbol.

Simple Geometric Symbol Group against the Dense Linear Background

Table 103. Descriptive Statistics for the Simple Pictorial Symbols in Search Time on the Dense Linear Background

Descriptives

		N	Mean	Std. Deviation	Std. Error	95% Confidence Interval for Mean		Minimum	Maximum
						Lower Bound	Upper Bound		
Time on the Dense Linear BK	Camping	64	20.83	8.349	1.044	18.74	22.91	7	57
	Picnic Area	26	23.62	7.333	1.438	20.65	26.58	11	44
	Snack Bar	26	27.12	8.194	1.607	23.81	30.43	15	43
	Trailer Site	25	24.12	8.151	1.630	20.76	27.48	15	54
	Gas Station	25	24.52	7.501	1.500	21.42	27.62	14	47
	Total	166	23.30	8.233	.639	22.04	24.56	7	57

Table 104. Descriptive Statistics for the Simple Pictorial Symbols in Search Accuracy on the Dense Linear Background

Descriptives

		N	Mean	Std. Deviation	Std. Error	95% Confidence Interval for Mean		Minimum	Maximum
						Lower Bound	Upper Bound		
Percent Correct on the Dense Linear BK	Camping	64	91.233	6.5514	.8189	89.596	92.869	61.1	100.0
	Picnic Area	26	85.577	9.3088	1.8256	81.817	89.337	50.0	95.0
	Snack Bar	26	97.253	4.5021	.8829	95.434	99.071	85.7	100.0
	Trailer Site	25	96.000	5.9391	1.1878	93.548	98.452	78.9	100.0
	Gas Station	25	90.182	5.0275	1.0055	88.107	92.257	77.3	95.5
	Total	166	91.849	7.4414	.5776	90.709	92.990	50.0	100.0

Time and accuracy were the two dependent variables employed in the analyses of the five symbols. Tables 103 and 104 show the number of searches, mean search times, and standard deviations for both time and accuracy for each symbol. Analysis of Variance shows that there are significant differences in the mean search times for these symbols, F (4, 161) = 3.21, $p < .001$. Further, there are significant differences in search accuracy, F (4, 161) = 13.59, $p < .001$ (Table 105). The mean search times for the individual symbol varied from 20.83 to 27.12 seconds, and the standard deviations varied from 7.33 to 8.34 (Table 103). The t tests showed that there were no significant differences in the search times for these symbols against this background. There was a significant difference between the camping symbol ($\bar{x}$ = 20.83, s = 8.34) and the snack bar symbol ($\bar{x}$ = 27.12, s = 8.19) in search time (Table 106).

Table 105. Significant Differences of Symbols on the Dense Linear Background

ANOVA[a]

		Sum of Squares	df	Mean Square	F	Sig.
Time	Between Groups	826.143	4	206.536	3.210	.014
	Within Groups	10358.797	161	64.340		
	Total	11184.940	165			
Percent Correct	Between Groups	2306.596	4	576.649	13.593	.000
	Within Groups	6830.204	161	42.424		
	Total	9136.800	165			

Table 106. *t* Tests for Equality of Means (Time) among Symbols in Search Time on the Dense Linear Background

Independent Samples Test							
t-test for Equality of Means (Time)							
Symbol	t	df	Sig. (2-tailed)	Mean Difference	Std. Error Difference	95% Confidence Interval of the Difference	
						Lower	Upper
Camping * Picnic	-1.485	88	.141	-2.787	1.877	-6.518	.944
Camping * Snack	-3.255	88	.002	-6.287	1.931	-10.126	-2.449
Camping * Trailer	-1.683	87	.096	-3.292	1.956	-7.180	.596
Camping * Gas	-1.927	87	.057	-3.692	1.916	-7.500	.116
Picnic * Snack	-1.623	50	.111	-3.500	2.156	-7.831	.831
Picnic * Trailer	-.233	49	.817	-.505	2.169	-4.864	3.855
Picnic * Gas	-.436	49	.665	-.905	2.077	-5.079	3.270
Snack * Trailer	1.308	49	.197	2.995	2.289	-1.605	7.596
Snack * Gas	1.178	49	.244	2.595	2.202	-1.830	7.021
Trailer * Gas	-.181	48	.857	-.400	2.215	-4.854	4.054

Mean search accuracy for the individual symbols varied from 85.57 percent to 97.25 percent, and the standard deviations varied from 4.50 to 9.30 (Table 104). *t* tests showed that there were no significant differences between snack bar symbol and trailer site symbol in search accuracy; however, the snack bar symbol ($\bar{x}$ = 97.25, *s* = 4.50) and trailer site symbol ($\bar{x}$= 96.00, *s* = 5.93) were found to be significantly more accurate than the other symbols. Furthermore, the picnic area symbol ($\bar{x}$ =85.57, *s* = 9.30) was found significantly less accurate than the other symbols (Table 107).

Table 107. *t* Tests for Equality of Means (Accuracy) among Symbols in Search Accuracy on the Dense Linear Background

Independent Samples Test							
t-test for Equality of Means (Accuracy)							
Symbol	t	df	Sig. (2-tailed)	Mean Difference	Std. Error Difference	95% Confidence Interval of the Difference	
						Lower	Upper
Camping * Picnic	3.269	88	.002	5.6557	1.7301	2.2174	9.0940
Camping * Snack	-4.285	88	.000	-6.0201	1.4048	-8.8118	-3.2284
Camping * Trailer	-3.164	87	.002	-4.7674	1.5067	-7.7621	-1.7727
Camping * Gas	.722	87	.472	1.0508	1.4549	-1.8409	3.9426
Picnic * Snack	-5.758	50	.000	-11.6758	2.0279	-15.7490	-7.6027
Picnic * Trailer	-4.745	49	.000	-10.4231	2.1965	-14.8370	-6.0091
Picnic * Gas	-2.185	49	.034	-4.6049	2.1072	-8.8394	-.3704
Snack * Trailer	.851	49	.399	1.2527	1.4720	-1.7054	4.2109
Snack * Gas	5.296	49	.000	7.0709	1.3352	4.3878	9.7541
Trailer * Gas	3.739	48	.000	5.8182	1.5563	2.6891	8.9472

It would appear from the analyses that the symbols against this background were the same in their search time performance. There were no significant differences among the symbols in the search time, except for the difference between the camping symbol and the snack bar symbol. The reason for having no differences among the symbols was due to the effect of the background. Also, the reason of being the camping symbol to be fast in the mean search time might due to the camping symbol design; the triangular (tent-like) shape of the camping symbol made a fast search easier. The snack bar symbol design against this background worked to make the symbol slow in the search time.

In addition, the results showed that the snack bar symbol and the trailer site symbol worked best in the in search accuracy. For the snack bar symbol, note the time that the searchers spent during the visual search process. On the other hand, the results showed that the picnic area was significantly less accurate than the other symbols. The reason for this result could be due to the search time that was spent during the visual search process, or it could be due to the characteristics of the picnic area symbol.

Simple Pictorial Symbol Group on the Gray Background

Time and accuracy were the two dependent variables used to analyze a single pictorial symbol on the gray background. Table 108 shows the number of searches, the mean search times, and the standard deviations for both time and accuracy for the trailer site symbol.

Table 108. Descriptive Statistics of the Trailer Site Symbol in Search Time and Accuracy on the Gray Background

Background	Symbol		Time	Percent Correct
Gray	Trailer Site	N	98	98
		Mean	25.76	96.77
		Std. Deviation	9.63	6.78

The response time for trailer site symbol ($\bar{x}$ = 25.76, s = 9.63), and the mean search accuracy was ($\bar{x}$ = 96.77, s = 6.78) (Table 108).

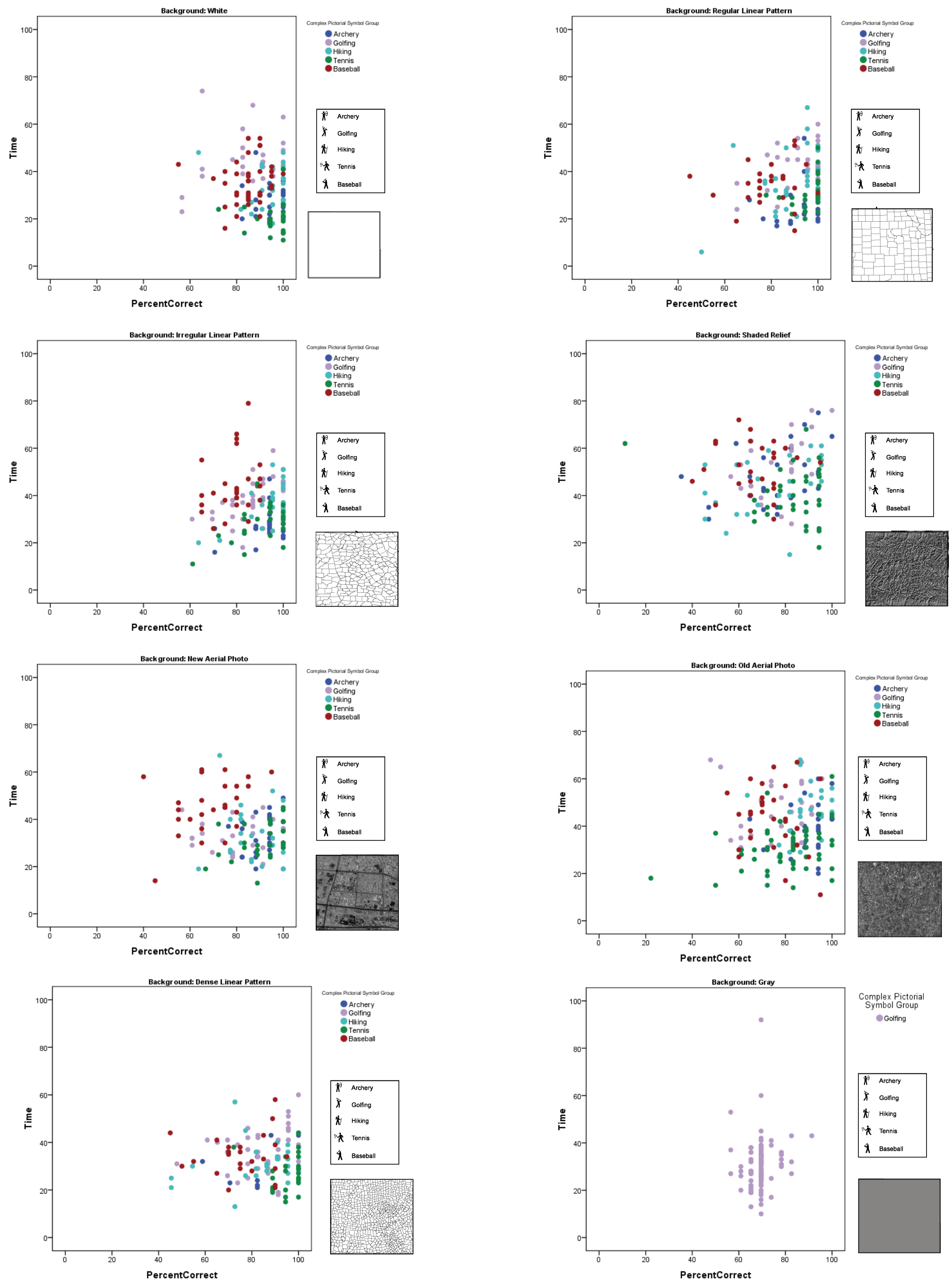


Figure 6. Complex pictorial symbol group on the eight backgrounds.

Complex Pictorial Symbol Group on the White Background

Table 109. Descriptive Statistics for the Complex Pictorial Symbols in Search Time on the White Background

Descriptives									
		N	Mean	Std. Deviation	Std. Error	95% Confidence Interval for Mean Lower Bound	95% Confidence Interval for Mean Upper Bound	Minimum	Maximum
Time on the White BK	Archery	26	29.04	7.702	1.510	25.93	32.15	18	48
	Golfing	26	45.00	11.132	2.183	40.50	49.50	23	74
	Hiking	25	32.24	9.084	1.817	28.49	35.99	18	48
	Tennis	23	20.39	6.394	1.333	17.63	23.16	11	41
	Baseball	40	35.15	8.900	1.407	32.30	38.00	16	54
	Total	140	32.90	11.554	.977	30.97	34.83	11	74

Table 110. Descriptive Statistics for the Complex Pictorial Symbols in Search Accuracy on the White Background

Descriptives									
		N	Mean	Std. Deviation	Std. Error	95% Confidence Interval for Mean Lower Bound	95% Confidence Interval for Mean Upper Bound	Minimum	Maximum
Percent Correct on the White BK	Archery	26	94.796	5.5995	1.0982	92.535	97.058	82.4	100.0
	Golfing	26	85.117	13.3683	2.6217	79.717	90.517	56.5	100.0
	Hiking	25	94.182	8.2489	1.6498	90.777	97.587	63.6	100.0
	Tennis	23	95.411	7.2343	1.5085	92.282	98.539	72.2	100.0
	Baseball	40	85.250	8.3934	1.3271	82.566	87.934	55.0	100.0
	Total	140	90.262	10.0377	.8483	88.585	91.940	55.0	100.0

The five complex pictorial symbols were analyzed using the two dependent variables: time and accuracy. Tables 109 and 110 show the number of searches, mean search times, and standard deviations for both time and accuracy for each symbol. Analysis of Variance shows that there are significant differences in the mean search times for the symbols, $F\ (4, 135) = 25.61, p < .001$. Further, there are significant differences in search accuracy, $F\ (4, 135) = 10.08, p < .001$ (Table 111). The mean search times for individual symbols varied from 20.39 to 45.00 seconds, and the standard deviations varied from 6.39 to 11.13 (Table 109). The response time for tennis ($\bar{x} = 20.39$, $s = 6.39$) was found to be significantly faster than the other symbols. On the other hand, *t* tests showed that there were significant differences between the golfing symbol ($\bar{x} = 45.00$, $s = 11.13$) and the other symbols – golfing was significantly slower than the other symbols (Table 112).

Table 111. Significant Differences of Symbols on the White Background

ANOVA[a]

		Sum of Squares	df	Mean Square	F	Sig.
Time	Between Groups	8006.500	4	2001.625	25.613	.000
	Within Groups	10550.100	135	78.149		
	Total	18556.600	139			
Percent Correct	Between Groups	3221.430	4	805.357	10.082	.000
	Within Groups	10783.588	135	79.878		
	Total	14005.018	139			

Table 112. *t* Tests for Equality of Means (Time) among Symbols in Search Time on the White Background

Independent Samples Test							
t-test for Equality of Means (Time)							
Symbol	t	df	Sig. (2-tailed)	Mean Difference	Std. Error Difference	95% Confidence Interval of the Difference	
						Lower	Upper
Archery * Golfing	-6.012	50	.000	-15.962	2.655	-21.294	-10.629
Archery * Hiking	-1.359	49	.180	-3.202	2.355	-7.934	1.531
Archery * Tennis	4.243	47	.000	8.647	2.038	4.547	12.747
Archery * Baseball	-2.870	64	.006	-6.112	2.129	-10.365	-1.858
Golfing * Hiking	4.475	49	.000	12.760	2.852	7.029	18.491
Golfing * Tennis	9.322	47	.000	24.609	2.640	19.298	29.920
Golfing * Baseball	3.977	64	.000	9.850	2.477	4.902	14.798
Hiking * Tennis	5.183	46	.000	11.849	2.286	7.247	16.451
Hiking * Baseball	-1.272	63	.208	-2.910	2.287	-7.480	1.660
Tennis * Baseball	-6.975	61	.000	-14.759	2.116	-18.990	-10.527

Search accuracy varied from 85.11 to 95.41 percent, and the standard deviations varied from 5.59 to 13.36 (Table 110). *t* tests showed that there were no significant differences between tennis, archery, and hiking symbols in accuracy; however, the tennis ($\bar{x}$ = 95.41, s = 7.23), archery ($\bar{x}$ = 94.79, s = 5.59), and hiking ($\bar{x}$ = 94.18, s = 8.24) symbols were found to be significantly more accurate than the other symbols. Additionally, the baseball ($\bar{x}$ =85.25, s = 8.39) and golfing ($\bar{x}$ 85.11, s = 13.36) symbols were found to be significantly less accurate than the other symbols (Table 113).

Table 113. *t* Tests for Equality of Means (Accuracy) among Symbols in Search Accuracy on the White Background

Independent Samples Test							
t-test for Equality of Means (Accuracy)							
Symbol	t	df	Sig. (2-tailed)	Mean Difference	Std. Error Difference	95% Confidence Interval of the Difference	
						Lower	Upper
Archery * Golfing	3.405	50	.001	9.6793	2.8424	3.9701	15.3885
Archery * Hiking	.312	49	.756	.6146	1.9673	-3.3388	4.5679
Archery * Tennis	-.334	47	.740	-.6142	1.8368	-4.3094	3.0810
Archery * Baseball	5.102	64	.000	9.5464	1.8713	5.8081	13.2847
Golfing * Hiking	-2.900	49	.006	-9.0648	3.1255	-15.3458	-2.7837
Golfing * Tennis	-3.289	47	.002	-10.2936	3.1299	-16.5902	-3.9970
Golfing * Baseball	-.050	64	.961	-.1329	2.6748	-5.4765	5.2106
Hiking * Tennis	-.547	46	.587	-1.2288	2.2479	-5.7536	3.2960
Hiking * Baseball	4.201	63	.000	8.9318	2.1259	4.6835	13.1802
Tennis * Baseball	4.857	61	.000	10.1606	2.0921	5.9772	14.3440

From the analyses it is clear that the tennis symbol was the best for the search task, in terms of both time and accuracy. The fastest search time was expected to be for the tennis symbol since it is clearly different in its design from the other symbols. Its characteristics make it easy to search for, and this would produce the fastest search times and the most accurate results. Since the characteristics of the tennis symbol are different, it is distinctive from the other symbols. In contrast, the baseball and golfing symbols were found to be slow in search time and in accuracy, the reason for that being that both of the symbols are similar in design.

Besides, there were no significant differences among the tennis, archery, and hiking symbols in search accuracy. The reason? The characteristics in their designs which helped the searchers to reach a high level of accuracy. These three symbols look distinctly different from the golfing and tennis symbols which were too similar to each other in their characteristics.

Moreover, as the results found golfing symbol the slowest in the mean search time, it was found that the baseball and golfing the lowest symbol in the mean search accuracy. These results that were expected because both symbols looked similar to each other, which totally confused the visual search process; these symbols could not pop out among the other symbols. Although searched for a long time, the accuracy level was still low.

Complex Pictorial Symbol Group on the Regular Linear Background

Table 114. Descriptive Statistics for the Complex Pictorial Symbols in Search Time on the Regular Linear Background

Descriptives									
		N	Mean	Std. Deviation	Std. Error	95% Confidence Interval for Mean Lower Bound	95% Confidence Interval for Mean Upper Bound	Minimum	Maximum
Time on the Regular Linear BK	Archery	22	27.27	9.770	2.083	22.94	31.60	17	54
	Golfing	26	43.15	8.992	1.763	39.52	46.79	24	60
	Hiking	26	37.08	13.118	2.573	31.78	42.38	6	67
	Tennis	25	30.20	7.136	1.427	27.25	33.15	20	50
	Baseball	25	34.52	8.875	1.775	30.86	38.18	15	53
	Total	124	34.71	11.104	.997	32.74	36.68	6	67

Table 115. Descriptive Statistics for the Complex Pictorial Symbols in Search Accuracy on the Regular Linear Background

Descriptives									
		N	Mean	Std. Deviation	Std. Error	95% Confidence Interval for Mean Lower Bound	95% Confidence Interval for Mean Upper Bound	Minimum	Maximum
Percent Correct on the Regular Linear BK	Archery	22	92.513	8.3548	1.7813	88.809	96.218	70.6	100.0
	Golfing	26	90.803	10.5305	2.0652	86.549	95.056	65.2	100.0
	Hiking	26	87.937	11.9186	2.3374	83.123	92.751	50.0	100.0
	Tennis	25	95.778	6.0604	1.2121	93.276	98.279	77.8	100.0
	Baseball	25	78.600	12.3761	2.4752	73.491	83.709	45.0	100.0
	Total	124	89.048	11.6118	1.0428	86.984	91.112	45.0	100.0

The group of symbols was analyzed using the two dependent variables: time and accuracy. Tables 114 and 115 show the number of searches, mean search times, and standard deviations for both time and accuracy for each symbol. Analysis of Variance shows that there are significant differences in the mean search times for the symbols, F (4, 119) = 9.68, $p < .001$. Further, there are significant differences in search accuracy among the symbols, F (4, 119) = 10.21, $p < .001$ (Table 116). The mean search times for individual symbol varied from 27.27 to 43.15 seconds, and the standard deviations varied from 7.13 to 13.11 (Table 114). *t* tests showed that there was no significant difference between the archery symbol ($\bar{x}$ = 27.27, s = 9.77) and the tennis symbol ($\bar{x}$ = 30.20, s = 7.13), and both were found significantly faster than the other symbols.

Table 116. Significant Differences of Symbols on the Regular Linear Background

ANOVA[a]

		Sum of Squares	df	Mean Square	F	Sig.
Time	Between Groups	3725.714	4	931.428	9.689	.000
	Within Groups	11439.834	119	96.133		
	Total	15165.548	123			
Percent Correct	Between Groups	4237.598	4	1059.400	10.210	.000
	Within Groups	12346.971	119	103.756		
	Total	16584.569	123			

On the other hand, *t* tests showed that there was a significant difference between the golfing symbol ($\bar{x}$ =43.15, s = 8.99) in search time and the other symbols; golfing was significantly slower than the other symbols (Table 117).

Table 117. *t* Tests for Equality of Means (Time) among Symbols in Search Time on the Regular Linear Background

Independent Samples Test							
t-test for Equality of Means (Time)							
Symbol	t	df	Sig. (2-tailed)	Mean Difference	Std. Error Difference	95% Confidence Interval of the Difference	
						Lower	Upper
Archery * Golfing	-5.860	46	.000	-15.881	2.710	-21.336	-10.426
Archery * Hiking	-2.891	46	.006	-9.804	3.392	-16.631	-2.977
Archery * Tennis	-1.183	45	.243	-2.927	2.475	-7.913	2.058
Archery * Baseball	-2.665	45	.011	-7.247	2.720	-12.725	-1.770
Golfing * Hiking	1.948	50	.057	6.077	3.119	-.188	12.342
Golfing * Tennis	5.684	49	.000	12.954	2.279	8.374	17.534
Golfing * Baseball	3.450	49	.001	8.634	2.503	3.604	13.663
Hiking * Tennis	2.312	49	.025	6.877	2.974	.900	12.854
Hiking * Baseball	.812	49	.421	2.557	3.149	-3.771	8.885
Tennis * Baseball	-1.897	48	.064	-4.320	2.278	-8.899	.259

The mean search accuracy for the individual symbols varied from 78.60 to 95.77 percent, and the standard deviations varied from 6.06 to 12.37 (Table 115). *t* tests showed that there was no significant difference between tennis symbol ($\bar{x}$ = 95.77, s = 6.06) and the archery symbol ($\bar{x}$ = 92.51, s = 8.35) in mean search accuracy, these two significantly more accurate than the other symbols. Additionally, baseball symbol ($\bar{x}$ =78.60, s = 12.37) was found significantly less accurate than the other symbols (Table 118).

Table 118. *t* Tests for Equality of Means (Accuracy) among Symbols in Search Accuracy on the Regular Linear Background

Independent Samples Test							
t-test for Equality of Means (Accuracy)							
Symbol	t	df	Sig. (2-tailed)	Mean Difference	Std. Error Difference	95% Confidence Interval of the Difference	
						Lower	Upper
Archery * Golfing	.615	46	.541	1.7107	2.7806	-3.8863	7.3077
Archery * Hiking	1.513	46	.137	4.5763	3.0253	-1.5134	10.6660
Archery * Tennis	-1.546	45	.129	-3.2644	2.1113	-7.5168	.9880
Archery * Baseball	4.453	45	.000	13.9134	3.1248	7.6197	20.2070
Golfing * Hiking	.919	50	.363	2.8656	3.1191	-3.3992	9.1305
Golfing * Tennis	-2.057	49	.045	-4.9751	2.4188	-9.8359	-.1143
Golfing * Baseball	3.798	49	.000	12.2027	3.2133	5.7453	18.6601
Hiking * Tennis	-2.943	49	.005	-7.8407	2.6642	-13.1947	-2.4868
Hiking * Baseball	2.745	49	.008	9.3371	3.4019	2.5007	16.1734
Tennis * Baseball	6.233	48	.000	17.1778	2.7560	11.6364	22.7192

The archery and tennis symbols were best, in terms of both time and accuracy. Their characteristics make them easy to search for. The golfing symbol was the slowest and the baseball was the least accurate. These results were expected because the golfing and baseball symbols looked similar to the each other, which made the visual search process difficult and confusable.

Complex Pictorial Symbol Group against the Irregular Linear Background

Table 119. Descriptive Statistics for the Complex Pictorial Symbols in Search Time on the Irregular Linear Background

Descriptives

		N	Mean	Std. Deviation	Std. Error	95% Confidence Interval for Mean Lower Bound	95% Confidence Interval for Mean Upper Bound	Minimum	Maximum
Time on the Irregular Linear BK	Archery	24	27.50	6.345	1.295	24.82	30.18	16	47
	Golfing	32	38.19	8.193	1.448	35.23	41.14	18	59
	Hiking	26	36.85	8.744	1.715	33.31	40.38	20	53
	Tennis	26	28.92	8.035	1.576	25.68	32.17	11	45
	Baseball	26	44.12	12.542	2.460	39.05	49.18	26	79
	Total	134	35.37	10.736	.927	33.53	37.20	11	79

Table 120. Descriptive Statistics for the Complex Pictorial Symbols in Search Accuracy on the Irregular Linear Background

Descriptives

		N	Mean	Std. Deviation	Std. Error	95% Confidence Interval for Mean Lower Bound	95% Confidence Interval for Mean Upper Bound	Minimum	Maximum
Percent Correct on the Irregular Linear BK	Archery	24	92.157	7.4944	1.5298	88.992	95.321	70.6	100.0
	Golfing	32	85.734	9.5150	1.6820	82.303	89.164	60.9	100.0
	Hiking	26	94.231	8.8661	1.7388	90.650	97.812	63.6	100.0
	Tennis	26	89.957	9.8155	1.9250	85.993	93.922	61.1	100.0
	Baseball	26	78.654	8.0694	1.5825	75.395	81.913	65.0	90.0
	Total	134	87.979	10.2814	.8882	86.222	89.735	60.9	100.0

The symbols were analyzed using the two dependent variables: time and accuracy. Tables 119 and 120 show the number of searches, mean search times, and standard deviations for both time and accuracy for each symbol. Analysis of Variance shows that there are significant differences both in the search times, F (4, 129) = 14.99, $p <$ .001, and in search accuracy, F (4, 129) = 12.64, $p < .001$ (Table 121). The mean search times varied from 27.50 to 44.12 seconds, and the standard deviations varied from 6.34 to 12.54 (Table 119). The response time for archery ($\bar{x}$ = 27.50, s = 6.34) and tennis ($\bar{x}$ = 28.92, s = 8.03) were found significantly faster than the other three complex pictorial symbols. On the other hand, t tests showed that there was significant difference between the baseball symbol ($\bar{x}$ = 44.12, s = 12.54) in search time and the other symbols; baseball was significantly slower than the other symbols (Table 122).

Table 121. Significant Differences of Symbols on the Irregular Linear Background

ANOVA[a]

		Sum of Squares	df	Mean Square	F	Sig.
Time	Between Groups	4866.322	4	1216.581	14.997	.000
	Within Groups	10464.760	129	81.122		
	Total	15331.082	133			
Percent Correct	Between Groups	3959.106	4	989.777	12.642	.000
	Within Groups	10100.076	129	78.295		
	Total	14059.183	133			

Table 122. *t*

Table 122. Tests for Equality of Means (Time) among Symbols in Search Time on the Irregular Linear Background

Independent Samples Test							
t-test for Equality of Means (Time)							
Symbol	t	df	Sig. (2-tailed)	Mean Difference	Std. Error Difference	95% Confidence Interval of the Difference	
						Lower	Upper
Archery * Golfing	-5.304	54	.000	-10.688	2.015	-14.727	-6.648
Archery * Hiking	-4.294	48	.000	-9.346	2.176	-13.722	-4.970
Archery * Tennis	-.691	48	.493	-1.423	2.059	-5.563	2.717
Archery * Baseball	-5.834	48	.000	-16.615	2.848	-22.342	-10.889
Golfing * Hiking	.602	56	.550	1.341	2.229	-3.124	5.807
Golfing * Tennis	4.320	56	.000	9.264	2.145	4.968	13.561
Golfing * Baseball	3.450	49	.001	8.634	2.503	3.604	13.663
Hiking * Tennis	3.402	50	.001	7.923	2.329	3.245	12.601
Hiking * Baseball	-2.424	50	.019	-7.269	2.998	-13.292	-1.247
Tennis * Baseball	-5.201	50	.000	-15.192	2.921	-21.060	-9.325

Mean search accuracy for the individual symbols varied from 78.65 to 94.23 percent, and the standard deviations varied from 7.49 to 9.81 (Table 120). *t* tests showed that there were no significant differences among the hiking ($\bar{x}$ = 94.23, s = 8.86), archery ($\bar{x}$ = 92.15, s = 7.49), and tennis ($\bar{x}$ = 89.95, s = 9.81) symbols in search accuracy, all more accurate than the other two symbols in the group. The baseball symbol ($\bar{x}$ = 78.65, s = 8.06) was found significantly less accurate than the other four symbols (Table 123).

Table 123. *t* Tests for Equality of Means (Accuracy) among Symbols in Search Accuracy on the Irregular Linear Background

Independent Samples Test							
t-test for Equality of Means (Accuracy)							
Symbol	t	df	Sig. (2-tailed)	Mean Difference	Std. Error Difference	95% Confidence Interval of the Difference	
						Lower	Upper
Archery * Golfing	2.730	54	.009	6.4232	2.3525	1.7068	11.1396
Archery * Hiking	-.889	48	.378	-2.0739	2.3317	-6.7622	2.6144
Archery * Tennis	.885	48	.381	2.1996	2.4854	-2.7976	7.1968
Archery * Baseball	6.116	48	.000	13.5030	2.2077	9.0641	17.9419
Golfing * Hiking	-3.486	56	.001	-8.4971	2.4372	-13.3795	-3.6147
Golfing * Tennis	-1.658	56	.103	-4.2236	2.5480	-9.3278	.8806
Golfing * Baseball	3.798	49	.000	12.2027	3.2133	5.7453	18.6601
Hiking * Tennis	1.647	50	.106	4.2735	2.5940	-.9367	9.4837
Hiking * Baseball	6.625	50	.000	15.5769	2.3511	10.8545	20.2993
Tennis * Baseball	4.536	50	.000	11.3034	2.4920	6.2981	16.3087

The analyses indicate that the archery and tennis symbols were best for the search task, for both time and accuracy. The design of these symbols made them visually different from the other symbols. Furthermore, the baseball symbol was the slowest in the search time, but the highest symbol in search accuracy. These results were expected because the baseball symbol characteristics look similar to the golfing symbol characteristics. Therefore, it took time in the visual search process, with low accuracy. And that indicates to the complexity of these symbols, since they look alike, and do not pop out from the background among the other symbols.

Complex Pictorial Symbol Group on the New Imagery Background

Table 124. Descriptive Statistics for the Complex Pictorial Symbols in Search Time on the New Imagery Background

Descriptives									
		N	Mean	Std. Deviation	Std. Error	95% Confidence Interval for Mean Lower Bound	95% Confidence Interval for Mean Upper Bound	Minimum	Maximum
Time on the New Imagery BK	Archery	25	33.40	8.145	1.629	30.04	36.76	19	49
	Golfing	22	33.09	6.831	1.456	30.06	36.12	21	45
	Hiking	23	33.61	11.789	2.458	28.51	38.71	19	67
	Tennis	26	31.19	7.869	1.543	28.01	34.37	13	45
	Baseball	27	45.67	11.310	2.177	41.19	50.14	14	61
	Total	123	35.61	10.749	.969	33.69	37.53	13	67

Table 125. Descriptive Statistics for the Complex Pictorial Symbols in Search Accuracy on the New Imagery Background

Descriptives									
		N	Mean	Std. Deviation	Std. Error	95% Confidence Interval for Mean Lower Bound	95% Confidence Interval for Mean Upper Bound	Minimum	Maximum
Percent Correct on the New Imagery BK	Archery	25	91.765	6.7924	1.3585	88.961	94.568	76.5	100.0
	Golfing	22	78.261	12.7291	2.7139	72.617	83.905	56.5	100.0
	Hiking	23	87.154	10.1318	2.1126	82.773	91.535	63.6	100.0
	Tennis	26	90.385	9.6299	1.8886	86.495	94.274	66.7	100.0
	Baseball	27	68.889	12.8103	2.4653	63.821	73.956	40.0	95.0
	Total	123	83.174	13.7171	1.2368	80.726	85.622	40.0	100.0

The symbol system was analyzed using the two dependent variables: time and accuracy. Tables 124 and 125 show the number of searches, mean search times, and the standard deviations for both time and accuracy for the five symbols. Analysis of Variance shows that there are significant differences in both the mean search times for these symbols, F (4, 118) = 10.08, $p < .001$, and the search accuracy among the symbols, F (4, 118) = 21.21, $p < .001$ (Table 126). The mean search times for individual symbols varied from 31.19 to 45.61 seconds, and the standard deviations varied from 6.83 to 11.78 (Table 124). *t* tests showed that there were no significant differences among the tennis ($\bar{x}$ = 31.19, s = 7.86), golfing ($\bar{x}$ = 33.09, s = 6.83), archery ($\bar{x}$ = 33.40, s = 8.14), and hiking ($\bar{x}$ = 33.61, s = 11.78) symbols in search time. There was a significant difference between the baseball symbol ($\bar{x}$ = 45.67, s = 11.31) and the other symbols; it was slower than the other symbols (Table 127).

Table 126. Significant Differences of Symbols on the New Imagery Background

ANOVA[a]

		Sum of Squares	df	Mean Square	F	Sig.
Time	Between Groups	3591.933	4	897.983	10.088	.000
	Within Groups	10503.335	118	89.011		
	Total	14095.268	122			
Percent Correct	Between Groups	9601.973	4	2400.493	21.213	.000
	Within Groups	13353.310	118	113.164		
	Total	22955.283	122			

Table 127. *t* Tests for Equality of Means (Time) among Symbols in Search Time on the New Imagery Background

Independent Samples Test							
t-test for Equality of Means (Time)							
Symbol Group	t	df	Sig. (2-tailed)	Mean Difference	Std. Error Difference	95% Confidence Interval of the Difference	
						Lower	Upper
Archery * Golfing	.140	45	.889	.309	2.210	-4.142	4.760
Archery * Hiking	-.072	46	.943	-.209	2.905	-6.056	5.638
Archery * Tennis	.985	49	.330	2.208	2.242	-2.298	6.714
Archery * Baseball	-4.456	50	.000	-12.267	2.753	-17.796	-6.738
Golfing * Hiking	-.179	43	.859	-.518	2.890	-6.345	5.310
Golfing * Tennis	.884	46	.381	1.899	2.147	-2.424	6.221
Golfing * Baseball	-4.575	47	.000	-12.576	2.749	-18.106	-7.045
Hiking * Tennis	.853	47	.398	2.416	2.834	-3.284	8.117
Hiking * Baseball	-3.685	48	.001	-12.058	3.272	-18.637	-5.479
Tennis * Baseball	-5.389	51	.000	-14.474	2.686	-19.867	-9.082

The mean search accuracy for the symbols varied from 68.88 to 91.76 percent, and the standard deviations varied from 6.79 to 12.81 (Table 125). *t* tests showed that there were no significant differences between the archery ($\bar{x}$ = 91.76, s = 6.79), tennis ($\bar{x}$ = 90.38, s = 9.62), and hiking ($\bar{x}$ = 87.15, s = 10.13) symbols, all more accurate than the other symbols. Additionally, the baseball symbol ($\bar{x}$ = 68.88, s = 12.81) was found significantly less accurate than the other symbols (Table 128).

Table 128. *t* Tests for Equality of Means (Accuracy) among Symbols in Search Accuracy on the New Imagery Background

Independent Samples Test							
t-test for Equality of Means (Accuracy)							
Symbol Group	t	df	Sig. (2-tailed)	Mean Difference	Std. Error Difference	95% Confidence Interval of the Difference	
						Lower	Upper
Archery * Golfing	4.614	45	.000	13.5038	2.9265	7.6096	19.3981
Archery * Hiking	1.866	46	.068	4.6106	2.4714	-.3641	9.5852
Archery * Tennis	.589	49	.558	1.3801	2.3421	-3.3265	6.0867
Archery * Baseball	7.950	50	.000	22.8758	2.8775	17.0962	28.6554
Golfing * Hiking	-2.599	43	.013	-8.8933	3.4217	-15.7938	-1.9927
Golfing * Tennis	-3.753	46	.000	-12.1237	3.2306	-18.6266	-5.6209
Golfing * Baseball	2.554	47	.014	9.3720	3.6689	1.9911	16.7528
Hiking * Tennis	-1.144	47	.259	-3.2305	2.8247	-8.9131	2.4521
Hiking * Baseball	5.521	48	.000	18.2653	3.3083	11.6134	24.9171
Tennis * Baseball	6.885	51	.000	21.4957	3.1222	15.2276	27.7638

The analyses showed that the symbols that worked best for the search task in terms of search time also worked best in the terms of search accuracy. The reason for that could be that these symbols (tennis, archery, and hiking) had characteristics that distinguished them from the other symbols.

In contrast, the results showed that the symbols that were slow in the mean search time were found to be low in accuracy. For example, the baseball symbol was slow in time and had a low accuracy. The reason for that is the complexity of the symbol characteristics that tend to confuse the visual search process.

Complex Pictorial Symbol Group on the Shaded Relief Background

Table 129. Descriptive Statistics for the Complex Pictorial Symbols in Search Time on the Shaded Relief Background

Descriptives									
		N	Mean	Std. Deviation	Std. Error	95% Confidence Interval for Mean Lower Bound	95% Confidence Interval for Mean Upper Bound	Minimum	Maximum
Time on the Shaded Relief BK	Archery	26	48.81	12.365	2.425	43.81	53.80	30	75
	Golfing	25	52.52	12.904	2.581	47.19	57.85	28	76
	Hiking	25	45.16	12.229	2.446	40.11	50.21	15	61
	Tennis	34	40.50	11.125	1.908	36.62	44.38	18	68
	Baseball	26	52.42	10.584	2.076	48.15	56.70	30	72
	Total	136	47.43	12.590	1.080	45.30	49.57	15	76

Table 130. Descriptive Statistics for the Complex Pictorial Symbols in Search Accuracy on the Shaded Relief Background

Descriptives									
		N	Mean	Std. Deviation	Std. Error	95% Confidence Interval for Mean Lower Bound	95% Confidence Interval for Mean Upper Bound	Minimum	Maximum
Percent Correct on the Shaded Relief BK	Archery	26	76.018	16.1244	3.1622	69.505	82.531	35.3	100.0
	Golfing	25	76.696	11.6313	2.3263	71.894	81.497	56.5	100.0
	Hiking	25	73.964	17.6920	3.5384	66.661	81.267	45.5	95.5
	Tennis	34	82.843	15.6758	2.6884	77.374	88.313	11.1	94.4
	Baseball	26	67.115	12.8975	2.5294	61.906	72.325	40.0	95.0
	Total	136	75.769	15.7009	1.3463	73.107	78.432	11.1	100.0

The symbol system was analyzed using the two dependent variables: time and accuracy. Tables 129 and 130 show the number of searches, mean search times, and standard deviations for both time and accuracy for the five symbols. Analysis of Variance indicates that there are significant differences in search times for the symbols, F (4, 131) = 5.56, $p < .001$; further, there are significant differences in search accuracy among the symbols, F (4, 131) = 4.16, $p < .001$ (Table 131). The mean search times for the individual symbols varied from 40.50 to 52.52 seconds, and the standard deviations varied from 10.58 to 12.90 (Table 129). The response times for the tennis ($\bar{x}$ = 40.50, s = 11.12) and hiking ($\bar{x}$ = 45.16, s = 12.22) symbols were found significantly faster than the other symbols in the group. t tests showed that there is a significantly faster search time for tennis and hiking. On the other hand, other t tests showed that there was no significant difference between the golfing ($\bar{x}$ = 52.52, s =12.90) and the baseball symbol ($\bar{x}$ = 52.42, s = 10.58) in search time, and

Table 131. Significant Differences of Symbols on the Shaded Relief Background

ANOVA[a]

		Sum of Squares	df	Mean Square	F	Sig.
Time	Between Groups	3106.920	4	776.730	5.562	.000
	Within Groups	18292.485	131	139.637		
	Total	21399.404	135			
Percent Correct	Between Groups	3753.052	4	938.263	4.163	.003
	Within Groups	29526.714	131	225.395		
	Total	33279.766	135			

these symbols were significantly slower than other symbols in the group (Table 132).

Table 132. *t* Tests for Equality of Means (Time) among Symbols in Search Time on the Shaded Relief Background

Independent Samples Test							
t-test for Equality of Means (Time)							
Symbol	t	df	Sig. (2-tailed)	Mean Difference	Std. Error Difference	95% Confidence Interval of the Difference	
						Lower	Upper
Archery * Golfing	-1.049	49	.299	-3.712	3.538	-10.823	3.398
Archery * Hiking	1.059	49	.295	3.648	3.445	-3.275	10.571
Archery * Tennis	2.731	58	.008	8.308	3.042	2.219	14.396
Archery * Baseball	-1.133	50	.263	-3.615	3.192	-10.027	2.796
Golfing * Hiking	2.070	48	.044	7.360	3.556	.211	14.509
Golfing * Tennis	3.832	57	.000	12.020	3.137	5.738	18.302
Golfing * Baseball	.029	49	.977	.097	3.299	-6.533	6.726
Hiking * Tennis	1.524	57	.133	4.660	3.057	-1.461	10.781
Hiking * Baseball	-2.271	49	.028	-7.263	3.199	-13.691	-.835
Tennis * Baseball	-4.201	58	.000	-11.923	2.838	-17.605	-6.241

The mean search accuracy for varied from 67.11 to 82.84 percent, and the standard deviations from 11.63 to 17.69 (Table 130). *t* tests showed that there were no significant differences in accuracy among the tennis ($\bar{x}$ = 82.84, s = 15.67), golfing ($\bar{x}$ =76.69, s = 11.63), and archery ($\bar{x}$ = 76.01, s = 16.12) symbols in mean search accuracy, and these three are significantly more accurate than the other two symbols in the group. Additionally, the baseball symbol ($\bar{x}$ = 67.11, s = 12.89) was found to be significantly less accurate than the other symbols (Table 133).

Table 133. *t* tests for Equality of Means (Accuracy) among Symbols in Search Accuracy on the Shaded Relief Background

Independent Samples Test							
t-test for Equality of Means (Accuracy)							
Symbol	t	df	Sig. (2-tailed)	Mean Difference	Std. Error Difference	95% Confidence Interval of the Difference	
						Lower	Upper
Archery * Golfing	-.172	49	.865	-.6776	3.9506	-8.6165	7.2614
Archery * Hiking	.434	49	.666	2.0545	4.7368	-7.4644	11.5733
Archery * Tennis	-1.651	58	.104	-6.8250	4.1347	-15.1016	1.4515
Archery * Baseball	2.199	50	.033	8.9027	4.0494	.7692	17.0362
Golfing * Hiking	.645	48	.522	2.7320	4.2346	-5.7822	11.2462
Golfing * Tennis	-1.653	57	.104	-6.1475	3.7187	-13.5941	1.2991
Golfing * Baseball	2.782	49	.008	9.5803	3.4436	2.6602	16.5004
Hiking * Tennis	-2.036	57	.046	-8.8795	4.3615	-17.6133	-.1457
Hiking * Baseball	1.584	49	.120	6.8483	4.3230	-1.8391	15.5356
Tennis * Baseball	4.151	58	.000	15.7278	3.7889	8.1434	23.3121

Since the shaded relief background is complex in its characteristics, it was expected that the search process would be affected significantly. Times would be slow and accuracy would be low compared to other backgrounds. The tennis symbol was best, both in time and accuracy. The tennis symbol differs in its design from the other symbols, which led the searchers to find the tennis symbol in shorter times with higher levels of accuracy compared to the other symbols. The hiking symbol was found to be fast, too, with its distinctive characteristics. The archery and golfing symbols were counted at a high accuracy level, but with a longer amount of time on this background. The search strategy may have been to spend a longer time in the search process, gaining a higher level of accuracy.

On the other hand, while the baseball symbol and the golfing symbol were the slowest in the mean search time, the baseball symbol had also the lowest accuracy. The reason for that was perhaps due to the complexity of the characteristics and the similarity to other symbols confused the searchers.

Complex Pictorial Symbol Group on the Old Imagery Background

Table 134. Descriptive Statistics for the Complex Pictorial Symbols in Search Time on the Old Imagery Background

Descriptives									
						95% Confidence Interval for Mean			
		N	Mean	Std. Deviation	Std. Error	Lower Bound	Upper Bound	Minimum	Maximum
Time on the Old Imagery BK	Archery	26	39.65	9.932	1.948	35.64	43.67	20	60
	Golfing	26	48.31	11.457	2.247	43.68	52.94	31	68
	Hiking	26	46.62	10.515	2.062	42.37	50.86	27	68
	Tennis	57	31.32	9.228	1.222	28.87	33.76	14	61
	Baseball	32	43.59	13.124	2.320	38.86	48.33	11	67
	Total	167	39.99	12.579	.973	38.07	41.92	11	68

Table 135. Descriptive Statistics for the Complex Pictorial Symbols in Search Accuracy on the Old Imagery Background

Descriptives									
						95% Confidence Interval for Mean			
		N	Mean	Std. Deviation	Std. Error	Lower Bound	Upper Bound	Minimum	Maximum
Percent Correct on the Old Imagery BK	Archery	26	90.498	8.4962	1.6662	87.066	93.929	64.7	100.0
	Golfing	26	76.756	13.9099	2.7280	71.138	82.374	47.8	95.7
	Hiking	26	88.287	8.2495	1.6179	84.955	91.619	63.6	100.0
	Tennis	57	81.316	14.6302	1.9378	77.434	85.198	22.2	100.0
	Baseball	32	74.062	10.2735	1.8161	70.359	77.766	55.0	95.0
	Total	167	81.731	13.2747	1.0272	79.703	83.759	22.2	100.0

The two dependent variables, time and accuracy, were used in the analyses of the five symbols on the "old imagery" background. Tables 134 and 135 show the number of searches, mean search times, and standard deviations for both time and accuracy for each symbol. Analysis of Variance shows that there are significant differences for these symbol in both search times, $F\,(4, 162) = 16.63, p < .001$, and search accuracy, $F\,(4, 162) = 9.69, p < .001$ (Table 136). The mean search times for the individual symbols varied from 31.32 to 48.31 seconds, and the standard deviations varied from 9.22 to 13.12 (Table 134). The response time for the tennis symbol ($\bar{x} = 31.32, s = 9.22$) was found to be significantly faster than the times of all the other symbols. *t* tests showed, on the other hand that there was significant difference between the tennis symbol and the other symbols. On the other hand, *t* tests showed that there were no significant differences among the golfing ($\bar{x} = 48.31, s = 11.45$), hiking ($\bar{x} = 46.62, s = 10.51$), and baseball ($\bar{x} = 43.59, s = 13.12$) symbols in mean search time,

Table 136. Significant Differences of Symbols on the Old Imagery Background

ANOVA[a]

		Sum of Squares	df	Mean Square	F	Sig.
Time	Between Groups	7647.383	4	1911.846	16.634	.000
	Within Groups	18619.611	162	114.936		
	Total	26266.994	166			
Percent Correct	Between Groups	5650.809	4	1412.702	9.697	.000
	Within Groups	23601.463	162	145.688		
	Total	29252.272	166			

Table 137. *t* Tests for Equality of Means (Time) among Symbols in Search Time on the Old Imagery Background

Independent Samples Test							
t-test for Equality of Means (Time)							
Symbol	t	df	Sig. (2-tailed)	Mean Difference	Std. Error Difference	95% Confidence Interval of the Difference	
						Lower	Upper
Archery * Golfing	-2.910	50	.005	-8.654	2.974	-14.626	-2.681
Archery * Hiking	-2.454	50	.018	-6.962	2.837	-12.659	-1.264
Archery * Tennis	3.728	81	.000	8.338	2.236	3.888	12.788
Archery * Baseball	-1.264	56	.211	-3.940	3.117	-10.184	2.305
Golfing * Hiking	.555	50	.581	1.692	3.050	-4.433	7.818
Golfing * Tennis	7.202	81	.000	16.992	2.359	12.298	21.686
Golfing * Baseball	1.439	56	.156	4.714	3.276	-1.849	11.277
Hiking * Tennis	6.704	81	.000	15.300	2.282	10.759	19.840
Hiking * Baseball	.951	56	.346	3.022	3.176	-3.341	9.384
Tennis * Baseball	-5.157	87	.000	-12.278	2.381	-17.010	-7.545

response times that were significantly slower than the other symbols (Table 137).

Search accuracy varied from 74.06 to 90.49 percent, and the standard deviations varied from 8.24 to 14.63 (Table 135). *t* tests showed that there were no significant differences between the archery and the hiking symbols in accuracy; however, the archery ($\bar{x}$ = 90.49, s = 8.49) and hiking ($\bar{x}$ = 88.28, s = 8.24) symbols were found to be significantly more accurate than the other symbols. Additionally, the baseball ($\bar{x}$ =74.06, s = 10.27) and golfing ($\bar{x}$ =76.75, s = 13.90) symbols were found to be significantly less accurate than the other symbols (Table 138).

Table 138. *t* Tests for Equality of Means (Time) among Symbols in Search Time on the Old Imagery Background

Independent Samples Test							
t-test for Equality of Means (Accuracy)							
Symbol	t	df	Sig. (2-tailed)	Mean Difference	Std. Error Difference	95% Confidence Interval of the Difference	
						Lower	Upper
Archery * Golfing	4.299	50	.000	13.7419	3.1966	7.3214	20.1624
Archery * Hiking	.952	50	.346	2.2110	2.3225	-2.4538	6.8758
Archery * Tennis	2.973	81	.004	9.1815	3.0880	3.0375	15.3256
Archery * Baseball	6.538	56	.000	16.4352	2.5139	11.3994	21.4711
Golfing * Hiking	-3.636	50	.001	-11.5309	3.1716	-17.9013	-5.1605
Golfing * Tennis	-1.337	81	.185	-4.5604	3.4106	-11.3464	2.2257
Golfing * Baseball	.848	56	.400	2.6934	3.1772	-3.6713	9.0580
Hiking * Tennis	2.266	81	.026	6.9705	3.0764	.8495	13.0915
Hiking * Baseball	5.717	56	.000	14.2242	2.4882	9.2398	19.2086
Tennis * Baseball	2.480	87	.015	7.2537	2.9253	1.4393	13.0681

The results for both of the imagery backgrounds (new and old) were similar. The effect of this type of background on the complex pictorial symbols depended on the individual symbols. The tennis symbol was faster on this background because the characteristics of this symbol differed from the other symbols.

In contrast, the golfing and baseball symbols were slow in search time and low in accuracy; these symbols were similar to each other in design. The hiking symbol was slow in time, but high in accuracy. The longer time spent in the search process for this symbol helped the searchers to find the symbol accurately.

Complex Pictorial Symbol Group on the Dense Linear Background

Table 139. Descriptive Statistics for the Complex Pictorial Symbols in Search Time on the Dense Linear Background

Descriptives

		N	Mean	Std. Deviation	Std. Error	95% Confidence Interval for Mean Lower Bound	95% Confidence Interval for Mean Upper Bound	Minimum	Maximum
Time on the Dense Linear BK	Archery	8	30.25	9.161	3.239	22.59	37.91	21	43
	Golfing	41	36.51	8.889	1.388	33.71	39.32	18	60
	Hiking	26	32.15	8.698	1.706	28.64	35.67	13	57
	Tennis	25	27.04	7.408	1.482	23.98	30.10	15	44
	Baseball	24	34.42	8.851	1.807	30.68	38.15	20	58
	Total	124	32.88	9.141	.821	31.25	34.50	13	60

Table 140. Descriptive Statistics for the Complex Pictorial Symbols in Search Accuracy on the Dense Linear Background

Descriptives

		N	Mean	Std. Deviation	Std. Error	95% Confidence Interval for Mean Lower Bound	95% Confidence Interval for Mean Upper Bound	Minimum	Maximum
Percent Correct on the Dense Linear BK	Archery	8	80.882	12.0757	4.2694	70.787	90.978	58.8	100.0
	Golfing	41	84.199	11.9765	1.8704	80.419	87.980	47.8	100.0
	Hiking	26	84.441	15.7025	3.0795	78.098	90.783	45.5	100.0
	Tennis	25	95.333	6.5499	1.3100	92.630	98.037	72.2	100.0
	Baseball	24	75.995	13.4635	2.7482	70.310	81.681	45.0	95.0
	Total	124	84.693	13.6432	1.2252	82.268	87.118	45.0	100.0

Tables 139 and 140 show the data for the five symbols, focusing on the two dependent variables, time and accuracy: the number of searches, mean search times, and standard deviations for both time and accuracy for each symbol. Analysis of Variance shows that there are significant differences in both search times, F (4, 119) = 5.16, $p < .001$, and search accuracy, F (4, 119) = 7.83, $p < .001$ (Table 141). The mean search times for the individual symbols varied from 27.04 to 36.51 seconds, and the standard deviations from 7.40 to 9.16 (Table 139). The response time for the tennis ($\bar{x}$ = 27.04, s = 7.40) was found significantly faster than the other symbols. On the other hand, t tests showed that there was no significant difference between the golfing ($\bar{x}$ =36.51, s = 8.88) and baseball ($\bar{x}$ =34.42, s = 8.85) symbols in search time, and that these times were significantly slower than the other symbols in the group (Table 142).

Table 141. Significant Differences of Symbols on the Dense Linear Background

ANOVA[a]

		Sum of Squares	df	Mean Square	F	Sig.
Time	Between Groups	1519.264	4	379.816	5.161	.001
	Within Groups	8757.922	119	73.596		
	Total	10277.185	123			
Percent Correct	Between Groups	4773.803	4	1193.451	7.837	.000
	Within Groups	18121.161	119	152.279		
	Total	22894.965	123			

Table 142. *t* Tests for Equality of Means (Time) among Symbols in Search Time on the Dense Linear Background

Independent Samples Test							
t-test for Equality of Means (Time)							
Symbol	t	df	Sig. (2-tailed)	Mean Difference	Std. Error Difference	95% Confidence Interval of the Difference	
						Lower	Upper
Archery * Golfing	-1.814	47	.076	-6.262	3.451	-13.206	.681
Archery * Hiking	-.535	32	.596	-1.904	3.558	-9.152	5.344
Archery * Tennis	1.008	31	.321	3.210	3.184	-3.283	9.703
Archery * Baseball	-1.144	30	.262	-4.167	3.643	-11.607	3.274
Golfing * Hiking	1.972	65	.053	4.358	2.210	-.056	8.772
Golfing * Tennis	4.463	64	.000	9.472	2.122	5.232	13.712
Golfing * Baseball	.919	63	.362	2.096	2.281	-2.463	6.654
Hiking * Tennis	2.256	49	.029	5.114	2.267	.559	9.669
Hiking * Baseball	-.911	48	.367	-2.263	2.483	-7.255	2.730
Tennis * Baseball	-3.169	47	.003	-7.377	2.328	-12.060	-2.694

The mean search accuracy for the individual symbols varied from 75.99 to 95.33 percent, and standard deviations varied from 6.54 to 15.70 (Table 140). *t* tests showed that there was significant difference between the tennis symbol ($\bar{x}$ = 95.33, *s* = 6.54) and the tennis symbol was found to be significantly more accurate than the other symbols. Additionally, the baseball ($\bar{x}$ = 75.99, *s* = 13.46) and archery symbols ($\bar{x}$ = 80.88, *s* = 12.07) were significantly less accurate than the other symbols, and there were no significant difference between them (Table 143).

Table 143. *t* Tests for Equality of Means (Accuracy) among Symbols in Search Accuracy on the Dense Linear Background

Independent Samples Test							
t-test for Equality of Means (Accuracy)							
Symbol	t	df	Sig. (2-tailed)	Mean Difference	Std. Error Difference	95% Confidence Interval of the Difference	
						Lower	Upper
Archery * Golfing	-.716	47	.478	-3.3170	4.6348	-12.6410	6.0070
Archery * Hiking	-.587	32	.561	-3.5582	6.0582	-15.8984	8.7820
Archery * Tennis	-4.374	31	.000	-14.4510	3.3035	-21.1886	-7.7134
Archery * Baseball	.910	30	.370	4.8870	5.3696	-6.0792	15.8532
Golfing * Hiking	-.071	65	.944	-.2412	3.3924	-7.0163	6.5339
Golfing * Tennis	-4.267	64	.000	-11.1340	2.6093	-16.3466	-5.9213
Golfing * Baseball	2.546	63	.013	8.2040	3.2229	1.7635	14.6445
Hiking * Tennis	-3.209	49	.002	-10.8928	3.3940	-17.7132	-4.0723
Hiking * Baseball	2.033	48	.048	8.4452	4.1533	.0945	16.7959
Tennis * Baseball	6.434	47	.000	19.3380	3.0055	13.2916	25.3843

These results show the same results found with the other backgrounds, that the tennis symbol was found to be achieved best for the search task, both in terms of search time and accuracy. And that result was expected since the characteristics of the symbol helped the searchers to find this symbol among the other symbols in their search process. Conversely, the baseball and golfing symbols were found to be slow in time; the symbols are similar to each other in design. Further, the baseball symbol was the lowest in search accuracy (along with the archery symbol), again due to the similarity of the characteristics of these symbols.

Complex Pictorial Symbol Group on the Gray Background

The symbol system was analyzed using the two dependent variables: time and accuracy. Table 144 shows the number of searches, mean search times, and the standard deviations for both time and accuracy for the golfing symbol. As noted, participants were using golfing symbol against the gray background.

Table 144. Descriptive Statistics of the Golfing Symbol in Search Time and Accuracy on the Gray Background

Background	Symbol		Time	Percent Correct
Gray	Golfing	N	98	98
		Mean	30.66	69.25
		Std. Deviation	10.18	5.15

The response time for golfing symbol ($\bar{x}$ = 30.66, s = 10.18), and the mean search accuracy was ($\bar{x}$ = 69.25, s = 5.15) (Table 144).

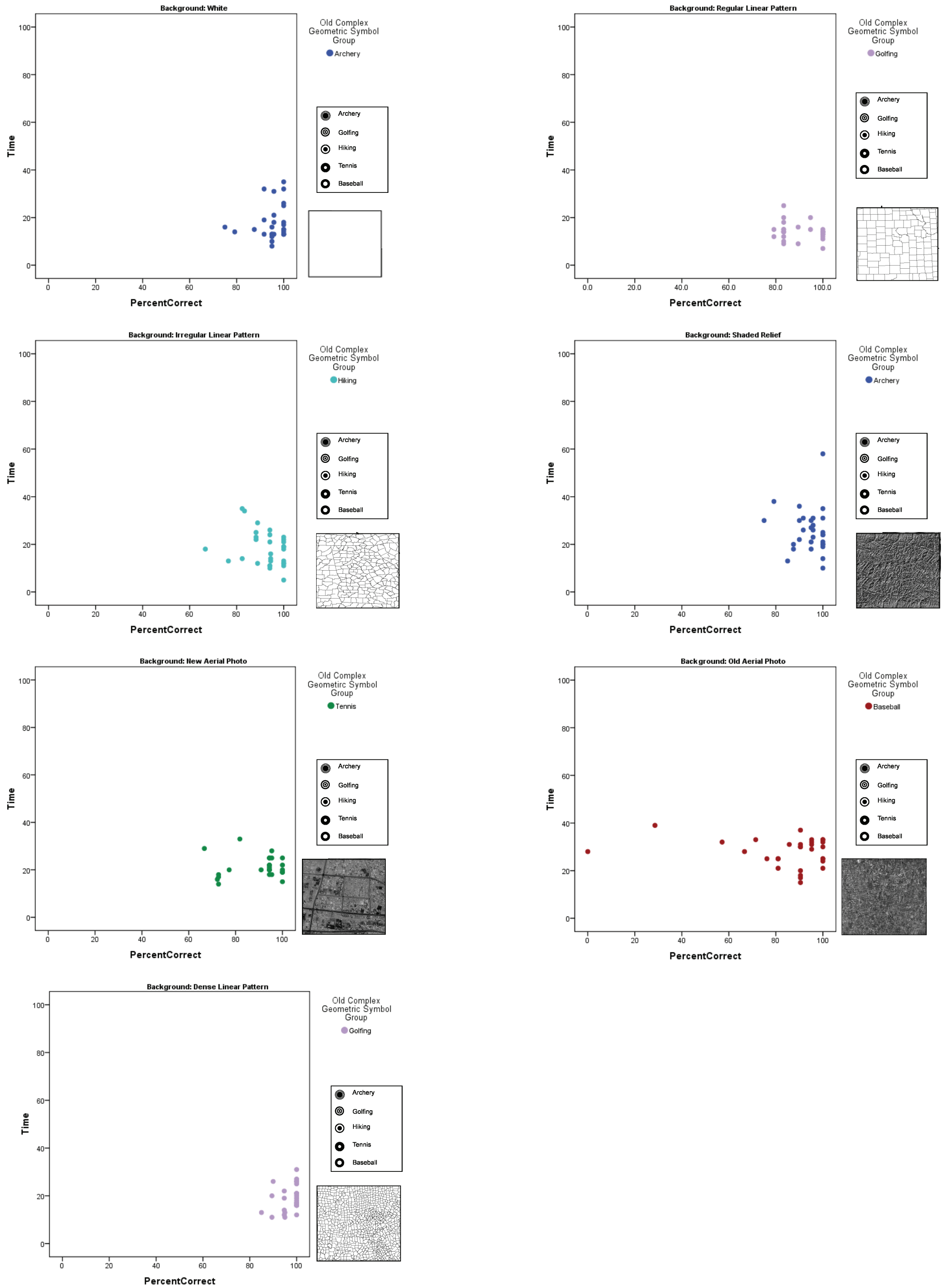


Figure 7. Old complex geometric symbol group on the seven backgrounds.

Old Complex Geometric Symbol Group on the Different Backgrounds

Table 145. Descriptive Statistics for the Old Complex Geometric Symbols in Search Time

Descriptives									
						95% Confidence Interval for Mean			
	Symbol	N	Mean	Std. Deviation	Std. Error	Lower Bound	Upper Bound	Minimum	Maximum
Time	Archery	58	21.88	9.083	1.193	19.49	24.27	8	58
	Golfing	52	16.44	5.267	.730	14.98	17.91	7	31
	Hiking	30	18.20	7.227	1.320	15.50	20.90	5	35
	Tennis	26	21.19	4.427	.868	19.40	22.98	14	33
	Baseball	30	27.77	5.876	1.073	25.57	29.96	15	39
	Total	196	20.68	7.792	.557	19.59	21.78	5	58

Table 146. Descriptive Statistics for the Old Complex Geometric Symbols in Search Accuracy

Descriptives									
						95% Confidence Interval for Mean			
	Symbol	N	Mean	Std. Deviation	Std. Error	Lower Bound	Upper Bound	Minimum	Maximum
Percent Correct	Archery	58	94.842	6.3589	.8350	93.170	96.514	75.0	100.0
	Golfing	52	93.583	7.3655	1.0214	91.532	95.634	79.2	100.0
	Hiking	30	92.723	8.1773	1.4930	89.670	95.777	66.7	100.0
	Tennis	26	90.132	10.6806	2.0946	85.818	94.446	66.7	100.0
	Baseball	30	84.444	22.1925	4.0518	76.158	92.731	.0	100.0
	Total	196	91.967	11.6713	.8337	90.323	93.612	.0	100.0

Before showing the results of the five old complex geometric symbols on the different backgrounds, the Tables 145 and 146 show the number of searches, mean search times, and standard deviations for both time and accuracy for each symbol. Analysis of Variance shows that there are significant differences in the mean search times for these symbols, F (4, 191) = 14.21, $p < .001$. Further, there are significant differences in search accuracy among the symbols, F (4, 191) = 4.78, $p < .001$ (Table 147). The mean search times for the symbols varied from 16.44 to 27.77 seconds, and the standard deviations varied from 4.42 to 9.08 (Table 145). The response time for golfing ($\bar{x}$ = 16.44, s = 5.26) and hiking ($\bar{x}$ =18.20, s = 7.22) symbols were found to be significantly faster than the other symbols; the t test showed that there was no significant difference between the golfing and the hiking symbols. On the other hand, t tests showed that there were significant differences between the baseball symbol and

Table 147. Significant Differences of Symbols on the Seven Backgrounds

ANOVA

		Sum of Squares	df	Mean Square	F	Sig.
Time	Between Groups	2715.201	4	678.800	14.211	.000
	Within Groups	9123.187	191	47.765		
	Total	11838.388	195			
Percent Correct	Between Groups	2417.551	4	604.388	4.781	.001
	Within Groups	24145.333	191	126.415		
	Total	26562.884	195			

Table 148. *t* Tests for Equality of Means (Time) among Symbols in Search Time on the Backgrounds

Independent Samples Test							
t-test for Equality of Means (Time)							
Symbol	t	df	Sig. (2-tailed)	Mean Difference	Std. Error Difference	95% Confidence Interval of the Difference	
						Lower	Upper
Archery * Golfing	3.783	108	.000	5.437	1.437	2.588	8.286
Archery * Hiking	1.924	86	.058	3.679	1.912	-.122	7.480
Archery * Tennis	.366	82	.715	.687	1.878	-3.049	4.423
Archery * Baseball	-3.215	86	.002	-5.887	1.831	-9.528	-2.247
Golfing * Hiking	-1.267	80	.209	-1.758	1.387	-4.519	1.003
Golfing * Tennis	-3.950	76	.000	-4.750	1.202	-7.145	-2.355
Golfing * Baseball	-8.988	80	.000	-11.324	1.260	-13.832	-8.817
Hiking * Tennis	-1.833	54	.072	-2.992	1.633	-6.266	.281
Hiking * Baseball	-5.625	58	.000	-9.567	1.701	-12.971	-6.162
Tennis * Baseball	-4.669	54	.000	-6.574	1.408	-9.398	-3.751

the other symbols in search time. The response time of the baseball symbol ($\bar{x}$ = 27.77, s = 5.87) was significantly slower than the other symbols (Table 148).

The search accuracy for the symbols varied from 84.44 to 94.84 percent, and the standard deviations varied from 6.35 to 22.19 (Table 146). *t*-tests showed that there were no significant differences among the archery ($\bar{x}$ = 94.84, s = 6.35), golfing ($\bar{x}$ = 93.58, s = 7.36), and hiking ($\bar{x}$ = 92.72, s = 8.17) symbols, and these three were found to be significantly more accurate than the other two symbols in the group. Additionally, the tennis ($\bar{x}$ =90.13, s = 10.68) and baseball ($\bar{x}$ =84.44, s = 22.19)

Table 149. *t* Tests for Equality of Means (Accuracy) among Symbols in Search Accuracy on the Backgrounds

Independent Samples Test							
t-test for Equality of Means (Accuracy)							
Symbol Group	t	df	Sig. (2-tailed)	Mean Difference	Std. Error Difference	95% Confidence Interval of the Difference	
						Lower	Upper
Archery * Golfing	.962	108	.338	1.2590	1.3087	-1.3351	3.8530
Archery * Hiking	1.341	86	.183	2.1186	1.5798	-1.0219	5.2592
Archery * Tennis	2.516	82	.014	4.7099	1.8716	.9866	8.4331
Archery * Baseball	3.329	86	.001	10.3975	3.1233	4.1887	16.6063
Golfing * Hiking	.489	80	.626	.8597	1.7584	-2.6397	4.3591
Golfing * Tennis	1.671	76	.099	3.4509	2.0652	-.6624	7.5642
Golfing * Baseball	2.730	80	.008	9.1386	3.3470	2.4778	15.7993
Hiking * Tennis	1.027	54	.309	2.5912	2.5239	-2.4688	7.6513
Hiking * Baseball	1.917	58	.060	8.2789	4.3181	-.3647	16.9225
Tennis * Baseball	1.192	54	.239	5.6876	4.7729	-3.8815	15.2568

symbols were found to be significantly less accurate than the other symbols (Table 149).

From the analyses, the golfing and hiking symbols were best for the search task, both in terms of time and accuracy. The golfing and hiking symbols have designs that are different from the rest of the symbols, so the searchers worked with these symbols quickly and with high accuracy. The archery symbol was found to be highly accurate, and the reason could be because its design was distinctive from the other symbols.

While the baseball symbol was found to be slow both in search time and in accuracy, the reason for this was expected, since the baseball symbol was similar to the tennis symbol in design which caused slow search time with low accuracy. Finally, the tennis symbol was found to be low in accuracy too, that because its design is similar to that of the baseball symbol.

Old Complex Geometric Symbols on the White Background

The symbol system was analyzed using the two dependent variables: time and accuracy. Table 150 shows the number of searches, mean search time and accuracy, and the standard deviations for both time and accuracy for the archery symbol on the white background.

Table 150. Descriptive Statistics for the Archery Symbol in Search Time and Accuracy on the White Background

Report

Symbol		Time	Percent Correct
Archery	N	28	28
	Mean	17.86	95.357
	Std. Deviation	7.240	6.2048

The response time for the archery symbol was $\bar{x}$ = 17.86, s = 7.24, and the mean search accuracy was $\bar{x}$ = 95.35, s = 6.20 (Table 150).

Old Complex Geometric Symbols on the Regular Linear Background

The symbol system was analyzed using the two dependent variables: time and accuracy. Table 151 shows the number of searches, mean search time and accuracy, and the standard deviations for both time and accuracy for the golfing symbol. As noted, participants were using the golfing symbol on the regular linear background.

Table 151. Descriptive Statistics for the Golfing Symbol in Search Time and Accuracy on the Regular Linear Background

Report

Symbol		Time	Percent Correct
Golfing	N	26	26
	Mean	14.08	90.132
	Std. Deviation	3.773	8.1697

The response time for the golfing symbol was $\bar{x}$ = 14.08, s = 3.77, and the mean search accuracy was $\bar{x}$ = 90.13, s = 8.16 (Table 151).

Old Complex Geometric Symbols on the Irregular Linear Background

The symbol system was analyzed using the two dependent variables: time and accuracy. Table 152 shows the number of searches, mean search time and accuracy, and the standard deviations for both time and accuracy for the hiking symbol. As noted, participants were using hiking symbol on the irregular linear background.

Table 152. Descriptive Statistics for the Hiking Symbol in Search Time and Accuracy on Irregular Linear Background

Report

Symbol		Time	Percent Correct
Hiking	N	30	30
	Mean	18.20	92.723
	Std. Deviation	7.227	8.1773

The response time for the hiking symbol was $\bar{x}$ = 18.20, s = 7.22, and the mean search accuracy was $\bar{x}$ = 92.72, s = 8.17 (Table 152).

Old Complex Geometric Symbols on the New Imagery Background

The symbol system was analyzed using the two dependent variables: time and accuracy. Table 153 shows the number of searches, mean search time and accuracy, and the standard deviations for both time and accuracy for the tennis symbol. As noted, participants were using tennis symbol on the new imagery background.

Table 153. Descriptive Statistics for the Tennis Symbol in Search Time and Accuracy on the New Imagery Background

Report

Symbol		Time	Percent Correct
Tennis	N	26	26
	Mean	21.19	90.132
	Std. Deviation	4.427	10.6806

The response time for the tennis symbol was $\bar{x}$ = 21.19, s = 4.42, and the mean search accuracy was $\bar{x}$ = 90.13, s = 10.68 (Table 153).

Old Complex Geometric Symbols on the Shaded Relief Background

The symbol system was analyzed using the two dependent variables: time and accuracy. Table 154 shows the number of searches, mean search time and accuracy, and the standard deviations for both time and accuracy for the archery symbol. As noted, participants were using the archery symbol on the shaded relief background.

Table 154. Descriptive Statistics for the Archery Symbol in Search Time and Accuracy on the Shaded Relief Background

Report

Symbol		Time	Percent Correct
Archery	N	30	30
	Mean	25.63	94.361
	Std. Deviation	9.118	6.5678

The response time for the archery symbol was $\bar{x} = 25.63$, $s = 9.11$, and the mean search accuracy was $\bar{x} = 94.36$, $s = 6.56$ (Table 154).

Old Complex Geometric Symbols on the Old Imagery Background

The symbol system was analyzed using the two dependent variables: time and accuracy. Table 145 shows the number of searches, mean search time and accuracy, and the standard deviations for both time and accuracy for the baseball symbol. As noted, participants were using the baseball symbol on the old imagery background.

Table 155. Descriptive Statistics for the Baseball Symbol in Search Time and Accuracy on the Old Imagery Background

Report

Symbol		Time	Percent Correct
Baseball	N	30	30
	Mean	27.77	84.444
	Std. Deviation	5.876	22.1925

The response time for the baseball symbol was $\bar{x}$ = 27.77, s = 5.87), and the mean search accuracy was $\bar{x}$ = 84.44, s = 22.19 (Table 155).

Old Complex Geometric Symbols on the Dense Linear Background

The symbol system was analyzed using the two dependent variables: time and accuracy. Table 146 shows the number of searches, mean search time and accuracy, and the standard deviations for both time and accuracy for the golfing symbol on the dense linear background.

Table 156. Descriptive Statistics for the Golfing Symbol in Search Time and Accuracy on the Dense Linear Background

Report

Symbol		Time	Percent Correct
Golfing	N	26	26
	Mean	18.81	97.034
	Std. Deviation	5.543	4.3761

The response time for the golfing symbol was about 18 seconds ($\bar{x}$ = 18.81, s = 5.54) and the mean search accuracy was 97 percent ($\bar{x}$ = 97.0, s = 4.38) (Table 156).

Summary

On pages 362-365 are four tables. Each table is a summary of the most important data from the 140 pages of analysis and discussion included in this chapter.

There are eight tables, one for each of the eight backgrounds on which the five symbols from each group are displayed. The mean times (T) and the percentage accuracy (A) are arranged in rank order. For each set of five search times (seconds) and accuracy levels (percentages), one for each of the symbols in the group, the values are coded: for those symbols with the fastest times and the highest levels of accuracy, the values are shaded in yellow (light gray). All values that are statistically grouped (there are no significant statistical differences in time or accuracy) are shaded in the same color. One to five values will be included in the fastest and most accurate statistically-based category. Similarly the longest times and the least accurate values are shaded in cyan (a darker gray); there are one to four values in these slowest and lowest groups.

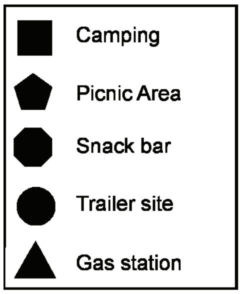
For example, for the simple pictorial symbols on the white background, four symbols shared the fastest time designation; the fifth symbol was statistically the slowest time. For the same background, only one symbol was the most accurate and three shared the statistically determined designation of least accurate.

On page 366 is a graph, relating time (Time_mean) and Accuracy (PercentCorrect_mean). On this graph are plotted the mean values for every symbol in the five groups. The individual responses are represented by colored dots representing the background for each symbol. The symbols are designated by number. The simple geometric group uses numbers 1 through 5 (camping through gas station); the (new) complex geometric uses numbers 6 through 10 (archery through baseball); numbers 11 through 15 designate the symbols in the simple pictorial group, and 16 through 20 designate the complex pictorial group. The old complex geometric symbols are designated with numbers 21 through 25.

The reader should note that the graph extends only from 10 through 60 on the Time axis, and from 60 through 100 on the Accuracy axis.

Further discussion and explanation will occur in chapter 10.

Table 157. Simple Geometric Symbols: Summary Time and Accuracy Data with Statistically Significant Relationships.



White BK

	T		A
G	17.88	C	98.07
C	20.77	T	96.70
S	22.47	G	94.31
T	22.62	S	92.44
P	28.89	P	89.81

Regular BK

	T		A
G	26.58	T	96.66
C	21.53	C	95.55
T	25.80	G	93.93
S	23.77	S	90.80
P	30.23	P	90.04

Irregular Linear BK

	T		A
G	23.62	G	96.85
C	24.83	T	96.36
P	28.32	C	94.79
T	28.54	S	90.97
S	34.27	P	89.48

New Imagery BK

	T		A
C	21.76	T	94.87
G	24.97	C	94.00
P	26.32	G	91.02
T	29.32	S	88.56
S	32.84	P	80.70

Shaded Relief BK

	T		A
G	25.46	T	94.44
C	28.81	C	93.84
P	33.76	G	89.86
S	34.30	P	86.35
T	37.38	S	79.81

Old Imagery BK

	T		A
C	22.88	C	96.15
G	23.88	T	91.20
S	31.64	G	90.34
T	32.29	P	85.74
P	33.15	S	77.47

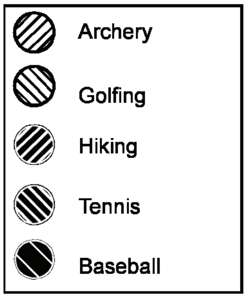
Dense Linear BK

	T		A
G	17.83	T	97.43
C	20.88	C	95.15
T	29.42	G	91.27
P	33.04	P	90.77
S	34.62	S	86.78

Gray BK

	T		A
T	31.4	T	92.85

Table 158. Complex Geometric Symbols: Summary Time and Accuracy Data with Statistically Significant Relationships.



White BK

	T		A
B	16.69	B	95.78
H	28.84	H	82.35
T	30.96	A	81.82
A	36.19	T	72.81
G	37.23	G	71.15

Regular BK

	T		A
B	18.46	B	97.72
H	33.92	A	81.94
A	37.25	G	77.40
T	37.88	H	75.69
G	39.49	T	75.61

Irregular Linear BK

	T		A
B	16.40	B	94.20
A	31.00	H	87.05
H	31.31	G	80.61
G	32.03	T	75.82
T	36.87	A	68.67

New Imagery BK

	T		A
A	27.44	B	95.57
T	29.23	A	80.03
G	30.14	H	77.12
H	30.86	T	74.54
B	31.50	G	68.33

Shaded Relief BK

	T		A
B	23.62	B	94.23
T	28.89	T	84.49
H	33.36	G	80.54
G	34.24	H	71.35
A	36.38	A	62.21

Old Imagery BK

	T		A
B	19.94	B	95.62
T	24.96	A	83.39
A	31.00	H	79.40
H	31.67	G	63.98
G	31.69	T	62.10

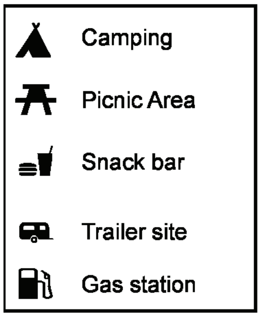
Dense Linear BK

	T		A
B	15.92	B	98.12
T	31.00	G	84.61
A	32.12	A	82.65
H	34.42	T	79.12
G	36.15	H	77.78

Gray BK

	T		A
G	36.38	G	64.45

Table 159. Simple Pictorial Symbols: Summary Time and Accuracy Data with Statistically Significant Relationships.



White BK

	T		A
S	18.41	S	97.79
G	19.47	C	97.43
T	19.74	T	95.19
C	21.65	G	94.31
P	26.38	P	93.07

Regular BK

	T		A
G	18.18	S	95.60
C	19.04	T	95.54
T	20.81	C	92.32
S	24.81	G	90.79
P	25.85	P	85.96

Irregular Linear BK

	T		A
S	22.50	S	97.80
P	24.62	T	95.34
T	25.50	C	90.74
C	26.08	G	90.55
G	26.54	P	90.31

New Imagery BK

	T		A
S	23.48	T	93.92
P	27.88	G	92.65
C	27.96	C	91.23
T	28.12	S	89.86
G	28.42	P	83.47

Shaded Relief BK

	T		A
C	26.50	G	44.58
T	28.96	T	89.35
S	31.08	C	88.24
P	37.73	S	86.11
G	42.23	P	83.46

Old Imagery BK

	T		A
T	19.71	S	96.15
G	24.75	C	95.94
C	25.42	T	92.10
S	27.62	G	89.63
P	28.73	P	89.42

Dense Linear BK

	T		A
C	20.83	S	97.25
P	23.62	T	96.00
T	24.12	C	91.23
G	24.52	G	90.18
S	27.12	P	85.57

Gray BK

	T		A
T	25.76	T	96.77

Table 160. Complex Pictorial Symbols: Summary Time and Accuracy Data with Statistically Significant Relationships.

Archery
Golfing
Hiking
Tennis
Baseball

White BK

	T		A
T	20.39	T	95.41
A	29.04	A	94.79
H	32.24	H	94.18
B	35.15	B	85.18
G	45.00	G	85.11

Regular BK

	T		A
A	27.27	T	95.77
T	30.20	A	92.51
B	34.52	G	90.80
H	37.08	H	87.93
G	43.15	B	78.60

Irregular Linear BK

	T		A
A	27.50	H	94.23
T	28.92	A	92.15
H	36.85	T	89.95
G	38.19	G	85.73
B	44.12	B	78.65

New Imagery BK

	T		A
T	31.19	A	91.76
G	33.09	T	90.38
A	33.40	H	87.15
H	33.61	G	78.26
B	45.67	B	68.88

Shaded Relief BK

	T		A
T	40.50	T	82.84
H	45.16	G	76.69
A	48.81	A	76.01
G	52.52	H	73.96
B	52.42	B	67.11

Old Imagery BK

	T		A
T	31.32	A	90.99
A	39.65	H	88.28
B	43.59	T	81.31
H	46.62	G	76.75
G	48.32	B	74.06

Dense Linear BK

	T		A
T	27.04	T	95.33
A	30.25	H	84.44
H	32.15	G	84.19
B	34.42	A	80.88
G	36.51	B	75.99

Gray BK

	T		A
G	30.66	G	69.25

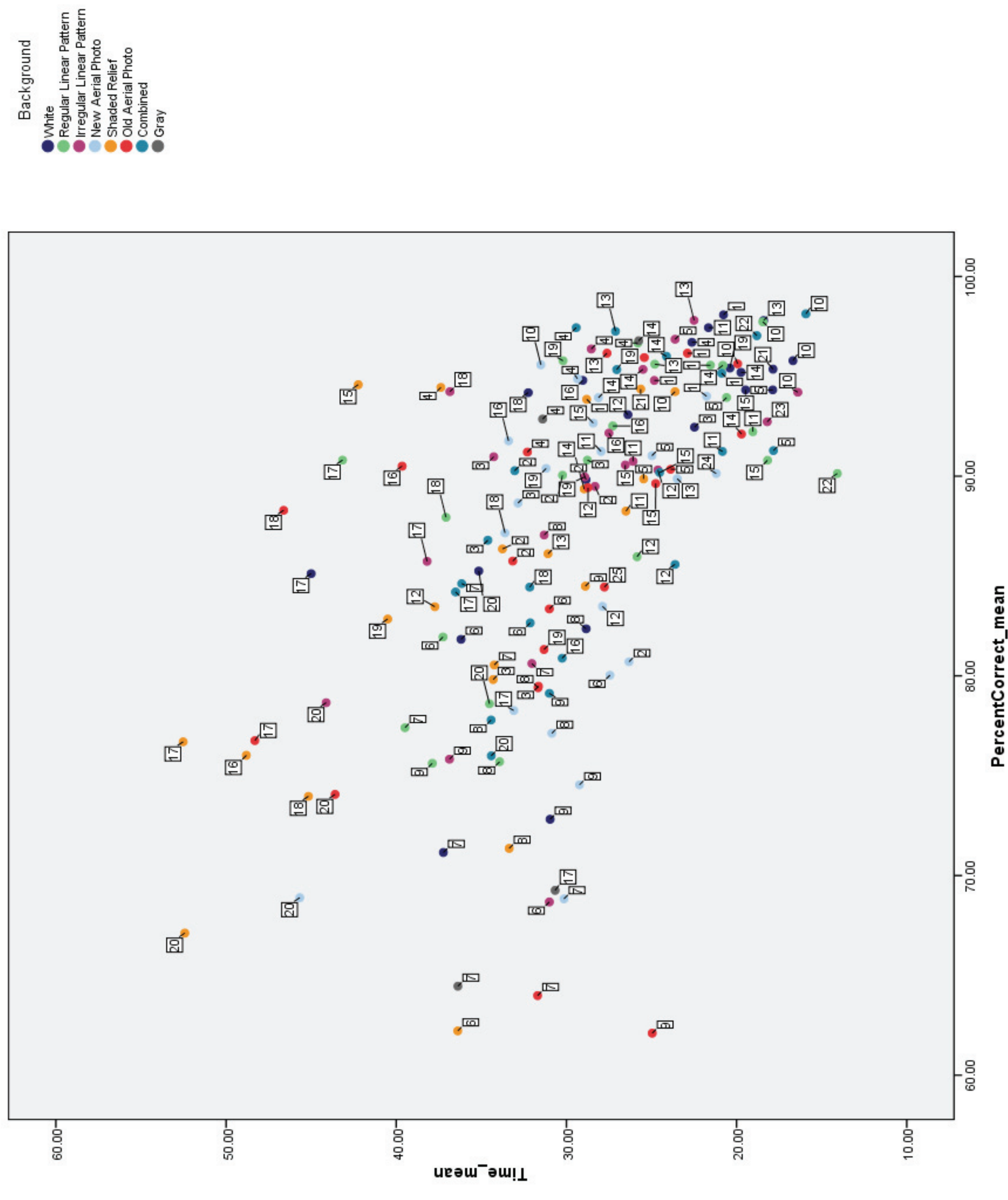


Figure 8. Individual symbols for all groups and all background, in Time-Accuracy Space.

Chapter Nine

Discussion of the GEOG 104 Tests

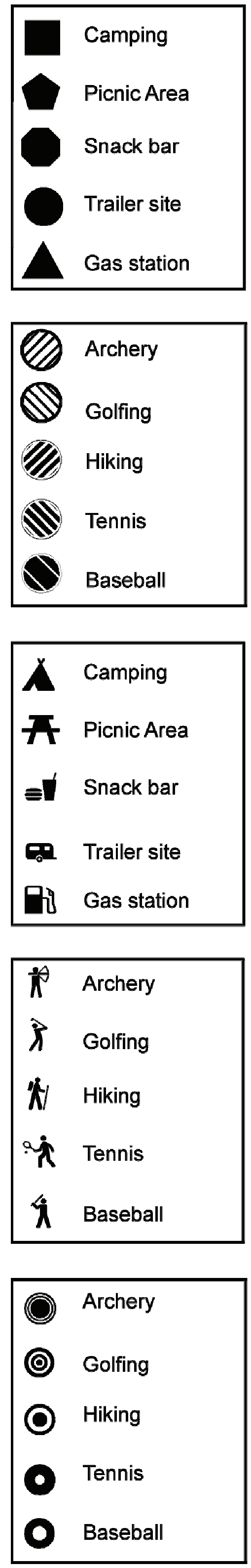
There were three days of testing in GEOG 104, in 50-minute class sessions. In the first session the entire period was devoted to the test, from the introductory cartoon and the explanation of the procedures to the class completing over 30 search tasks. In the second session, another dozen search tasks were completed by each student (then there was the presentation of the first part of a video on volcanism). The third session had only a few search tasks, these necessary to fill several gaps in the overall testing program (most of the class was spent on the video on volcanism).

In the previous two chapters the data in the GEOG 104 class have been examined in detail, beginning with a broad view of the backgrounds and the symbol groups in order clarify the nature of the interactions among them. This examination of the results found the dense clusters that resulted when search time was graphed against accuracy. The "same" dense cluster occurred for the five different symbol groups for each background and, then again, for the eight backgrounds.

The hypotheses for the study involve two basic factors: the eight backgrounds and the five symbol groups (three geometric and two pictorial). The forty combinations of the backgrounds with the symbol factors vary in complexity. Given the two task issues, the two dependent variables, time and accuracy, it was expected that there would be diverse results.

Hypotheses for the background begin, first, with the question of contrast. When there are differences between the characteristics of the background and the point symbols, contrast differences are created; detection, discrimination, and identification of the point symbols will be easy or difficult. With high contrast levels, the search process will be faster and more accurate, but when a background and a symbol have little difference, lacking contrast, this will have a major impact on search time and accuracy.

Hypotheses with respect to symbol characteristics assert, first, that pictorial symbols will be recognized faster and more accurately than geometric symbols. Further, simple symbol design will result in fast search time and high accuracy. Also, similarity between the target symbol and non-target or distractor symbols will cause difficulty in accurately and quickly detecting the target symbol and will increase the amount of search time and lower the accuracy level.



All Backgrounds with All Symbol Groups

It was found in the analysis comparing search time with accuracy, for all backgrounds with all symbol groups, that the performances were distributed in four different parts, short-time with high accuracy, short-time with low accuracy, long-time with high accuracy, and long-time with low accuracy. However, most of the performances were in the short-time with high accuracy category. The distributions of the performances that showed in the data analysis depended on the two factors, the background and the symbol group. Therefore to know more about what the overall distribution meant, it was necessary to display the five different symbol groups separately for each background, as well as display for each of the symbol groups the relationship to each background. The questions that arise all deal with the interactions among all of these elements and how each element contributes to the other elements as well as the whole.

Different Symbol Groups with Each Background

The characteristics of the both factors (backgrounds and symbol groups) played a role affecting the performance of the visual search process, in both time and accuracy, whether the characteristics of the background and /or the symbol were simple or complex, similar to each other, or different in form to each other. Sometimes the background affected the symbol groups positively or negatively, and sometimes the symbol group affected the background positively or negatively. For example, when the background characteristics were simple, the visual search processes worked best in both time and accuracy. And the opposite is true, and these results agreed with a study by Neider and Zelinsky (2006), who examined the effects of target background similarity on visual search, finding that the response time and errors increased when there is similarity between the characteristics of the target and the background.

Besides, it was found that sometimes, even if the background has no noise-producing characteristics or was simple in its characteristics, it could still influence the search performance negatively, because of the complexity of the characteristics of the symbol group. Note the performance of SG4 (complex pictorial) where the white background was involved in the slowest search time in the entire study. Even though the background was white, the characteristics of the symbol group were so complex that the performance was poor. Even if the symbol group is simple in its characteristics, it could be influenced in the search performance because the complexity of the background. For instance, the search performance for SG3 (simple pictorial) with the shaded relief background yielded times greater than any search with other backgrounds.

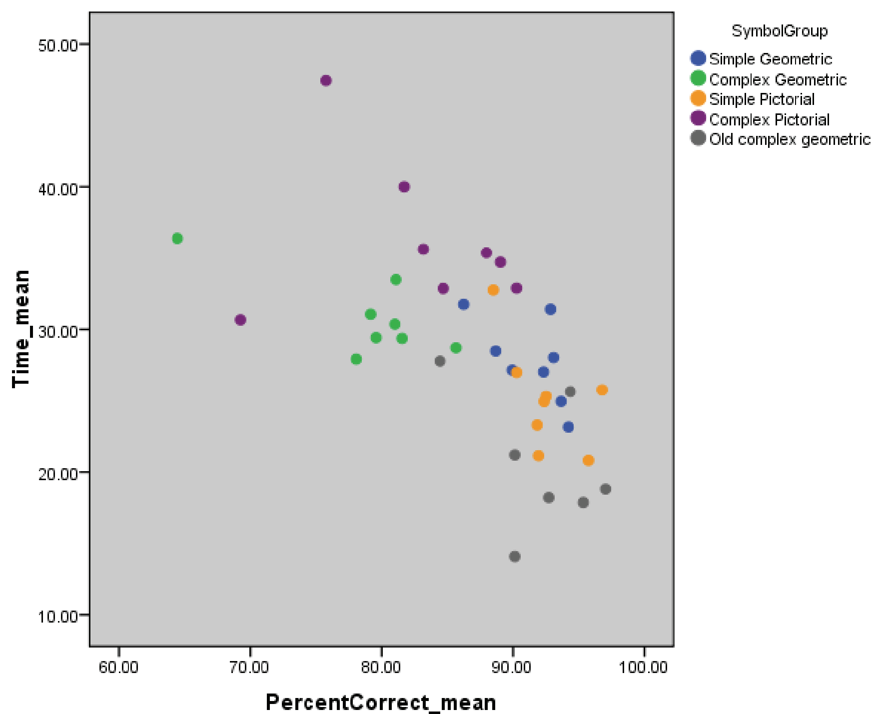


Figure 1. Different symbol groups with all backgrounds.

As the figure above (and the mean data for time and accuracy for all of the symbol groups with all of the backgrounds illustrates, Time and accuracy for all groups was greater (time) and less (accuracy) for the shaded relief and the two imagery backgrounds than for the white and three linear backgrounds.

The search performances for SG5 (old complex geometric) and SG3 (simple pictorial) were best, both terms of time and accuracy on all backgrounds. SG5 was at the top of the time list for all seven backgrounds, and for six of the seven accuracy measurements. SG3 was fastest on four of the backgrounds, and highly accurate on six of them. On the other hand, performances of SG2 (complex geometric) and SG4 (complex pictorial) were the worst, both in terms of time and accuracy (SG4, lowest in 7 of 8 times, and 5 of 8 in accuracy; SG2 lowest in 2 of 8 for time, and all 8 in accuracy). Consider the following reasons for these results.

There are several reasons that SG3 had excellent search times and accuracy. The characteristics of the individual symbols are simple in design, and each symbol looks different than the others. Each symbol has a unique character that distinguishes it from the other symbols. In addition, the symbols represent the meaning of the feature. Therefore, the searchers can directly associate the symbol, without referring to the legend, since it is pictorially simple and does not need interpretation. This group provides a good illustration of the “similarity” situation in visual search. These results agree with Johnson (1983), who found that similarity between symbols caused confusion and a low rate of accuracy in visual search.

Although SG5 is called "complex geometric," it worked the best in both time and accuracy with all but one of the backgrounds. Comparing the characteristics of this complex geometric group (a symbol set based on organizing circles within circles) to the new complex geometric group (organizing diagonal lines within a set of circles), it is clear that the old design is distinctly less complex than the new one (recall that this was used during the introductory/pilot test stage of this research, and was replaced because there was a need for a complex geometric set that was a bit more complex!).

Note that the SG5 symbols were tested on the third day, and that test included only four sheets, two of them with SG5 symbols. One sheet used large size symbols, and the other sheet small sizes. Perhaps, for example, the small number of test sheets helped the participants work without feeling tired or fatigued, compared to the previous two days of testis, involving a much larger number of sheets. That agrees with Welford (1968, 1980) when he found that reaction time becomes slower when the subject is fatigued! On the other hand, it could have been the fact that these were now veteran visual searchers – they handled the task with significantly more knowledge. And the testing program was over!

In strong comparison to SG3 and SG5 are the results for SG2 (complex geometric) and SG4 (complex pictorial); these were the worst in search time and accuracy. SG2 was the worst in two of the eight times and in all of the accuracy measurements. SG4 was at the bottom of performance in seven of the eight times, and five of the eight accuracy categories.

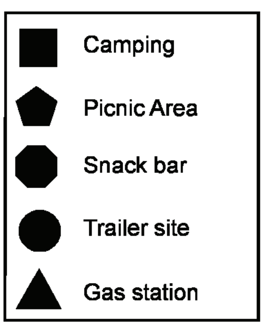
The reasons of finding SG2 to be in low performance in both terms, search time and accuracy, are various; in particular, the characteristics of the SG2 group, while simple in design, yields a visually complex set of symbols; each symbol in this group looks similar to the others. Therefore, each symbol does not have a unique character that distinguishes it from the other symbols. For example, the archery symbol is similar to the golfing symbol in all characteristics except in the orientation of the lines. Similarly, the hiking symbol and the tennis symbol are similar except for the orientation of the lines. The only one which was different and could be distinguished from the other symbols is the baseball symbol, since it is different from the others in design characteristics.

SG4 is complex in its design so it was found to be low in its performance in both search time and accuracy with almost all of the backgrounds. The reasons for that were referred to earlier. The SG4 symbols complex in shape; the differences between one symbol and another are subtle. Duncan and Humphreys (1989) found that the difficulty of visual search increases with increases in the similarity of targets to non-targets, and the opposite is also true. Similarly, Wolfe et al. (1989) found that more distractors and more equality between distractors and targets make the visual search less efficient, slower and less accurate. Since most of the symbols have the same characteristics, targets and non-targets (distractors) look alike, and as a result, it confuses the searchers, and produces low performance with all of the backgrounds. Nevertheless, even though the situation is very complex, and search times were significantly greater than for other symbol groups, some results are not all that different than those for other symbol groups. For backgrounds with complex characteristics, accurate searches required a greater amount of time. The level of contrast between the symbol and the background is critical. Also, it was noticeable that SG4 has low performance with backgrounds that even had simple characteristics and that because of the complexity characteristics of the symbol group.

Analysis of the Five Different Symbols Groups with Each Background:

Since there are five different symbol groups, each with five different symbols, that were tested with the eight backgrounds, the following discussion will start with each symbol group in order to discuss the specific results for each symbol with the backgrounds.

Simple Geometric Symbol Group

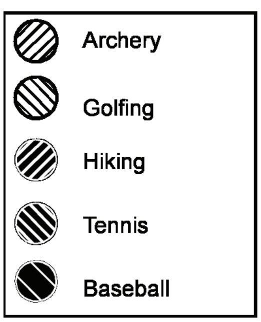


This group includes five different simple geometric symbols (camping, picnic area, snack bar, trailer site, and gas station). The camping and gas station symbols worked best in terms of search time and accuracy with most backgrounds. While the picnic area and snack bar symbols were found to be slow in time and low in accuracy.

The reason that caused the camping and gas station symbol to have this result, was because the difference between these symbols and the other symbols in its shape's characteristics, since the camping was represented by a square, and the gas station was represented by a triangle; both shapes are different in their characteristics from the others, the pentagon, circle and octagon. Therefore, these differences helped in “popping out” the symbol and enabled the searchers to detect and discriminate these symbols faster and more accurate than most other symbols. Simply, the target symbol looks different from the non-target symbols. Also, it is should be noted that the distribution range of the camping and the gas station symbols, in the search time and accuracy, occurred in a short-time with high accuracy with most backgrounds.

What caused the picnic area and snack bar symbols to have their results? Were the similarity in shape characteristics among them, since the picnic area was represented by a pentagon and the snack bar by an octagon? It seems reasonable to conclude that these similarities caused confusion in the search process, and generated slow search times with low accuracy.

Complex Geometric Symbol Group

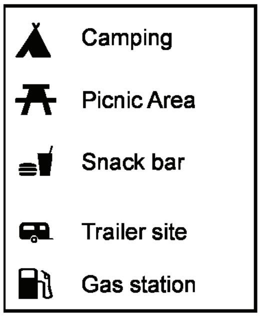


This group includes five different complex geometric symbols (archery, golfing, hiking, tennis, and baseball). The baseball symbol worked best in terms of search time and accuracy with all backgrounds (in only one case was it slower than other symbols in the group; on the New Imagery background it was four seconds slower than the shortest time, but this difference was not statistically significant). The reason for the baseball symbol to have this result was because the difference between the baseball symbol and the other symbols is its characteristics, since it was represented by a black circle with two oriented white lines inside it, The archery, golfing, hiking, and tennis symbols, with four or five lines, were found to be slower in time and low in accuracy with all the backgrounds.

The other symbols were represented as following, the archery symbol was a white circle with right oriented thin black lines inside it; the golfing symbol was a white circle with thin left oriented black lines inside it; the hiking symbol was a black circle with thick right oriented white lines inside it; and the tennis was a black circle with thick left oriented white lines inside it. Therefore, the baseball symbol is a "pop out" symbol and allowed the searchers to detect and discriminate this symbol faster and more accurately than the other symbols, since the target symbol looks different from the non-target symbols.

On the other hand, the reason that caused the archery, golfing, hiking, and tennis symbols to have their results were the similarity in the characteristics among them. These similarities caused difficulty for the searchers in detecting the required symbol through the visual search processes, and as a result it created the slow search time with low accuracy, since the target symbol in every case looks like the non-target symbols. It was found from the distribution range of the archery, golfing, hiking, and tennis symbols, in search time and accuracy, varies little in its location along the time and accuracy with the all backgrounds, even with the background that has simple characteristics, it was found that the distributions range of these symbols with the white background was spread from short and/or long time to low and/or high accuracy.

Simple Pictorial Symbol Group



This group includes five simple pictorial symbols (camping, picnic area, snack bar, trailer site, and gas station). From the results it was found that the performance of these symbols varied little from one background to another whether in search time and/ or in accuracy (only the shaded relief background falls separate from the main cluster. The performance of the camping, gas station, and trailer site symbols were fast in term of mean search time with the white, regular linear, irregular linear, and dense linear backgrounds. The reason for that referred to the shape characteristic of these symbols that helped to be searched in fast time with these kinds of background. For example, the camping symbol was distinguished by the two tent poles at the top of the teepee, the snack bar symbol was characterized by the straw in the drink cup, the gas station symbol was distinguished by the hose attached to the gas pump, and the trailer site symbol was featured by the two windows. These results agree with Treisman and Gelade, 1980 and Treisman and Gormican, 1988, who found that a search for a target could be detected without attention if it differs from the distractors by some highly discriminable feature (feature target). The same results were found by Lloyd (1997b), who noted that when the target has unique characteristics that distinguish it from the other symbols, search is parallel, and the target symbol "pops out" and the time for the search decreases.

The picnic area symbol was found to be slow in time and low in accuracy with the white, regular linear pattern, irregular linear pattern, and new imagery backgrounds. That indicated even though a long time has been spent with the picnic area symbol, it did not produce a highly accurate response, so the result of the picnic area symbol confirmed that symbol shape does not include unique characteristics that distinguish it; for example, the symbol shape is solid and has not included a feature in its design to pop out as the other symbols that included such features.

In addition, the snack bar symbol was found to be fast and accurate with the new imagery background and that because the design of the snack bar symbol, represented by a drink and a sandwich, allowed the searchers to detect the symbol in a short time. The snack bar symbol was accurate with the old imagery and dense linear pattern backgrounds, and the reason for that is because the snack bar symbol was slow in mean search time, and that produced the high accuracy with these backgrounds. Here is indicated the impact of backgrounds characteristics in the visual search process.

Moreover, it was found that the camping, trailer site, and snack bar symbols were fast in search time with the shaded relief background; however, their performance, accuracy, was low. The characteristics of the shaded relief background are complex and do not allow the searchers to detect a target symbol in a short time with high accuracy. So that when the searching for the camping, trailer site, and snack bar symbols was fast, the result was with low accuracy, and the opposite was true, when the search for the gas station symbol was slow in time, it got a high accuracy. Furthermore, while the trailer site symbol was found quickly with the old imagery background, the accuracy was low.

Additionally, it was noticeable that the distribution range of these symbols, in term of search time and accuracy, with the shaded relief background was different from the distribution of the symbols with the other backgrounds, and that indicated to the complexity of the shaded relief background that affected in the search.

Complex Pictorial Symbol Group

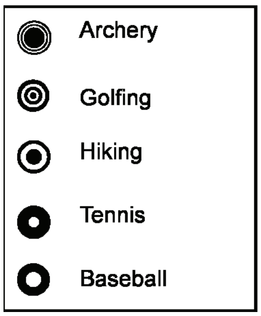
This group includes five different complex pictorial symbols (archery, golfing, hiking, tennis, and baseball). Although all of the symbols were complex in shape, there were some symbols that have attributes that could make them different a little bit from each other or make them similar to each other. It was found that the tennis symbol worked best in terms of search time and accuracy with all backgrounds. The golfing and baseball symbols were found to be slow in time and low in accuracy with all backgrounds.

The reason that caused the tennis symbol to have this result was because of the difference between the tennis symbol and the other symbols in shape characteristics. First of all, the tennis symbol body movement is different from the movement of the other symbols which all stand up. Second, the tennis symbol individual holds the tennis racket and the ball on the right side direction, while the other symbols hold the equipment in the top side direction. As a result, as the tennis symbol was different from the others, and consequently allowed the searchers to detect and discriminate this symbol faster and more accurately than the other symbols. The target symbol looks different from the non-target symbols. Also, it is clear that the distribution range of the tennis symbol, in search time and accuracy, is located in the short-time with high accuracy sector with the most of the backgrounds.

On the other hand, the reason that caused the golfing, and baseball symbols to have these results were the similarity in the characteristics between them, since the golfing symbol individual holds the golf club in the right hand upward, and the baseball symbol individual holds the bat in the left hand upward. Therefore, these similarities caused the difficulty to the searchers in detecting the required symbol through the visual search processes, and consequently it produced slow search times with low accuracy. The target symbol looks like the non-target symbols. The distribution range of the golfing and baseball symbols, in search time and accuracy, is located in the long-time and high-accuracy sector with most of the backgrounds, even with the backgrounds that have simple characteristics; the distribution ranges of these symbols with the white background was spread from short and/or long time to low and/or high accuracy. These results agree with Treisman and Gelade (1980) and Treisman and Gormican (1988), who found that search for a target defined by a combination of features requires attention to detect the required target. Further, Christ (1975) and Teichner and Mocharnuk (1979) found that the time finding a target symbol increases linearly with increases in the local density and/or the global density.

Besides the tennis symbol, there were the archery and hiking symbols which worked best in search time and/or accuracy with some backgrounds. The reason was because these symbols had some characteristics that could distinguish them from one another.

Old Complex Geometric Symbol Group



This group includes five different complex geometric symbols (archery, golfing, hiking, tennis, and baseball). Each symbol was tested with one background or two. From the results it was found that golfing and hiking symbols worked best in terms of search time and accuracy with the backgrounds. The tennis and baseball symbols were found to be slow in time and low in accuracy.

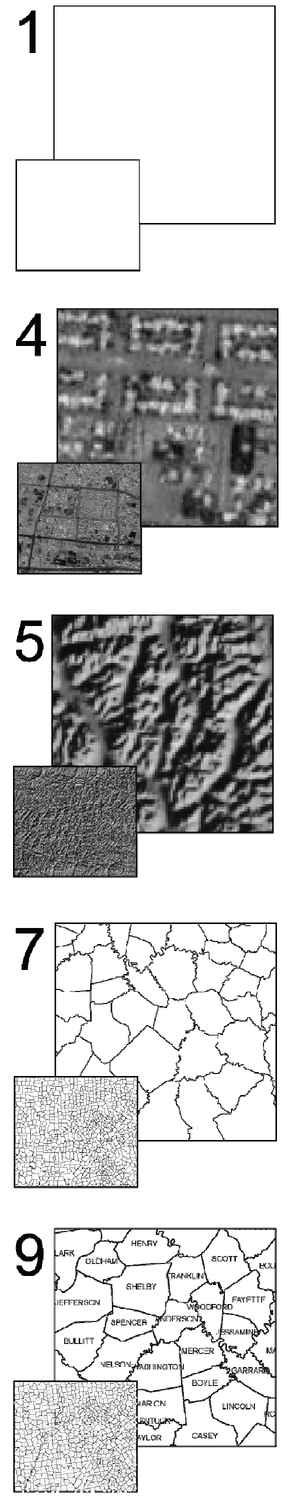
The reason that caused the golfing and hiking symbols to have this result was because the different characteristics of these symbols from the other symbols, which make the symbol pop out and allow the searchers to detect and discriminate this symbol faster and with more accuracy than the other symbols, because the target symbol looks different from the non-target symbols s. The golfing symbol was represented by circle that includes another circle and small dot, and the hiking symbol was represented by a circle than includes a big dot. Also, it is detectable that the distribution range of the golfing and hiking symbols, in search time and accuracy, is located in the short-time with high accuracy backgrounds.

On the other hand, the reason that caused the baseball symbol to have these results was the similarity in the characteristics of this symbol and the tennis symbol. Both symbols are represented by a circle, but the thickness of the circle for the tennis symbol was thicker than the baseball symbol. Therefore, these similarities caused the difficulty to the searchers in detecting the required symbol through the visual search processes, and as a result it created the slow search time with low accuracy, since the target symbol looks like the non-target symbols. Also, the baseball symbol was tested with the old imagery background which affected the performance of the baseball symbol in search time and accuracy. It was found beside the low accuracy of the baseball; there was the tennis that had a low accuracy, too, and the reason because of the similarity between the tennis symbol shape and the baseball symbol shape The distribution range of the baseball symbol, in the search time and accuracy, is diverse in its location in terms of time and accuracy.

The archery symbol was tested with two backgrounds, white and the shaded relief. The symbol was faster in the search time with the white background. The reason for this result is the complex characteristics of the shaded relief background and its impact on the visual search process. The mean accuracy was the same, so there was no difference between the mean accuracy of the symbol on the two backgrounds.

In addition, the golfing symbol was also tested with two backgrounds, the regular linear and the dense linear. There was no difference between the performance of the golfing symbol with the two backgrounds, in both search time and accuracy.

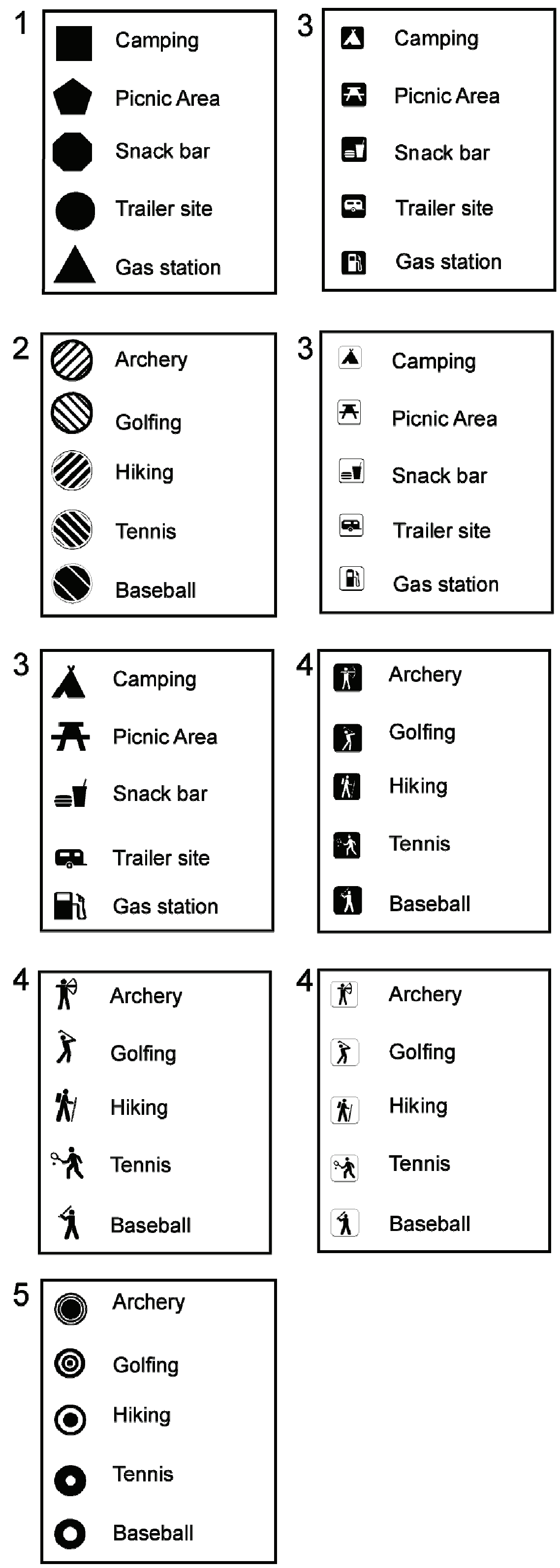
Chapter 10
GEOG 111: The Last Test



In light of the results of early tests, there was a need to design another test in order to test some hypotheses that were not tested in the original test. Additionally, test results suggested some additional ideas that, if added to the test, could yield new insights about the visual search process. These revisions included the creation and addition of a new background, the dense linear background with county names; changes to the design of SG2 and SG5 such as filling in the open space with white instead of making it transparent; and the surrounding some symbols with a box, either a white background with a black symbol or a white symbol on a black background. This test will examine the new background that was added; also it will examine the new changes that happened with the symbols.

This analysis consisted of multiple sections. The first section is the analysis of backgrounds that were tested with the five different symbol groups. The following five backgrounds (BK) were tested: white (BK1), revised aerial photo image (BK4), shaded relief

(BK5), dense linear patter (BK7), and dense linear with type (BK9). The second part of the analysis tested each symbol group with the five different types of backgrounds. Besides the five symbol groups (SG) that were tested with these five backgrounds: simple geometric (SG1), revised complex geometric (SG2), simple pictorial (SG3), complex pictorial (SG4), and initial complex geometric (SG5). There were in the third section analysis of newly designed symbols: symbols without boxes that were tested in the previous tests, white symbols in black boxes, and black symbols in white boxes. This section, will do different comparisons in order to find any enhancement in the performance task, whether in the time variable or in the accuracy.



Results of the Background Analysis

The background system was analyzed according to the two dependent variables: time and accuracy. Descriptive statistics for each variable are listed in Table 1. Tables 1 and 2 show the total number of the searches, the mean search times, and the standard deviation for each background type for time and accuracy, respectively. The mean search times for individual background varied from 19.12 to 28.20 seconds, and the standard deviations varied from 6.18 to 7.53.

Table 1. Descriptive Statistics for Search Time of the Five Different Backgrounds

Descriptives

		N	Mean	Std. Deviation	Std. Error	95% Confidence Interval for Mean		Minimum	Maximum
						Lower Bound	Upper Bound		
Time	White	66	19.12	6.186	.761	17.60	20.64	9	35
	New Imagery	88	26.17	8.137	.867	24.45	27.89	13	43
	Shaded Relief	88	28.20	7.893	.841	26.53	29.88	14	52
	Dense Linear	44	23.34	8.493	1.280	20.76	25.92	11	49
	Dense with type	110	25.24	7.537	.719	23.81	26.66	12	45
	Total	396	24.87	8.173	.411	24.07	25.68	9	52

Table 2. Descriptive Statistics for Search Accuracy of the Five Different Backgrounds

Descriptives

		N	Mean	Std. Deviation	Std. Error	95% Confidence Interval for Mean Lower Bound	95% Confidence Interval for Mean Upper Bound	Minimum	Maximum
Percent Correct	White	66	91.529	13.2779	1.6344	88.264	94.793	23.5	100.0
	New Imagery	88	84.594	15.7035	1.6740	81.267	87.921	14.3	100.0
	Shaded Relief	88	84.910	17.6143	1.8777	81.177	88.642	16.0	100.0
	Dense Linear	44	86.042	21.5203	3.2443	79.499	92.585	.0	100.0
	Dense with type	110	86.972	13.5145	1.2886	84.418	89.525	27.3	100.0
	Total	396	86.641	16.0668	.8074	85.054	88.229	.0	100.0

The analysis of variance shows significant differences in the mean search times among the backgrounds, F (4, 391) = 14.58, p < .001. However, there are no significant differences in the mean search accuracy among the backgrounds, F (4, 391) =2.193, p = .069 (Table 3).

Table. 3. Significant Differences of Backgrounds

ANOVA

		Sum of Squares	df	Mean Square	F	Sig.
Percent Correct	Between Groups	2236.954	4	559.238	2.193	.069
	Within Groups	99729.039	391	255.061		
	Total	101965.992	395			
Time	Between Groups	3426.154	4	856.539	14.586	.000
	Within Groups	22961.533	391	58.725		
	Total	26387.687	395			

The response time with BK 1 ($\bar{x}$ = 19.12, s = 6.18) was found to be significantly faster than with the other backgrounds. The *t* tests showed significant difference between BK1 and the other backgrounds (Table 4). Additionally, it shows that the response times with BK5 ($\bar{x}$ = 28.20, s =7.89) and BK4 ($\bar{x}$ =26.17, s = 8.13) are significantly slower than the other backgrounds. The *t* tests showed significant differences between BK5 and BK4 and the other backgrounds, indicating that participants achieved significantly slower search times in BK5 (shaded relief) and BK4 (imagery) than the other backgrounds (Table 4).

Table 4. *t* Tests for Equality of Means (Time) among Backgrounds

Independent Samples Test							
t-test for Equallity of Means (Time)							
Backgrounds	t	df	Sig. (2-tailed)	Mean Difference	Std. Error Difference	95% Confidence Interval of the Difference	
						Lower	Upper
BK4 * BK9	.836	196	.404	.934	1.117	-1.268	3.137
BK4 * BK5	-1.683	174	.094	-2.034	1.208	-4.419	.351
BK5 * BK9	2.696	196	.008	2.968	1.101	.797	5.139
BK7 * BK9	-1.359	152	.176	-1.895	1.395	-4.651	.860
BK1 * BK9	-5.561	174	.000	-6.115	1.100	-8.285	-3.945

Table 2 shows that the search accuracy for individual backgrounds varied from 84.59 to 91.52, and the standard deviation from 13.27 to 21.52. The analysis of variance showed no differences between the backgrounds in search accuracy (p = .069) (Table 3). The t tests of the mean search accuracy for each of the background types showed significant differences in search accuracy between BK1 ($\bar{x}$ = 91.53, s =13.27) and the other backgrounds. Participants had with this background higher accuracy than with other backgrounds (Table 5). BK4 ($\bar{x}$ = 84.59, s = 15.70), BK5 ($\bar{x}$ = 84.91, s = 17.61), BK7 ($\bar{x}$ = 86.04, s = 21.52), and BK9 ($\bar{x}$ = 86.97, s = 13.51) had significantly less accurate searches than BK1. The t tests showed no significant differences between BK4, BK5, BK7, and BK9, these with significantly slower search times in BK4, BK5, BK7, and BK9 than the other backgrounds (Table 5).

Table 5. *t* Test for Equality of Means (Accuracy) among Backgrounds

Independent Samples Test							
t-test for Equallity of Means (Accuracy)							
Backgrounds	t	df	Sig. (2-tailed)	Mean Difference	Std. Error Difference	95% Confidence Interval of the Difference	
						Lower	Upper
BK4 * BK9	-1.144	196	.254	-2.3776	2.0776	-6.4750	1.7198
BK4 * BK5	-.125	174	.900	-.3155	2.5156	-5.2804	4.6494
BK5 * BK9	-.932	196	.352	-2.0621	2.2124	-6.4252	2.3010
BK7 * BK9	-.322	152	.748	-.9294	2.8872	-6.6336	4.7749
BK1 * BK9	2.180	174	.031	4.5569	2.0905	.4309	8.6830

The Background Analysis

It would appear from the analyses, then, that BK1 performs best for the search task, both in terms of search time and accuracy. The fastest search time occurred with BK1 since the background is white and has no "noise" to affect the visual search (Table 6).

Moreover, the results are found that BK4 (imagery) and BK5 (shaded relief) were the slowest in the search time and accuracy. The result of BK5 was expected because of the complex characteristics of this background, and the same prediction was made about BK4, since it has a gray tone that causes low contrast between the symbols and the background. Noticeably, results in search time and accuracy showed that most of the four symbol groups have slower time and less accuracy with BK4 and BK5 than the other backgrounds (Table 6 and Table 7).

Table 6. Search Time of the Different Backgrounds and Symbol Groups

Time * Background * Symbol Group				
Time				
Background	Symbol Group	Mean	N	Std. Deviation
White	Simple Geometric	22.91	22	5.723
	Complex Geometric	14.86	22	4.443
	Simple Pictorial	19.59	22	5.629
	Total	19.12	66	6.186
New Imagery	Complex Geometric	30.36	22	5.038
	Simple Pictorial	20.41	22	3.446
	Complex Pictorial	34.5	22	5.672
	Old complex geometric	19.41	22	5.578
	Total	26.17	88	8.137
Shaded Relief	Complex Geometric	26.14	22	4.19
	Simple Pictorial	21.77	22	4.608
	Complex Pictorial	32.45	44	8.079
	Total	28.2	88	7.893
Dense Linear	Simple Geometric	17.41	22	4.182
	Complex Geometric	29.27	22	7.516
	Total	23.34	44	8.493
Dense with type	Simple Geometric	23.23	22	3.116
	Complex Geometric	27.32	22	5.702
	Simple Pictorial	22.59	22	5.696
	Complex Pictorial	35.09	22	5.911
	Old complex geometric	17.95	22	3.443
	Total	25.24	110	7.537

Table 7. Accuracy of the Different Backgrounds and Symbol Groups

Accuracy * Background * Symbol Group				
Accuracy				
Background	Symbol Group	Mean	N	Std. Deviation
White	Simple Geometric	85.561	22	17.7613
	Complex Geometric	97.045	22	7.9671
	Simple Pictorial	91.979	22	9.8674
	Total	91.529	66	13.2779
New Imagery	Complex Geometric	77.273	22	18.1138
	Simple Pictorial	89.899	22	12.6728
	Complex Pictorial	80.83	22	17.8843
	Old complex geometric	90.374	22	8.8087
	Total	84.594	88	15.7035
Shaded Relief	Complex Geometric	84.22	22	18.0489
	Simple Pictorial	97.129	22	4.7983
	Complex Pictorial	79.144	44	18.6213
	Total	84.91	88	17.6143
Dense Linear	Simple Geometric	93.802	22	8.0025
	Complex Geometric	78.283	22	27.5338
	Total	86.042	44	21.5203
Dense with type	Simple Geometric	91.414	22	9.9569
	Complex Geometric	79.545	22	17.5625
	Simple Pictorial	90.693	22	10.0186
	Complex Pictorial	78.947	22	13.9723
	Old complex geometric	94.258	22	5.3647
	Total	86.972	110	13.5145

Results of the Symbol Analysis

The symbol system was analyzed according to the two dependent variables: time and accuracy. Tables 8 and 9 show the total number of the searches, the mean search times, and the standard deviation of time and accuracy for each symbol group, respectively. As noted, participants were given four different symbol groups.

Table 8. Descriptive Statistics of Search Time for the Four Different Symbol Groups

Descriptives

		N	Mean	Std. Deviation	Std. Error	95% Confidence Interval for Mean		Minimum	Maximum
						Lower Bound	Upper Bound		
Time	Simple Geometric	66	21.18	5.159	.635	19.91	22.45	11	35
	Complex Geometric	110	25.59	7.775	.741	24.12	27.06	9	49
	Simple Pictorial	88	21.09	4.984	.531	20.03	22.15	12	36
	Complex Pictorial	88	33.62	7.063	.753	32.13	35.12	17	52
	Old complex geometric	44	18.68	4.639	.699	17.27	20.09	12	33
	Total	396	24.87	8.173	.411	24.07	25.68	9	52

Table 9. Descriptive Statistics of Search Accuracy for the Four Different Symbol Groups

Descriptives

		N	Mean	Std. Deviation	Std. Error	95% Confidence Interval for Mean		Minimum	Maximum
						Lower Bound	Upper Bound		
Percent Correct	Simple Geometric	66	90.259	12.9154	1.5898	87.084	93.434	23.5	100.0
	Complex Geometric	110	83.273	19.9311	1.9004	79.507	87.040	.0	100.0
	Simple Pictorial	88	92.425	10.0036	1.0664	90.305	94.544	44.4	100.0
	Complex Pictorial	88	79.517	17.2133	1.8349	75.869	83.164	35.3	100.0
	Old complex geometric	44	92.316	7.4705	1.1262	90.045	94.588	58.8	100.0
	Total	396	86.641	16.0668	.8074	85.054	88.229	.0	100.0

The analysis of variance shows significant differences in the mean search times among the backgrounds, F (4, 391) = 66.06, $p < .001$. Also, there are significant differences in the mean search accuracy among the backgrounds, F (4, 391) =11.74, $p < .001$ (Table 10).

Table 10. Significant Differences of Symbol Groups

ANOVA

		Sum of Squares	df	Mean Square	F	Sig.
Percent Correct	Between Groups	10939.306	4	2734.827	11.747	.000
	Within Groups	91026.686	391	232.805		
	Total	101965.992	395			
Time	Between Groups	10641.835	4	2660.459	66.064	.000
	Within Groups	15745.852	391	40.271		
	Total	26387.687	395			

The mean search times for individual symbol group varied from 18.68 to 33.63 seconds, and the standard deviation varies from 4.63 to 7.77 (Table 8). The response time of SG5 ($\bar{x}$ =18.68, s = 4.63) is significantly faster than the other symbol groups. The *t* test showed participants achieving significantly faster search time in SG5 than the other symbol groups, $p < .001$. Additionally, the response time of SG4 ($\bar{x}$ =33.63, s =7.06) was significantly slower than the other symbol groups, and the *t* test showed that the participants achieved significantly slower search time in SG 4 than the other symbol groups (Table 11).

Table 11. ***t*** **Test for equality of Means (Time) among Symbol Groups**

Independent Samples Test							
t-test for Equallity of Means (Time)							
Symbol Group	t	df	Sig. (2-tailed)	Mean Difference	Std. Error Difference	95% Confidence Interval of the Difference	
						Lower	Upper
SG3 * SG1	.110	152	.912	.091	.824	-1.537	1.719
SG1 * SG5	2.591	108	.011	2.500	.965	.587	4.413
SG5 * SG3	-2.678	130	.008	-2.409	.900	-4.189	-.629
SG2 * SG1	-4.096	174	.000	-4.409	1.077	-6.534	-2.284
SG2 * SG4	7.523	196	.000	8.034	1.068	5.928	10.140

The mean search accuracy for individual symbol groups varied from 79.51 to 92.42, and the standard deviation varied from 7.47 to 19.93 (Table 9). Since the *t* test showed no significant differences between SG3, SG5, and SG1 in the mean search accuracy, SG3 ($\bar{x}$ = 92.42, *s* = 10.00), SG5 ($\bar{x}$ = 92.31, *s* = 7.47), and SG1 ($\bar{x}$ = 90.25, *s* = 12.91), searches for these symbol groups were found to be significantly more accurate than searches for the other symbol groups. Additionally, a *t* test showed no significant differences between SG2 ($\bar{x}$ =83.27, *s* = 19.93), and SG 4 ($\bar{x}$ = 79.51, *s* = 17.21) in the mean search accuracy, so both groups were found significantly less accurately than the other symbol groups, and the *t* test showed that the participants achieved significantly less accuracy in searches for them than in searches for the other symbol groups (Table 12).

Table 12. ***t*** **Test for equality of Means (Time) among Symbol Groups**

Independent Samples Test							
t-test for Equallity of Means (Accuracy)							
Symbol Group	t	df	Sig. (2-tailed)	Mean Difference	Std. Error Difference	95% Confidence Interval of the Difference	
						Lower	Upper
SG3 * SG1	-1.173	152	.243	-2.1658	1.8466	-5.8142	1.4826
SG1 * SG5	-.955	108	.342	-2.0573	2.1551	-6.3290	2.2145
SG5 * SG3	-.064	130	.949	-.1085	1.7066	-3.4848	3.2678
SG2 * SG1	2.544	174	.012	6.9858	2.7465	1.5650	12.4066
SG2 * SG4	-1.399	196	.163	-3.7568	2.6850	-9.0519	1.5383

The Symbol Analysis

It would appear from the analyses, then, that SG5 performs best for the search task, both in terms of search time and accuracy. The fastest search time was not expected because the characteristic of SG5's design is complex and was expected to demand significant time in the visual search process. Results in the mean search time showed that searches for SG5 were achieved more quickly with the most of the backgrounds when compared to the other symbol groups (Table 6 and Table 7).

In addition, the results found that SG4 was slower in the search time than the other symbol groups, a result that was expected because of the complexity in SG4 design; additionally, all of the symbols look similar to each other, and those similarities contributed to this result. Additionally, results in the mean search time showed that symbols in SG4 were found more slowly than symbols in other symbol groups against most of the backgrounds (Table 6).

In addition, SG3, SG5, and SG1 were found to produce more accurate searches, because of the simplicity in the symbols' designs, especially those in SG3 and SG1. After symbols in SG5 were changed, searching for them quickly and with accuracy became much easier.

Moreover, the analysis found that SG2 and SG4 were found less accurately in searches against most of the backgrounds when compared to other symbol groups, a result that was expected because of the complexity in SG2 and SG4 design; additionally, all of the symbols look similar to each other. Specifically, SG2's design, which includes different orientations of the symbols, confused participants; so that some of the searchers counted symbols oriented both right and left as the same symbol.

Finally, results in the mean search accuracy showed that SG2 and SG4 had lower accuracy with most of the backgrounds when compared to the other symbol groups (Table 7).

Comparison between the performances of the new design of symbol

Table 13 shows the total number of the searches, the mean search times, and the standard deviation for symbols' design, no box, black-on-white, white-on-black, in time and accuracy, respectively. The response time results were: white-on-black ($\bar{x}$ = 24.32, s = 6.42), no box ($\bar{x}$ = 24.86, s = 8.36), and black-on-white ($\bar{x}$ = 25.29, s =8.44). Although the t-test showed no significant differences with no box, black-on-white, and white-on-black design in the mean search time (Table 14), it showed that the participants' performance with black-on-white ($\bar{x}$ = 89.97, s = 13.75) and no box

($\bar{x}$ = 85.41, s =16.95) were significantly different in the mean search accurate, t (350) = -2.037, p=.046 (Table 14).

Table 13. Descriptive Statistics of Time Search and Accuracy Search of Three Designs

Descriptives

		N	Mean	Std. Deviation	Std. Error	95% Confidence Interval for Mean		Minimum	Maximum
						Lower Bound	Upper Bound		
Time	No box	286	24.86	8.366	.495	23.89	25.84	9	52
	Black on white	66	25.29	8.449	1.040	23.21	27.36	12	43
	White on black	44	24.32	6.429	.969	22.36	26.27	14	43
	Total	396	24.87	8.173	.411	24.07	25.68	9	52
Percent Correct	No box	286	85.415	16.9548	1.0026	83.442	87.389	.0	100.0
	Black on white	66	89.979	13.7556	1.6932	86.598	93.361	47.8	100.0
	White on black	44	89.602	11.9968	1.8086	85.955	93.249	44.4	100.0
	Total	396	86.641	16.0668	.8074	85.054	88.229	.0	100.0

Table 14. *t* Tests for Equality of Means Time and Accuracy among Three Designs

Independent Samples Test

t-test for Equallity of Means (Time)

	t	df	Sig. (2-tailed)	Mean Difference	Std. Error Difference	95% Confidence Interval of the Difference	
						Lower	Upper
No box * White on black	.414	328	.679	.545	1.318	-2.047	3.138
No box * Black on White	-.371	350	.711	-.424	1.145	-2.675	1.827
White on black* Black on white	.646	108	.519	.970	1.500	-2.004	3.943

Independent Samples Test

t-test for Equallity of Means (Accuracy)

	t	df	Sig. (2-tailed)	Mean Difference	Std. Error Difference	95% Confidence Interval of the Difference	
						Lower	Upper
No box * White on black	-1.577	328	.116	-4.1865	2.6542	-9.4079	1.0350
No box * Black on White	-2.037	350	.042	-4.5639	2.2406	-8.9706	-.1571
White on black* Black on white	.148	108	.882	.3774	2.5464	-4.6701	5.4248

Also, the *t* tests showed no significant difference between no box ($\bar{x}$ = 85.41, *s* =16.95) and white-on-black (M=89.60%, SD=11.99%) in the mean search accuracy, *t* (328) = -1.577, *p* = 0.116, nor any significant difference between black-on-white ($\bar{x}$ = 89.97, *s* = 13.75) and white-on-black ($\bar{x}$ =89.60, *s* =11.99) in the mean search accuracy, *t* (108) = .148, *p* = 0.882. The analysis of variance shows no significant differences in the mean search times among the no box, black-on-white, and white-on-black design, F (2,393) =.186, p = 0.830. However, it shows significant differences in the mean search accuracy among no box, black-on-white, and white-on-black design, F (2, 393) =3.03, p = .049 (Table 15). These results indicate that the new design has no impact in the search time, as in the accuracy.

Table 15. Significant Differences of the Three Designs

ANOVA

		Sum of Squares	df	Mean Square	F	Sig.
Time	Between Groups	24.929	2	12.465	.186	.830
	Within Groups	26362.758	393	67.081		
	Total	26387.687	395			
Percent Correct	Between Groups	1550.838	2	775.419	3.035	.049
	Within Groups	100415.155	393	255.509		
	Total	101965.992	395			

In addition, there was comparison between the symbol with box and no box, and the results showed that the participants' performance with no box ($\bar{x}$ = 24.86, s = 8.36) and box ($\bar{x}$ =24.90, s =7.68) were not significantly different in the mean search time, t (394) =-.040, p = 0.968. However, there were significantly differences in the mean search accuracy, t (394) = -2.464, p= 0.014 (Tables 16 and Table 17).

Table 16. Descriptive Statistics of Time Search and Accuracy Search between no Box and Box

Descriptives

		N	Mean	Std. Deviation	Std. Error	95% Confidence Interval for Mean Lower Bound	95% Confidence Interval for Mean Upper Bound	Minimum	Maximum
Time	No box	286	24.86	8.366	.495	23.89	25.84	9	52
	box	110	24.90	7.688	.733	23.45	26.35	12	43
	Total	396	24.87	8.173	.411	24.07	25.68	9	52
Percent Correct	No box	286	85.415	16.9548	1.0026	83.442	87.389	.0	100.0
	box	110	89.828	13.0249	1.2419	87.367	92.290	44.4	100.0
	Total	396	86.641	16.0668	.8074	85.054	88.229	.0	100.0

Table 17. *t* Tests for Equality of Means Time and Accuracy between no Box and Box

Independent Samples Test

t-test for Equallity of Means (Time and Accuracy)

No box * Box	t	df	Sig. (2-tailed)	Mean Difference	Std. Error Difference	95% Confidence Interval of the Difference Lower	95% Confidence Interval of the Difference Upper
Time	-.040	394	.968	-.036	.918	-1.841	1.769
Accuracy	-2.464	394	.014	-4.4129	1.7911	-7.9343	-.8915

Finally, the accuracy and speed of locating a specific symbol from a symbol set (in this case, the archery symbol from the complex pictorial symbol group) against a specific background (in this case, shaded relief) was analyzed. In one test, the symbol was tested with no box, and another time, it was tested as a white-on-black design. The results for that appear in Table 18, which indicated that the response time with white-on-black ($\bar{x}$ = 28.23, s =6.38) was found to be significantly shorter than a search for the archery symbol with no box ($\bar{x}$ = 36.68, s =7.44).

Table 18. Descriptive Statistics of the Archery Symbol in Time Search and Accuracy Search between no Box and White on Black

Descriptives-Archery only

		N	Mean	Std. Deviation	Std. Error	95% Confidence Interval for Mean		Minimum	Maximum
						Lower Bound	Upper Bound		
Time	No box	22	36.68	7.448	1.588	33.38	39.98	21	52
	White on black	22	28.23	6.384	1.361	25.40	31.06	20	43
	Total	44	32.45	8.079	1.218	30.00	34.91	20	52
Percent Correct	No box	22	68.984	18.9684	4.0441	60.574	77.394	35.3	94.1
	White on black	22	89.305	11.5721	2.4672	84.174	94.436	58.8	100.0
	Total	44	79.144	18.6213	2.8073	73.483	84.806	35.3	100.0

The analysis of variance shows significant differences in the mean search times between the no box, and white-on-black design, $F\ (1, 42) = 16.343$, $p < .001$, a result similar to the results for search accuracy $F\ (1, 42) = 18.40$, $p <.001$ (Table 19). Additionally, the *t* tests showed significant difference between the symbol with white-on-black design and the symbol with no box in the mean search time, $t\ (42) = 4.043$, $p <.001$ and in the mean accuracy search time, $t\ (42) = -4.290$, $p < .001$ (Table 20).

Table 19. Significant Differences of the Archery Symbol in Time Search and Accuracy Search between no Box and White on Black

ANOVA

		Sum of Squares	df	Mean Square	F	Sig.
Time	Between Groups	786.273	1	786.273	16.343	.000
	Within Groups	2020.636	42	48.110		
	Total	2806.909	43			
Percent Correct	Between Groups	4542.309	1	4542.309	18.400	.000
	Within Groups	10368.040	42	246.858		
	Total	14910.349	43			

Table 20. *t* Tests for Equality of Means Time and Accuracy for the Archery Symbol between no Box and White on Black

Independent Samples Test

		t-test for Equality of Means						
		t	df	Sig. (2-tailed)	Mean Difference	Std. Error Difference	95% Confidence Interval of the Difference Lower	Upper
Time	Equal variances assumed	4.043	42	.000	8.455	2.091	4.234	12.67
	Equal variances not assumed	4.043	41.041	.000	8.455	2.091	4.231	12.67
Percent Correct	Equal variances assumed	-4.290	42	.000	-20.3209	4.7373	-29.8810	10.76
	Equal variances not assumed	-4.290	34.730	.000	-20.3209	4.7373	-29.9407	10.70

GEOG 111: Comparison between the first test and the last test

This section will compare the first test's results and the last test's results for GEOG 111 participants in order to discover if students' visual search performance changes, whether positively or negatively, over the course of the two tests. The following compares different variables of the task performance that were previously analyzed. Search time and search accuracy using various backgrounds and symbols will be analyzed.

Results of the Time and Accuracy

Tables 21 and 22 show the total number of searches, the mean search times, and the standard deviation for each group of test (first test, last test) in time and accuracy, respectively. The response time with first test group ($\bar{x}$= 21.42, s = 0.316) was found to be significantly faster than the last test group ($\bar{x}$= 24.87, s = 0.411). Additionally, the response accuracy with the first test group ($\bar{x}$= 91.40, s = 11.87), was found to be higher than the last test group ($\bar{x}$ = 16.07, s = 0.81).

Table 21. Descriptive Statistics of Search Time for the First Test and Last Test

Group Statistics					
	group	N	Mean	Std. Deviation	Std. Error Mean
Time	First Test	536	21.42	7.31	0.316
	Last Test	396	24.87	8.173	0.411

Table 22. Descriptive Statistics of Search Accuracy for the First Test and Last Test

Group Statistics					
	group	N	Mean	Std. Deviation	Std. Error Mean
%Correct	First Test	536	91.40%	11.87%	0.51%
	Last Test	396	86.64%	16.07%	0.81%

The *t* test showed significant difference in the mean search time and accuracy between the first group and last group, $p < .001$ (Table 23 and Table 24).

Table 23. *t* Test for Equality of Means (Time) between the First Test and Last test

Independent Samples Test								
		t-test for Equality of Means						
							95% Confidence Interval of the Difference	
		t	df	Sig. (2-tailed)	Mean Difference	Std. Error Difference	Lower	Upper
Time	Equal variances assumed	-6.779	930	0	-3.454	0.509	-4.454	-2.454
	Equal variances not assumed	-6.667	794.86	0	-3.454	0.518	-4.471	-2.437

Table 24. *t* Test for Equality of Means (Accuracy) between the First Test and Last Test

Independent Samples Test								
		t-test for Equality of Means						
							95% Confidence Interval of the Difference	
		t	df	Sig. (2-tailed)	Mean Difference	Std. Error Difference	Lower	Upper
%Correct	Equal variances assumed	5.2	930	0	4.76%	0.91%	2.96%	6.55%
	Equal variances not assumed	4.975	694.316	0	4.76%	0.96%	2.88%	6.64%

The Time and Accuracy Analysis

These results demonstrate that the first test yielded faster and more accurate searches than the last test. Variables that may have affected these results include changes in background between the first and last test, new symbol design, and reduction in the symbol size. These changes were discussed in previous analyses.

The Background Analysis

The background system was analyzed according to the two dependent variables: time and accuracy. Since not all the backgrounds were used in both the first and last tests, only those backgrounds used in both tests were analyzed for differences in participants' time and accuracy. The matched backgrounds that were tested in both tests are white background (BK1) and shaded relief (BK5). Descriptive statistics for each variable that was tested with the white background are listed in Table 25. Table 25 show the total number of searches, the mean search times, and the standard deviation for the white background BK1 for time and accuracy, respectively. The response times with first test group ($\bar{x}$= 18.86, s = 6.41) and the last test group ($\bar{x}$= 19.12, s = 6.18) are not significantly different from each other. The response accuracy with first test group ($\bar{x}$= 92.65, s = 9.34) and the last test group ($\bar{x}$= 91.53, s = 13.28) are not significantly different from each other. The *t* test showed no significant difference between the first test group and the last test group in the mean search time and accuracy for BK1 (Table 25 and Table 26).

Table 25. Descriptive statistics of Search Accuracy of the White Background that was tested in the both Tests, First and Last test

Group Statistics[a]

	group	N	Mean	Std. Deviation	Std. Error Mean
Time	First Test	228	18.86	6.411	0.425
	Last	66	19.12	6.186	0.761
%Correct	First Test	228	92.65%	9.34%	0.62%
	Last	66	91.53%	13.28%	1.63%

Table 26. *t* Test for Equality of Means Time and Accuracy of the White Background that was Tested in the both Tests, First and Last Test

Independent Samples Test[a]								
		t-test for Equality of Means						
							95% Confidence Interval of the Difference	
		t	df	Sig. (2-tailed)	Mean Difference	Std. Error Difference	Lower	Upper
Time	Equal variances assumed	-0.289	292	0.773	-0.257	0.889	-2.007	1.493
	Equal variances not assumed	-0.295	108.703	0.769	-0.257	0.872	-1.985	1.471
%Correct	Equal variances assumed	0.778	292	0.437	1.12%	1.45%	-1.72%	3.97%
	Equal variances not assumed	0.644	84.461	0.521	1.12%	1.75%	-2.35%	4.60%

Table 27 shows the descriptive statistics for each test group that was tested with the shaded relief background. Table 27 shows the total number of searches, the mean search times, and the standard deviation for the shaded relief BK5 for time and accuracy, respectively. The response times with first test group ($\bar{x}$= 26.85, s = 7.56) and the last test group ($\bar{x}$=28.2, s = 7.56) are not significantly different from each other. The response accuracy with first test group ($\bar{x}$= 85.15, s = 18.08) and the last test group ($\bar{x}$= 48.91, s = 17.61) are not significantly different from each other. The *t* tests showed no significant difference between the first test group and the last test group in mean search time and accuracy (Table 27 and Table 28).

Table 27. Descriptive Statistic of Search Time and Accuracy of the Shaded Relief Background that was Tested in the Both Tests, First and Last test

Group Statistics[a]

	group	N	Mean	Std. Deviation	Std. Error Mean
Time	First Test	81	26.85	7.563	0.84
	Last	88	28.2	7.893	0.841
%Correct	First Test	81	85.15%	18.08%	2.01%
	Last	88	84.91%	17.61%	1.88%

Table 28. *t* Tests for Equality of Means Time and Accuracy of the Shaded Relief Background that was Tested in the both Tests, First and Last Test

Independent Samples Test[a]								
		t-test for Equality of Means						
							95% Confidence Interval of the Difference	
		t	df	Sig. (2-tailed)	Mean Difference	Std. Error Difference	Lower	Upper
Time	Equal variances assumed	-1.135	167	0.258	-1.353	1.191	-3.705	0.999
	Equal variances not assumed	-1.137	166.724	0.257	-1.353	1.189	-3.701	0.995
%Correct	Equal variances assumed	0.087	167	0.931	0.24%	2.75%	-5.18%	5.66%
	Equal variances not assumed	0.087	165.019	0.931	0.24%	2.75%	-5.19%	5.67%

The Background Analysis

It would appear from the analyses, then, that the participants' performance on the first test group and last test group was the same for the search task, both in terms of search time and accuracy, in searches against BK1. This result was expected because BK1 has no noise to affect the visual search process. Consequently, the contrast between the symbol and the background is very strong, and the symbols stand out against the background and were easy to locate in both tests. Although the last test group was tested with symbols that were boxed, the use of boxes did not change participants' performance, either in terms of accuracy or time. This suggests that the simplicity of BK1 makes searches fast and accurate regardless of the complexity of the symbols being located on the background.

On the other hand, the participants' consistent performance in the first test group and last test group with BK 5 was not expected. Changes made in the design of the symbol were anticipated to produce different results in search time and accuracy between the first and last tests. For example, some symbols were white symbols in black boxes while others were black symbols in white boxes. It seems that these new designs in the symbols did not enhance the participant's accuracy or search time. So, both symbols that were in boxes or without boxes produced the same performance in time and accuracy with the shaded relief background. This similarity indicates that the complexity of the background.

The Symbol Analysis

The symbol system was analyzed according to the two dependent variables: time and accuracy. The results of only those symbols groups used in both tests were compared. These were simple geometric symbol group (SG1), initial complex geometric symbol group (SG5), simple pictorial symbol group (SG3), and simple pictorial symbol group (SG4). Not included in the comparison the initial complex geometric symbol group (SG5) and revised complex geometric symbol group (SG2) since these groups did not appear in both tests.

Descriptive statistics for each test group that was tested with SG1 are listed in Table 29. Table 29 shows the total number of searches, the mean search times, and the standard deviation for SG1 for time and accuracy, respectively. The response times with first test group ($\bar{x}$ = 22.01, s = 5.96) and the last test group ($\bar{x}$= 21.18, s = 5.15) are not significantly different from each other. The response accuracy with first test group ($\bar{x}$= 93.12, s = 7.91) and the last test group ($\bar{x}$= 90.26, s =12.92) are not significantly different from each other. The t test showed no significant difference between the first test group and the last test group in the mean search time and accuracy (Table 29 and Table 30).

Table 29. Descriptive Statistics of Search Time and Accuracy of the Simple Geometric Symbol Group SG 1 that was Tested in the both Tests, First and Last Test.

Group Statistics[a]

	group	N	Mean	Std. Deviation	Std. Error Mean
Time	First Test	128	22.01	5.964	0.527
	Last	66	21.18	5.159	0.635
%Correct	First Test	128	93.12%	7.91%	0.70%
	Last	66	90.26%	12.92%	1.59%

Table 30. *t* Tests for Equality of Means Time and Accuracy of the Simple Geometric Symbol Group SG 1 that was Tested in the both Tests, First and Last Test.

Independent Samples Test[a]

		t-test for Equality of Means						
		t	df	Sig. (2-tailed)	Mean Difference	Std. Error Difference	95% Confidence Interval of the Difference Lower	Upper
Time	Equal variances assumed	0.956	192	0.34	0.826	0.864	-0.879	2.531
	Equal variances not assumed	1.001	149.191	0.319	0.826	0.825	-0.805	2.457
%Correct	Equal variances assumed	1.907	192	0.058	2.86%	1.50%	0.10%	5.81%
	Equal variances not assumed	1.646	90.806	0.103	2.86%	1.74%	0.59%	6.31%

Additionally, a comparison between the symbols used in the both tests discovered the difference between the performances of these symbols. The symbol that was tested in the both tests with the same background was the symbol for picnic area symbol, which is a simple geometric without a box symbol tested against the white background (BK1). A comparison between the performance of this symbol in both tests using a *t* test showed no significant difference between the symbol of the picnic area that was tested in the first test ($\bar{x}$ = 21.18, s = 5.52) and the picnic area that was tested in the last test ($\bar{x}$ = 22.91, s = 5.72) in the mean search time, Additionally, there was no significant difference between the symbol of the picnic area that was tested in the first test ($\bar{x}$ = 89.54, s =11.50), and the picnic area that was tested in the last test ($\bar{x}$= 85.56, s = 17.76) in mean search accuracy (Table 31 and Table 32).

Table 31. Descriptive Statistics of Search Time and Accuracy of the Simple Geometric Symbol (Picnic Area) that was Tested in the both Tests, First and Last Test

Group Statistics					
	group	N	Mean	Std. Deviation	Std. Error Mean
Time	First Test	11	21.18	5.528	1.667
	Last	22	22.91	5.723	1.220
%Correct	First Test	11	89.5455%	11.50099%	3.46768%
	Last	22	85.5615%	17.76128%	3.78672%

Table 32. *t* Tests for Equality of Means Time and Accuracy of the Simple Geometric Symbol (Picnic Area) that was Tested in the both Tests, First and Last test

Independent Samples Test								
		t-test for Equality of Means						
		t	df	Sig. (2-tailed)	Mean Difference	Std. Error Difference	95% Confidence Interval of the Difference	
							Lower	Upper
Time	Equal variances assumed	-.82	31	.415	-1.727	2.090	-5.991	2.536
	Equal variances not assumed	-.83	20.751	.413	-1.727	2.066	-6.026	2.572
%Correct	Equal variances assumed	.67	31	.505	3.98396%	5.91265%	-8.074%	16.042%
	Equal variances not assumed	.77	28.662	.444	3.98396%	5.13459%	-6.522%	14.490%

Table 33 shows the descriptive statistics for each test group that was tested with SG 5. Table 33 shows the total number of searches, the mean search times, and the standard deviation for SG 5 for time and accuracy, respectively. The response times with first test group ($\bar{x}$ = 19.87, s = 6.34) and the last test group ($\bar{x}$=18.68, s =

4.63) are not significantly different from each other. The response accuracy with first test group ($\bar{x}$ = 92.61, s = 12.11) and the last test group ($\bar{x}$ = 92.32, s = 7.47) are not significantly different from each other. The t test showed no significant difference between the first test group and the last test group in the mean search time and accuracy (Table 33 and Table 34).

Table 33. Descriptive Statistics of Search Time and Accuracy of the Old Complex Geometric Symbol Group SG 5 that was Tested in the both Tests, First and Last Test

Group Statistics[a]					
	group	N	Mean	Std. Deviation	Std. Error Mean
Time	First Test	142	19.87	6.343	0.532
	Last	44	18.68	4.639	0.699
%Correct	First Test	142	92.61%	12.11%	1.02%
	Last	44	92.32%	7.47%	1.13%

Table 34. *t* Test for Equality of Means Time and Accuracy of the Old Complex Geometric Symbol Group SG 5 that was Tested in the both Tests, First and Last test

Independent Samples Test								
		t-test for Equality of Means						
		t	df	Sig. (2-tailed)	Mean Difference	Std. Error Difference	95% Confidence Interval of the Difference Lower	Upper
Time	Equal variances assumed	1.146	184	.253	1.184	1.033	-.854	3.223
	Equal variances not assumed	1.348	97.279	.181	1.184	.879	-.560	2.929
%Correct	Equal variances assumed	.150	184	.881	.28928%	1.93263%	3.5236%	4.10224%
	Equal variances not assumed	.191	117.755	.849	.28928%	1.51708%	-2.715%	3.29358%

Table 35 shows the descriptive statistics for each test group that was tested with SG2, which was used in the last test, and SG5, which was used in the first test. Table 15 shows the total number of searches, the mean search times, and the standard deviation for SG 2 and SG 5 for time and accuracy, respectively. The response times with first test group that tested with SG5 ($\bar{x}$=19.87, s = 6.34) was found to be significantly faster than the last test group that tested with SG2 ($\bar{x}$ = 25.59, s = 7.77). Therefore, the *t* test showed significant difference between the first test group and the last test group in the mean search time. The response accuracy with first test group that tested with SG5 ($\bar{x}$= 92.60, s = 12.11) was found to be significantly more accurate than the last test group that tested with SG2 ($\bar{x}$= 83.27, s = 19.93). The t test showed significant difference between the first test group and the last test group in the mean search accuracy, $p < .001$ (Table 35 and Table 36).

Table 35. Descriptive Statistics of Search Time and Accuracy between the Old complex geometric symbol group SG 5 that was Tested in the First Test and the New complex geometric symbol group SG 2 that was tested in the Last Test

Group Statistics[a]

	group	N	Mean	Std. Deviation	Std. Error Mean
Time	First Test-SG 5	142	19.87	6.343	.532
	Last Test- SG 2	110	25.59	7.775	.741
%Correct	First Test	142	92.6056%	12.11233%	1.01644%
	Last	110	83.2733%	19.93112%	1.90036%

Table 36. *t* Test for Equality of Means Time and Accuracy between the Old Complex Geometric Symbol Group SG 5 that was Tested in the First Test and the New Complex Geometric Symbol Group SG 2 that was Tested in the Last Test

Independent Samples Test[a]

		t-test for Equality of Means						
		t	df	Sig. (2-tailed)	Mean Difference	Std. Error Difference	95% Confidence Interval of the Difference: Lower	Upper
Time	Equal variances assumed	-6.436	250	.000	-5.725	.890	-7.477	-3.973
	Equal variances not assumed	-6.273	207.691	.000	-5.725	.913	-7.524	-3.926
% Correct	Equal variances assumed	4.593	250	.000	9.33232%	2.03204%	5.33022%	13.334%
	Equal variances not assumed	4.330	169.560	.000	9.33232%	2.15511%	5.07801%	13.586%

Table 37 shows the descriptive statistics for each test group that was tested with SG3. Table 37 shows the total number of searches, the mean search times, and the standard deviation for SG3 for time and accuracy, respectively. The response times with first test group ($\bar{x}$ = 17.8, s = 5.48) was found to be significantly faster than the last test group ($\bar{x}$ = 21.09, s = 4.98). Therefore, the t test showed significant difference between the first test group and the last test group in the mean search time. The response accuracy with the first test group ($\bar{x}$= 93.31, s = 8.83) and the last test group ($\bar{x}$ = 92.42, s = 10.00) was not significantly different from each other. The t test showed no significant difference between the first test group and the last test group in the mean search accuracy (Table 37 and Table 38).

Table 37. Descriptive statistics of Search Time and Accuracy of the Simple Pictorial Symbol Group SG 3 that was Tested in the both Tests, First and Last Test

Group Statistics[a]					
	group	N	Mean	Std. Deviation	Std. Error Mean
Time	First Test	137	17.8	5.485	0.469
	Last	88	21.09	4.984	0.531
%Correct	First Test	137	93.31%	8.83%	0.75%
	Last	88	92.42%	10.00%	1.07%

Table 38. Table of *t* Test for Equality of Means Time and Accuracy of the Simple Pictorial Symbol Group SG 3 that was Tested in the both Tests, First and Last Test

Independent Samples Test[a]								
		t-test for Equality of Means						
		t	df	Sig. (2-tailed)	Mean Difference	Std. Error Difference	95% Confidence Interval of the Difference	
							Lower	Upper
Time	Equal variances assumed	-4.555	223	0	-3.295	0.723	-4.721	-1.87
	Equal variances not assumed	-4.651	198.266	0	-3.295	0.708	-4.692	-1.898
%Correct	Equal variances assumed	0.699	223	0.485	0.89%	1.27%	-1.62%	3.39%
	Equal variances not assumed	0.681	168.833	0.497	0.89%	1.31%	-1.69%	3.47%

Additionally, a comparison between similar symbols used in the both tests revealed no differences between the performances of these symbols in the tests. A comparison was made between the simple pictorial picnic symbol tested on the white background, which was tested in the first test, and the simple pictorial picnic symbol surrounded by a white box, which was tested in the last test. The results of the *t* test showed no significant difference between the symbol of the picnic area that was tested in the first test ($\bar{x}$ = 16.91, s = 3.17), and the picnic area symbol that was tested in the last test ($\bar{x}$ = 19.59, s =5.62) in the mean search time, Additionally, there was no significant difference between the symbol of the picnic area that was tested in the first test ($\bar{x}$ = 90.45, s = 9.60), and the picnic area that was tested in the last test ($\bar{x}$= 91.97, s = 9.86) in mean search accuracy (Table 39 and Table 40).

Table 39. Descriptive Statistics of Search Time and Accuracy of the Simple Pictorial Symbol (Picnic Area) that was tested in the both Tests, First and Last Test

Group Statistics					
	group	N	Mean	Std. Deviation	Std. Error Mean
Time	First Test-Symbol without box	11	16.91	3.177	.958
	Last Test-Symbol with box	22	19.59	5.629	1.200
%Correct	First Test-Symbol without box	11	90.4545%	9.60587%	2.89628%
	Last Test-Symbol with box	22	91.9786%	9.86738%	2.10373%

Table 40. Table of *t* Test for Equality of Means Time and Accuracy of the Simple Pictorial Symbol (Picnic area) that was Tested in the both Test, First and Last Test

Independent Samples Test								
		t-test for Equality of Means						
		t	df	Sig. (2-tailed)	Mean Difference	Std. Error Difference	95% Confidence Interval of the Difference	
							Lower	Upper
Time	Equal variances assumed	-1.46	31	.154	-2.682	1.836	-6.426	1.063
	Equal variances not assumed	-1.74	30.384	.091	-2.682	1.535	-5.816	.452
%Correct	Equal variances assumed	-.422	31	.676	-1.5240%	3.61290%	-8.892%	5.84450%
	Equal variances not assumed	-.426	20.604	.675	-1.5240%	3.57968%	-8.977%	5.92900%

Table 41 shows the descriptive statistics for each test group that was tested with SG4. Table 41 shows the total number of searches, the mean search times, and the standard deviation for SG4 for time and accuracy, respectively. The response times with first test group ($\bar{x}$= 26.4, s = 8.35) was found to be significantly faster than the response times with the last test group ($\bar{x}$ = 33.62, s = 7.06). Therefore, the *t* test showed significant difference between the first test group and the last test group in the mean search time. The response accuracy with the first test group ($\bar{x}$ = 86.33, s = 15.74) was found to be significantly more accurate than with the last test group ($\bar{x}$

= 79.52, *s* =17.21). The *t* test showed significant difference between the first test group and the last test group in the mean search accuracy (Table 41 and Table 42).

Table 41. Descriptive Statistic of Search Time and Accuracy of the of the Complex Pictorial Symbol Group that was Tested in the both Test, First and Last Test

Group Statistics[a]					
	group	N	Mean	Std. Deviation	Std. Error Mean
Time	First Test	129	26.4	8.351	0.735
	Last	88	33.62	7.063	0.753
%Correct	First Test	129	86.33%	15.74%	1.39%
	Last	88	79.52%	17.21%	1.83%

Table 42. *t* Test for Equality of Means Time and Accuracy of the Complex Pictorial Symbol Group that was Tested in the both Test, First and Last test

Independent Samples Test[a]								
		t-test for Equality of Means						
							95% Confidence Interval of the Difference	
		t	df	Sig. (2-tailed)	Mean Difference	Std. Error Difference	Lower	Upper
Time	Equal variances assumed	-6.657	215	0	-7.23	1.086	-9.37	-5.089
	Equal variances not assumed	-6.87	205.205	0	-7.23	1.052	-9.305	-5.155
%Correct	Equal variances assumed	3.015	215	0.003	6.82%	2.26%	2.36%	11.27%
	Equal variances not assumed	2.964	175.718	0.003	6.82%	2.30%	2.28%	11.36%

The Symbol Analysis

It would appear from the analyses, then, that the performances of the participants with SG1 were found not to be significantly different between the first test group and the last test group in terms of search time and accuracy, indicating no difference in the visual search process, despite the difference in size of the symbols in each test; the symbols were large in the first test and small in the second. However, there was no significant difference in the results of the two tests. Therefore the size variable had no impact on the participants' performance. Moreover, the result that showed no significant differences in mean search time or accuracy between the picnic area symbols that were tested in both tests, again indicating that, in the case of the simple geometric picnic symbol, the size factor does not affect the task performance.

In addition, the results found that the performance of the participants in both terms of search time and accuracy with SG5 was similar between the first test and last test. This result indicates that the changes to SG5 did not modify the participants' performances. Therefore, their results in the both tests were similar.

The results of the comparison of the participant's performance in time and accuracy in searches for symbols in SG5 and SG2 were expected because the complex of SG2 design which lead to these results.

The significant differences in participant searches for SG3, which were faster with the first test group than with the last test group, might be due to the revisions to SG3. Since some symbols in SG3 changed in from the initial test, those changes could affect in the results; see the previous analyses for a discussion of those changes.

Also, the *t* test found no significant difference in the performance of participants in searches for SG3 in terms of accuracy, and that means the performance of the participants in the accuracy are the same despite changes in the symbol design. Also, the *t* test found no significant differences in time or accuracy in searches for boxed and unboxed symbols between the first and last test. It demonstrated that the new design of the symbols had no effect in the visual search with this kind of symbol or with the type of the background against which the symbol was placed.

Moreover, the results found searches for SG4 to be faster and more accurate in the first test group than the last test group. This result could be because the symbols of SG4 that were tested in the first test were revised in the last test. Thus, these revised symbols were new to them and were more complex than the first design and slowed their search and made it less accurate.

Chapter Eleven

Conclusion

The hypotheses framed in chapter one of this study represented expectations of certain visual search outcomes for the various combinations of point symbols and map backgrounds tested. They are repeated below for ease of reference. The test results were analyzed and discussed in detail in chapters four through ten. This concluding overview summarizes the findings and discusses their implications for map design. It also points out further questions arising from the results. By combining these questions raised with additional questions about other significant aspects of visual search that fell beyond the scope of this study, it is possible to make recommendations for further research into visual search for point symbols on maps.

Expectations

The hypotheses from chapter one are repeated here:

1. Pictorial symbols are generally recognized faster and more accurately than geometric symbols.
2. Simple point symbols are easier to identify than complex point symbols.
3. Very different point symbol shapes are easier to discriminate than similar point symbol shapes.
4. Point symbols differing in only one graphic characteristic are easier to discriminate (by parallel search) than point symbols differing in two or more graphic characteristics (requiring serial search).

5. The more contrast in value (lightness and darkness) between point symbols and map background, the easier will be visual search for point symbols.

6. The less texture in the map background, the easier visual search for point symbols will be.

Findings

The test results have not shown hypothesis one to be true, at least not in this instance. The simple pictorial and simple geometric symbols were comparably fast and accurate to search, while the complex pictorial and new complex geometric symbols were similarly slower and/or inaccurate. Instead, this result indicates that hypothesis two is correct and that simplicity versus complexity of shape is an important factor here.

However, simplicity versus complexity is almost certainly not the only factor. Within the simple pictorial and simple geometric groups, some symbols performed better than others. Those symbols which performed better, such as the triangle, square, circle, and snack bar, were more distinctive in shape, indicating that hypothesis three is also true.

The good test results for the old complex geometric symbols indicate that yet another factor was at play. While the nested circular symbols were relatively complex in design, the Gestalt phenomenon meant that the eye of the viewer assembled their parts into good figures, that is, simpler and stronger shapes that were perceived as/more fast and accurately as the simple geometric and simple pictorial symbols. This result did not figure in the original list of hypotheses, although graphic characteristics contributing to Gestalt perception were discussed in the chapter two literature review,.

The results for the new complex geometric and the complex pictorial symbols indicate that hypothesis 4 was also true. The new complex geometric symbols varied in both spacing of the diagonal line pattern fill and orientation, thus resulting in slower, less accurate serial search. With the complex pictorial symbols, the two variables were the positions of the figures involved in sport activities and the distinctive shape of the sports equipment they were using. Both were characteristic of the sports being pursued, but the differences lay in small graphic details and also required serial search.

In line with hypotheses five and six, results for value and texture contrast for backgrounds do indicate that a minimal white background, which has maximal contrast with the black symbols, performs well. At the other end of the contrast scale, the medium to dark gray highly textured imagery and relief shading backgrounds were somewhat slower and less accurate. However, the linear backgrounds performed relatively better than expected, suggesting that noise outside the figure may have less negative impact on visual search than expected, as long as there is sufficient tonal contrast. Several imagery backgrounds employed during earlier testing also performed better than expected, suggesting that the eye tends to blend or ignore textures with limited tonal range or that recur in a systematic pattern.

However, background texture did have a marked effect on visual search when the point symbols were transparent, so the background showed through the interior portions of the point symbol that were not black. This occurred with both the old and new complex geometric symbols, which performed less well when the symbols were transparent. This result was not predicted in the original hypotheses, although the lower tonal contrast of transparent symbols with the background must have been a factor. This conclusion is supported by the test results, which showed that opaque versions of the same symbols with white interiors performed better. A similar heightened contrast effect was also noted when some symbols, tested both enclosed in black-outline squares with white interiors and plain without enclosure, performed better when set off within the square.

Another finding was that differences in orientation of line-pattern fill within symbols were hard for participants to discriminate. Although not included in the original hypotheses, the fact that orientation is less satisfactory for conveying information than other visual variables was noted in the chapter two literature review. The review of literature also mentioned findings that information presented within a symbol is harder to process than information presented at its exterior.

Other findings not addressed in the hypotheses included the individual and group performance of the participants. Group testing proved to be satisfactory, although not as accurate in time recording as more time-intensive individual testing would have been. However, the test design had to be adjusted to minimize errors. During the initial iteration of testing misidentifications indicated that participants were confused by the legend in the margin including all five symbols and identifying the target symbol by an arrow. Later iterations reduced this type of error by showing only the target symbol in the margin. Participants also had difficulty remembering and recording both their time and target symbol count at the end of the test, so the instructions were amended to make these tasks simpler.

Implications for Map Design

The results of this study indicate that point symbols, whether geometric or pictorial, should have graphic characteristics which make them as distinctive as possible. Orientation should be avoided, but shape works well as a graphic characteristic, if designed right. When designing point symbols, the choice should be for simplicity over perceptually hard-to-process complexity. Large prominent shape characteristics are more distinctive than minute details.

While map context is important for conveying geographical location, perceptually speaking, less is more. That is, less contextual noise will allow the point symbols to stand out from the background and communicate more effectively. The map background should be as simple as possible, and it should also contrast tonally as much as possible with the point symbols. If less-than-ideal symbol-background value contrast is unavoidable, enclosing the dark point symbols in black outlines with white fill is an effective graphic device to enhance symbol visibility.

Directions for Further Research

This study, which dealt with selected map symbol and background designs, could be expanded by further research into questions raised by this study and questions identified during the literature review but not addressed in this study. There is ample scope for future research into the perceptual interaction between point symbols and map background context during visual search.

Would other designs of complex pictorial symbols have performed better than the rather schematic ones tested (and chosen because they are commonly used on maps)? Perhaps pictorial symbols designed more like caricatures and exaggerating the size of identifying characteristics of the sports activity symbols, would have performed better. Although they would have to be larger and more detailed, three-dimensional sketches and miniature photographs could also be tested.

How can Gestalt principles be employed to design complex point symbols that form good perceptual figures? Unintentionally, the old complex symbols brought this to the fore, when their performance proved better than expected. Further testing aimed at establishing guidelines for good Gestalt in point symbol design could be of immediate value for map design.

Testing of point symbol design incorporating the other visual variables, as well as shape, size, and orientation, could also contribute to the establishment of guidelines for good point symbol design. For example, color is a strong contender for enhancement of point symbol design and is readily achievable (although not always with a desirable level of consistency) in computer map production and display. Guidelines indicating which variable to avoid or employ with suggestions for employing them effectively would be helpful to the cartographer.

Transparency is a graphic feature readily produced with computer technology, but the results for the old and new complex geometric symbols indicate that it is unsuitable for interiors of point symbols. In contrast, transparency is accepted as a useful feature when designing layered area symbols. Further research into the perceptual processes involved in transparency could lead to a better understanding of ways that transparency can be harnessed effectively in design of different types of map symbols.

The use of labels to identify map features was discussed in chapter two. Although not incorporated in the present study, there is potential for studying the ways that labels affect visual search for point symbols. For example, a study could be made of the relative utility of map labels in English and other languages on maps used by college students in foreign countries, who are expected to use English-language textbooks but function more easily in their native language. Will native-language labels aid visual search significantly? Are dual-language map labels of potential value?

Although the need for high point symbol-map background value contrast is clear, other aspects of context design need to be explored in greater depth. Network of line symbols, shaded relief and aerial photographic or remote sensing imagery are commonly used as map backgrounds, and best design practices for combining them with point symbols to be established.

Last and perhaps most important, there is the bigger issue of the perceptual interaction between all of the symbols and text conveying the main message of the map and the background, which is there to provide geographical location and supplementary information. Much remains to be learned about designing all these map foreground and background elements for optimum functionality when combined in the same map image. If point symbols are going to be colored, for example, will they stand out best against a monochrome background? How can hierarchical networks of line symbols or backgrounds of shaded relief or imagery be designed, so they will work effectively as map backgrounds? It is an exciting direction for research, because it is situated at the interface between theoretical research into map perception and its practical application in mapmaking.

Bibliography

American Institute of Graphic Arts (AIGA). (2008). "Symbol Signs." Retrieved September 4, 2008, from http://www.aiga.org/content.cfm/symbol-signs.

American Institute of Graphic Arts (AIGA). (1981). *Symbol Signs: The System of Passenger/Pedestrian Oriented Symbols Developed for the United States Department of Transportation*. New York: Hastings House.

Arend, A., Muthig, K., and Wandmacher, J. (1987). "Evidence for Global Superiority in Menu Selection by Iicons." *Behavior and Information Technology*, 6, 411-426.

Arnheim, R. (1966). "Image and Thought." In *Sign, Image, Symbol* ed. Gyorgy Kepes. New York: George Braziller.

Arnheim, R. (1971). *Art and Visual Perception: A Psychology of the Creative Eye*. Los Angeles: University of California Press.

Arnheim, R. (1976). "The Perception of Maps." *The American Cartographer*, 3, no. 1:5-10.

Atkinson, R., Holmgren, J., and Juola, J. (1969). "Processing Time as Influenced by the Number of Elements in a Visual Display." *Perception and Psychophysics*, 6, 321-327.

Attneave, F. (1957). "Physical Determinants of the Judged Complexity of Shapes." *Journal of Experimental Psychology,* 53, 221.

Bertin, J. (1967). *Semiologie graphique*. Paris: Mouton.

Bertin, J. (1983). *Semiology of Graphics*. Trans. W. J. Berg. Madison: University of Wisconsin Press.

Bies, J. D., and Long, R.A. (1983). *Mapping and Topographic Drafting*. Cincinnati: South-Western Pub. Company.

Bocker, M. (1996). "A Multiple Index Approach for the Evaluation of Pictograms and Icons." *Computer Standards and Interfaces,* 18, no. 2:107-115.

Brennan, N., and Lloyd, R. (1993). "Searching for Boundaries on Maps: The Cognitive Process." *Cartography and Geographic Information Systems*, 20, no. 4:222-36.

Bruyas, M. P., Le Breton, B., and Pauzie, A. (1998). “Ergonomic Guidelines for the Design of Pictorial Information.” *International Journal of Industrial Ergonomics,* 21, 409-413.

Cahill, M. C., and Carter, R. C., Jr. (1976). “Color Code Size for Searching Displays of Different Density.” *Human Factors*, 18, 273-280.

Carrasco, M., Evert, D. L., Chang, I., and Katz, S. M. (1995). “The Eccentricity Effect: Target Eccentricity Affects Performance on Conjunction Searches.” *Perception and Psychophysics,* 57, 1241-1261.

Cave, K., and Wolfe, J. (1990). “Modeling the Role of Parallel Processing in Visual Search.” *Cognitive Psychology*, 22, no. 2:225-71.

Chandler, D. (1994). “Semiotics for Beginners.” Retrieved July 24, 2008, from http://www.aber.ac.uk/media/Documents/S4B/semiotic.html.

Christ, R. E. (1975). “Review and Analysis of Color Coding Research for Visual Displays.” *Human Factors*, 17, 542-570.

Christner, C. A., and Ray, H. W. (1961). “An Evaluation of the Effect of Selected Combinations of Target and Background Coding on Map-Reading Performance-Experiment V.” *Human Factors*, 3, 131-146.

Clarke, L. M. (1989). “An Experimental Investigation of the Communicative Efficiency of Point Symbols on Tourist Maps.” *The Cartographic Journal*, 26, no. 2:105-110.

Cohen, R. (1985). *The Development of Spatial Cognition*. Hillsdale, N.J.: Lawrence Erlbaum Associates.

Corcoran, D. W. J., and Jackson, A. (1977). “Basic Processes and Strategies in Visual Search.” In *Attention and Performance VI*, ed. S. Dornic. Hillsdale, N.J.: Erlbaum.

Craig, A. (1981). “Monitoring for one kind of signal in the presence of another.” *Human Factors,* 23, 191-198.

Crook, M. N. (1957). “Facsimile-Generated Analogues for Instrumental Form Displays.” In *Form Discrimination as Related to Military Problems, eds.* Wulfeck, J. W. and Taylor, J. H. Washington, D.C.: National Academy of Science.

Danka, I. “Pictorial Meaning: Abstract Symbols vs. Moving Pictures.” Retrieved August, 30, 2008, from http://www.socialscience.tmobile.hu/2007/Danka_abstract_with_photo.pdf.

Daru, M. (2001). “Jacques Bertin and the Graphic Essence of Data.” *Information Design Journal*, 10, no. 1:20-25.

Dent, B. D. (1999). *Cartography: Thematic Map Design*. 5th ed. Boston : WCB/McGraw-Hill.

Desimone, R. and Duncan, J. (1995). “Neural Mechanisms of Selective Visual Attention.” *Annual Review of Neuroscience,* 18,193–222.

Dobson, M. W. (1983). “Visual Information Processing and Cartographic Communication: The Utility of Redundant Stimulus Dimensions.” In *Graphic Communication and Design in Contemporary Cartography*. Vol.2 of *Progress in Contemporary Cartography,* ed. D.R.F. Taylor, 149-175. New York: Wiley.

Dondis, Donis A. (1973). *A Primer of Visual Literacy*. Cambridge, Mass.: MIT Press.

Droste, F.G. (1989). “Symbols, Icons, and Sign Process.” *Linguistics*, 27, no. 5:921-38.

Drury, C. (1975). “Inspection of Sheet Metal: Model and Data.” *Human Factors*, 17, 257-265.

Drury, C. (1982). “Improving Inspection Performance.” In *Handbook of Industrial Engineering,* ed. G. Salvendy. New York: Wiley.

Drury, C. G., and Clement, M.R. (1978). “The Effect of Area, Density, and Number of Background Characters on Visual Search.” *Human Factors,* 20, 597-602.

Duncan, J. (1983). “Category Effects in Visual Search: A Failure to Replicate the "Oh-Zero" Phenomenon.” *Perception and Psychophysics,* 34, 221-232.

Duncan, J. and Humphreys, G. (1989). “Visual Search and Stimulus Similarity.” *Psychological Review,* 96, 433-458.

Duncan, J. and Humphreys, G. (1992). “Beyond the Search Surface: Visual Search and Attentional Engagement.” *Journal of Experimental Psychology: Human Perception and Performance*, 18, 578-588.

Edigo, C., and Patterson, J. (1988). “Pictures and Category Labels as Navigational Aids for Catalog Browsing.” *Proceedings of the CHI 1988 Conference on Human Factors in Computing Systems*. Washington, D.C.: ACM (New York).

Edworthy, J., and Adams, A. (1996). *Warning Design: A Research Prospective*. London, U.K.: Taylor and Francis.

Ells, J. G., and Dewar, R. E. (1979). "Rapid Comprehension of Verbal and Symbolic Traffic Sign Messages." *Human Factors,* 21, 161-168.

Eriksen, C. W. (1952). "Location of Objects in a Visual Display as a Function of the Number of Dimensions on Which the Objects Differ." *Journal of Experimental Psychology*, 44, 126-132.

Eriksen, C. W. (1953). "Objects Location on a Complex Perceptual Field." *Journal of Experimental Psychology*, 45, 56-60.

Estes, W. K. (1972). "Interactions of Signal and Background Variables in Visual Processing." *Perception and Psychophysics,* 12, 278-286.

Filippakopoulou, V., Nakos, B., Michaelidou, E., and Stamou, L. "Evaluation of the Selectivity Variables." Retrieved July, 13, 2008, from http://www.edeil.ntua. gr/Vasikh_ Ereyna/Thalis/Thalis_projects_English_summaries/Fillipakopoulou.pdf.

Fleming, M., and Levie, H. (1977). *Instructional Message Design*. Englewood Cliffs, N.J.: Educational Technology Publications.

Forrest, D., and Castner, H. (1985). "The Design and Perception of Point Symbols for Tourist Maps." *The Cartographic Journal*, 22 (June), 11-19.

Frank, Lawrence K. (1966). "The World as a Communication Network." In *Sign, Image, Symbol,* ed. Gyorgy Kepes. New York: George Braziller.

Garner, W. R. (1976). "Interaction of Stimulus Dimensions in Concept and Choice Processes." *Cognitive Psychology*, 8, 98-123.

Geisler, W., and Chou, K. L. (1995). "Separation of Low-level and High-level Factors in Complex Tasks: Visual Search." *Psychological Review,* 102, 356-378.

Geyer, L. H., Patel, S., and Perry, R. F. (1979). "Detectability of Multiple Flaws." *Human Factors*, 21, 7-12.

Gibson, J. J. (1950). *The Perception of the Visual World*. Boston: Houghton Mifflin.

Giedion, G. (1996). "Symbolic Expression in Prehistory and in the First High Civilizations." In *Sign, Image and Symbol*, ed. G. Kepes, 78-91. New York: George Braziller.

Gilmartin, Patricia P. (1981a). “Influences of Map Context on Circle Perception.” *Annals of the Association of American Geographers*, 71, no. 2:253-258.

Gilmartin, Patricia P. (1981b). “The Interface of Cognitive and Psychophysical Research in Cartography.” *Cartographica*, 18, no. 3:9-20.

Gilmore, G. C., Tobias, T. R., and Royer, F. L (1985). “Aging and Similarity Grouping in Visual Search.” *Journal of Gerontology,* 40, 586-592.

Glendenning, R. M. (1966). *Lands and Peoples of the World*. Boston: Ginn and Company.

Golledge, R.G., and Stimson, R. J. (1987). *Analytical Behavioral Geography*. London: Croom Helm.

Grether, W. F., and Baker, C. A.. (1972). “Chapter Three.” In *Human Engineering Guide to Equipment Design*, eds. H. P. Van Cott and R.G. Kincade, 41-121. Washington, D.C.: U.S. Government Printing Office.

Gurak, L. J. (1992). “Toward Consistency in Visual Information: Standardized Icons Based on Task.” *Technical Communication*, 39, no.1:33-37.

Haber, R. N. (1970). “How We Remember What We See.” *Scientific American,* 222, no. 5:104-112.

Haramundanis, K. (May 1996). “Why Icons Cannot Stand Alone.” *ACM SIGDOC Asterisk Journal of Computer Documentation*, 20, no. 2:1-8.

Harley, J. B. (1987). “The Map and the Development of History of Cartography.” In *Cartography in Prehistoric, Ancient, and Medieval Europe*, eds. J. B. Harley and D. Woodward, 1-42. Vol. 1 of *The History of Cartography*. Chicago: The University of Chicago Press.

Hemenway, K. (1982). “Psychological Issues in the Use of Icons in Command Menus.” *Proceedings of the CHI 1988 Conference on Human Factors in Computing Systems*. Washington, DC: ACM (New York).

Hitt, W. D. (1961). “An Evaluation of Five Different Abstract Coding Methods.” *Human Factors,* 3, 120-130.

Hopkin, V. D. (1994). “Color on Air-Traffic-Control Displays.” *Information Display,* 1, 14-18.

Hopkin, V. D. and Taylor, R. M. (1979). *Human Factors in the Design and Evaluation of Aviation Maps.* Farnborough, Hampshire, UK, AGARD-AG-225, Advisory Group for Aerospace Reserch and Development. Paris: NATO.

Horton, W. K. (1994). *The Icon Book: Visual Symbols for Computer Systems and Documentation*. New York: John Wiley and Sons

Huang, K. C., and Chiu, T. L. (2007). "Visual Search Performance on an lcd Monitor: Effects of Color Combination of Figure and Icon Background, Shape of Icon, and Line Width of Icon Border." *Perceptual and Motor Skills,* 104*,* no. 2:562-574.

Jacobs, R. J., Johnston, A. W., and Cole, B. L. (1975). "The Visibility of Alphabetic and Symbolic Traffic Signs." *Australian Road Research,* 5 (7), 68-86.

Johnson, G. (1983). *Qualitative Symbology: An Evaluation of the Pictorial Signs of the National Park Service as Cartographic Symbols*. Unpublished master's thesis, Virginia Polytechnic Institute and State University.

Jung, C. (1946). *Psychological Types*. Trans. H. Godwin Baynes. London: K. Paul, Trench, Trubner and Co.

Keates, J. S. (1982). *Understanding Maps*. New York: Halsted Press.

Kennedy, J.M. (1974). *A Psychology of Picture Perception*. 1st ed. San Francisco, CA: Jossey-Bass.

Kilkoyne, J.R. (1973). *Pictographic Symbols in Cartography: A Study of Efficient Map Reading*, Unpublished Ph.D diss., University of Washington.

King, L. E. (1971). A Laboratory Comparison of Symbol and Word Roadway Signs. *Traffic Engineering and Control, 12,* 518-520.

Kosslyn, S. M., and Koenig, O. (1992). *Wet Mind: The New Cognitive Neuroscience*. New York: Free Press.

Krauskopf, J., Duryea, R. A., and Bitterman, M., E. (1954). "Threshold for Visual Form." *American Journal of Psychology*, 52, 31.

Krauskopf, J., and Gegenfurtner, K. (1992). "Color Discrimination and Adaptation. *Vision Research*, 32, 2165-2175.

Kretschmer, Ingrid. (1980)."Theoretical Cartography: Position and Tasks." *International Yearbook of Cartography,* 20, 142-155.

Krueger, L. (1984). “Self-Termination in Same-Different Judgments: Multiletter Comparison with Simultaneous and Sequential Presentation.” *Journal of Experimental Psychology: Learning, Memory, and Cognition*, 10, 271-285.

Krumhansl, C. L., and Thomas, E. A. (1977). “Effect of Level of Confusability on Reporting Letters from Briefly Presented Visual Displays.” *Perception and Psychophysics,* 21, 269-279.

Laurel, B., and Mountford, S. J. (1990). *The Art of Human-Computer Interface Design*. Reading, Mass.: Addison-Wesley.

Lloyd, R. (1988). “Searching for Map Symbols: The Cognitive Process.” *The American Cartographer*, 15(4), 363-78.

Lloyd, R. (1997a). *Spatial Cognition: Geographic Environments.* Dordrecht, The Netherlands: Kluwer Academic Publishers.

Lloyd, R. (Spring 1997b).”Visual Search Processes Used in Map Reading.” *Cartographica*. 34(1), 11-31.

Lloyd, R., and T. Steinke. (1984). “Recognition of Disoriented Maps: The Cognitive Process.” *Cartographic Journal*, 21, 55-9.

Lodding, K. N. (1983).” Iconic Interfacing.” *IEEE Computer Graphics and Applications,* 24, 11-20.

Luskin, B. J. (1996). “Toward an Understanding of Media Psychology.” *T.H.E. Journal* 23, no. 7:82-84.

MacEachren, A. M. (1995). *How maps work: Representation, visualization, and design*. New York: Guilford Press.

Marr, D. (1982). *Vision: A Computational Investigation into the Human Representation and Processing of Visual Information*. San Francisco: W. H. Freeman.

McCleary, George F., Jr. (1987). “Discovering Cartography as a Behavioral Science.” *Journal of Behavioral Psychology* 7, 347-355.

McIntyre, C., Fox, R., and Neale, J. (1970). “Effects of Noise Similarity and Redundancy on the Information Processed from Brief Visual Displays.” *Perception and Psychophysics*, 7, 328-332.

McNair, J. R. (1996). “Computer Icons and the Art of Memory.” *Technical Communication Quarterly*, 5(1), 77-86.

Miyahara, E., Smith, V. C., and Pokorny, J. (1993). "How Surrounds Affect Chromaticity Discrimination." *Journal of the Optical Society of America A*, 10, 545-553.

Mocharnuk, J. B. (1978). "Visual Target Acquisition and Ocular Scanning Performance." *Human Factors,* 20, 611-632.

Modley, R. (1966). "Graphic Symbols for Worldwide Communication," in *Sign, Image, Symbols*, ed. G. Kepes. New York: George Braziller.

Monk, T.H. (1976). Target Uncertainty in Applied Visual Search. *Human Factors,* 18, 607-612.

Monk, T. H., and Brown, B. (1975). "The Effect of Target Surround Density on Visual Search Performance." *Human Factors*, 17, 356-360.

Monkhouse, F. J., and Wilkinson, H. R. (1978). *Maps and Diagrams: Their Compilation and Construction*. 3rd ed. London: Methuen.

Monmonier, M . (1993). *Mapping it Out: Expository Cartography for the Social Sciences and Humanities.* Chicago: University of Chicago Press.

Morrison, Joel. (1972). [p. 19 quote: defines contemporary cartography as a science of cartographic ommunication –HOW TO FIND?]

Muehrcke, Phillip C. (1972). *Thematic Cartography*.Washington, D.C.: Association of American Geographers.

Müller, J.C. and Zeshen, W. (1990). A Knowledge Based System for Cartographic Symbol Design. *The Cartographic Journal*, 27, 24-30.

Nakayama, K. and Silverman, G. H. (1986) "Serial and Parallel Processing of Visual Feature Conjunctions." *Nature*, *320*, 264–265.

"Natural Resources Canada. The Atlas of Canada. Map Symbology." Retrieved April, 9, 2008, from http://atlas.gc.ca/sitefrancais/english/learningresources/ carto_ corner/map_ content_carto_symbology.html.

Neider, M. B., and Zelinsky, G. J. (2006). "Searching for Camouflaged Targets: Effects of Target-Background Similarity on Visual Search." *Vision Research*, 46(14), 2217-2235.

Neisser, U., Novick, R., and Lazar, R. (1964). "Searching for novel targets." *Perceptual and Motor Skills,* 19, 427-432.

Nelson, F. (1995). Colour detection on bivariate choropleth maps: The visual search process. *Cartographic*, 32, 33-43.

Nelson, E.S., Dow, D., Lukinbeal, C., and Farley, R. (1997). "Visual Search Processes and the Multivariate Point Symbol." *Cartographica,* 34(4), 19-33.

Nothdurft, H. C. (1991). "Texture Segmentation and Popout from Orientation Contrast." *Vision Res*., 31, 1073–1078.

Nothdurft, H. C. (1993). "The Role of Features in Preattentive Vision: Comparison of Orientation, Motion and Colour Cues." *Vision Res.,* 33, 1937–1958.

Olson, J.M. (1979). "Cognitive Cartographic Experimentation." *The Canadian Cartographer*, 16, 34-44.

Orbison, W., D. (1939). "Shape as a Function of the Vector Field." *American Journal of Psychology*, 52, 31.

Osterrieth, P., A. (1945). "Le test de copie d'une figure complexe." *Archives de Psychologie*, 30, 205.

Paivio, A. (1971). *Imagery and Verbal Processes*. New York: Holt, Rinehart, and Winston.

Palmer, J. (1994). "Set-Size Effects in Visual Search: The Effect of Attention Is Independent of the Stimulus for Simple Tasks." *Vision Research,* 34, 1703-1721.

Petchenik, B.B. (Sep., 1975). "Cognition in Cartography." In: *Proceedings of the International Symposium on Computer-Assisted Cartography (Auto-Carto II),* 12 (25), 183-93.

Peterson, M. (1985). "Evaluating a Map's Image." *The American Cartographer*, 12, 41-55.

Phillips, W.F. (1973). *A Study of Symbol Design for Elementary School Maps*, PhD diss., University of Kansas.

Prinzmetal, W. (1981). "Principles of Feature Integration in Visual Perception." *Perception and Psychophysics*, 30, 330-340.

Ratajski, Lech. (1978). "The Main Characteristics of Cartographic Communication as a Part of Theoretical Cartography." *International Yearbook of Cartography*, 18, 21-32.

Reisberg, D. (2001). *Cognition*, 2nd ed. New York: W.W. Norton and Company.

Rheingold, H. (1990). "An Interview with Don Norman." In *The Art of Human-Computer Interface Design*, eds.B. Laurel and S. J. Mountford, 5 -10.

Robinson. A, and Petchenik, B. (1975). "The Map as a Communication System." *The Cartographic Journal*, 12(1), 7-14.

Robinson. A, and Petchenik, B. (1976). *The Nature of Maps: Essays toward Understanding Maps and Mapping.* Chicago: The University of Chicago Press.

Robinson, A. H., Sale, R. D., Morrison, J. L., and Muehrcke, P. C. (1984). *Elements of cartography*. 5th ed. New York: John Wiley.

Robinson, A., Morrison, J., Muehrcke, P., and Kimerling, A. (1995). *Elements of cartography*. 6th ed. New York: John Wiley.

Rock, I. and Heimer, W. (1957). "The Effect of Retinal and Phenomenal Orientation on the Perception of Form." *American Journal of Psychology*, 70, 493.

Rogers, Y. (1989). "Icon Design for the User Interface." *International Reviews of Ergonomics,* 2,129-154.

Rohr, G., and Keppel, E. (1984). *Iconic Interfaces.* In eds. H. W. Hendrick and O. Brown, Jr., Human Factors in Organizational Design and Management, Amsterdam, The Netherlands: North-Holland, 1984.

Rosenholtz, R., Nagy, A. L., and N. R. Bell. (2004). "The Effect of Background Color on Asymmetries in Color Search." *Journal of Vision*, 4, no. 3, Article 9:224-240.

Rushdoony, H.A. (1968). "A Child's Ability to Read Maps: Summary of the Research." *Journal of Geography*, 67, 213-22.

Saarinen, J. (1996). "Localisation and Discrimination of Pop-Out Targets." *Vision Research,* 36, 313–316.

Sanders, M. S. and McCormick, E. J. (1993). *Human Factors in Engineering and Design*. 7th ed. New York: McGraw-Hill.

Sanders, M. S. and McCormick, E. J. (1976). *Workbook for Human Factors in Engineering and Supply.* Dubuque, Iowa: Kendall/Hunt.

Scanlan, L. A. (1977). “Target Acquisition in Realistic Terrain.” In *Proceedings, 21st Annual Meeting of the Human Factors Society*, eds. A. S. Neal and R. Palasek. Santa Monica, CA: Human Factors.

Sheehan, J. J. and Drury, C. C. (1967). “Ergonomic and Economic Factors in an Industrial InspectionTask.” *International Journal of Production Research,* 7, 333-341.

Shortridge, B. G. (1982). “Stimulus Processing Models from Psychology: Can We Use Them in Cartography?” *American Cartographer,* 9*,* 155-167.

Simola, J. M., and Kojo, I. V. (2003). “Eye Movements during Directed Visual Search: The Effects of Background versus Target-Distractor Confusability.” *Journal of Vision,* 3(9), 428.

Smith, S.L., and Thomas, D.W. (1964).”Color versus Shape Coding in Information Displays,” *Journal of Applied Psychology*, 48, no. 3:137-146.

Spitz, G. and Drury, C. C. (1978). “Inspection of Sheet Materials Ttest of Model Predictions.” *Human Factors,* 20, 521-528.

Standing, L. (1973). “Learning 10,000 Pictures.” *Quarterly Journal of Experimental Psychology,* 25, no. 2:207-222.

Sternberg, S. (1975). “Memory Scanning: New Findings and Current Controversies.” *Quarterly Journal of Experimental Psychology*, 27, 1-32.

Teichner, W. H. and Mocharnuk, J. B. (1979). “Visual Search for Complex Targets.” *Human Factors,* 21, 259-276.

Thorndyke, P. W., Hayes-Roth, B., and Stasz, C. (1980). *Performance Models for Spatial and Locational Cognition. A Report Prepared for the Office of Naval Research.* [s.l.]: The Rand Corporation.

Thralls, Z. A. (1958). *The Teaching of Geography*. New York: Appleton-Century-Crofts.

Treisman, A. (1982). “Perceptual grouping and attention in visual search for features and for objects.” *Journal of Experimental Psychology: Human Perception and Performance*, 8, 194-214.

Treisman, A. (1985). “The Magical Number Seven and Some Other Features of Category Scaling: Properties of a Model for Absolute Judgment.” *Journal of Mathematical Psychology,* 29, 175-230.

Treisman, A. (1988). Feature and objects: The fourteenth Bartlett Memorial Lecture. *The Quarterly Journal of Experimental Psychology*, *40A* (2), 201-37.

Treisman, A., and Gelda.G. (1980). "A Feature integration theory of attention." *Cognitive Psychology*, 12, 97-136.

Treisman, A., and Gormican. S. (1988). "Feature Analysis in Early Vision: Evidence from Search Asymmetries." *Psychological Review,* 95, 15-84.

Treisman, A., and Soto. S. (1990. "Conjunction Search Revisited." *Journal of Experimental Psychology: Human Perception and Performance,* 16, 459-478.

Townsend, J. T. (1990). Serial vs Parallel Processing: Sometimes They Look like Tweedledum and Tweedledee but They Can (and Should) Be Distinguished. *Psychol. Sci.,* 1, 46–54.

Tullis, T. (1986). "Optimizing the usability of computer-generated displays." In *Proceedings of HCI'86 Conference on People and Computers: Designing for Usability*, 604-613. London: British Computer Society.

Tversky, B. (1981). "Distortions in Memory for Maps." *Cognitive Psychology,* 13, 407-33.

Verghese, P., and Nakayama, K. (1994). "Stimulus Discriminability in Visual Search." *Vision Research,* 34, 2453-2467.

Vernon, M. D. (1971). *The Psychology of Perception*. 2nd ed. Middlesex, England: Penguin Books; The Open University.

Walker, R. E., Nicolay, R. C., and Stearns, C. R. (1965). "Comparative Accuracy of Recognizing American and International Road Signs." *Journal of Applied Psychology,* 49, 322-375.

Walters, D., Biederman, I., and Weisstein, N. (1983). "The Combination of Spatial Frequency and Orientation Is Not Effortlessly Perceived." *Investigative Ophthalmology and Visual Science,* 24,124.

Warren, R. M. and Warren, R. P. (1968). *Helmholtz on Perception: Its Physiology and Development*. New York: Wiley.

White, J. V. (1982). *Editing by Design. A Guide to Effective Word-and-Picture Communication for Editors and Designers*. New York: R. R. Bowker.

Wickens, C. D. (1984). *Engineering Psychology and Human Performance.* Columbus, Ohio: Charles E Merrill Publishing Company.

Williams, E. K. (1999). *Visual Search: A Novel Psychophysics for Preattentive Vision.* [Boston, Mass.?]: Research Science Institute.

Williams, L.G. (1967). "The Effect of Target Specifications on Objects Fixated during Visual Search." *Acta Psychologica*, 27, 355-360.

Williams, L.G. (1971). "Obtaining Information from Displays with Discrete Elements." In *Map Design and the Map User*, eds. H. Castner and T. McGrath. *Cartographica,* Monograph 2, 26-34.

Williams, R. L. (1956). *Statistical Symbols for Maps: Their Design and Relative Values*. New Haven ,Conn.: Yale University Map Laboratory.

Wolfe, J. M. (1994). "Guided Search 2.0: A Revised Model of Visual Search." *Psychonomic Bulletin and Review*, 1, no. 2:202-38.

Wolfe, J. M., Cave, K. R., and Franzel, S. L (1989). "Guided Search: An Alternative to the Feature Integration Model of Visual Search." *Journal of Experimental Psychology: Human Perception and Performance*, 15, no. 3:419-433.

Wolfe, J. M., and Horowitz, T. S. (2004). "What Attributes Guide the Deployment of Visual Attention and How Do They Do It?" *Natural Reviews, Neuroscience*, *5*, 1-7.

Zelinsky, G., Sheinberg, D., and Bulthoff, H. (1993). "Eye movements during visual search." *Investigative Ophthalmology and Visual Science,* 34, 1236.

Zwaga, H. J., and Boersema, T. (1983). "Evaluation of a Set of Graphic Symbols." *Applied Ergonomics,* 14, 43-54.

Appendix 1

Self-Test

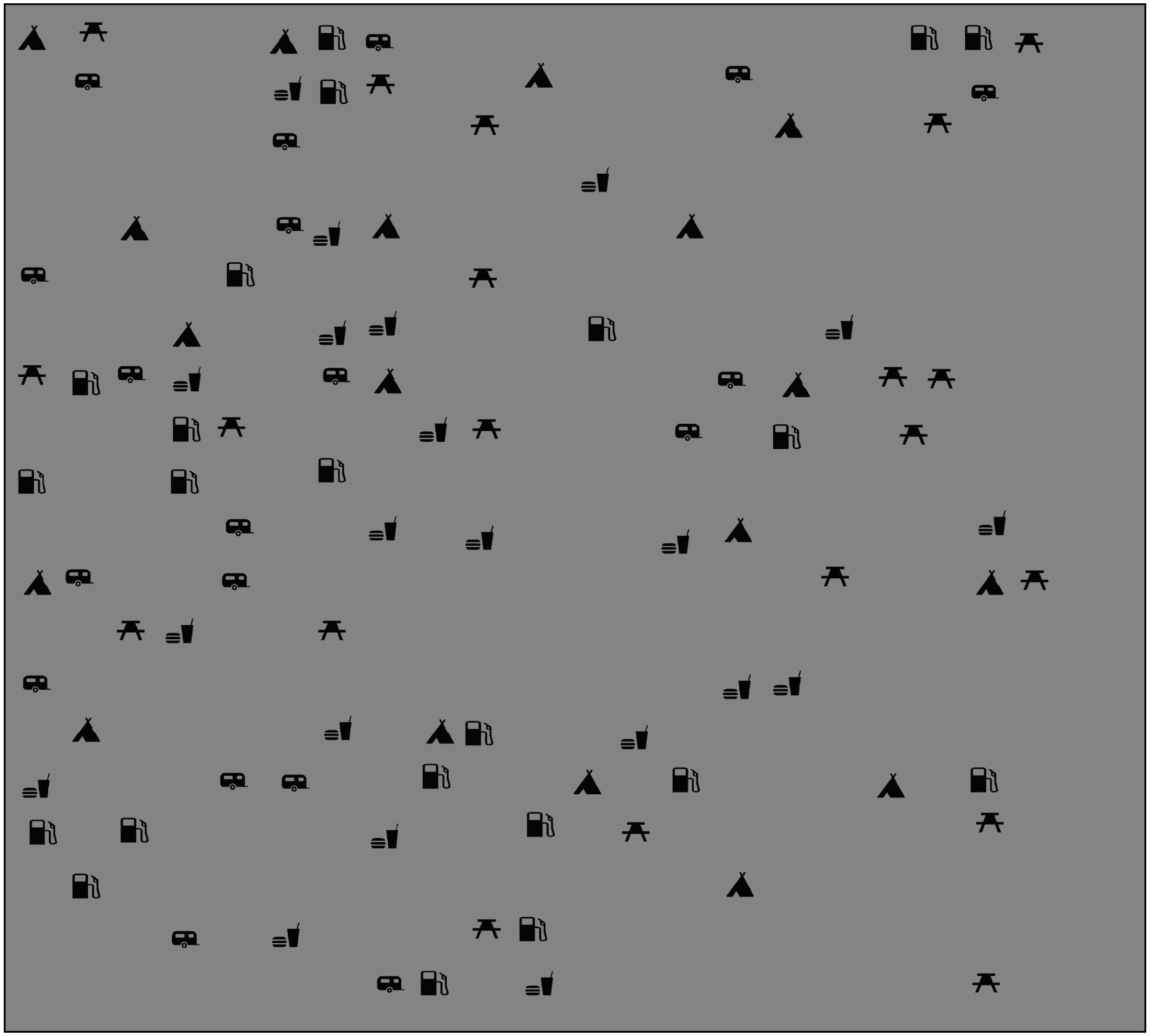
See Chapter One for an explanation (page 8).

Snack bar

Time Start 00:00

Time End

Number of symbols



Trailer site

Time Start 00:00

Time End

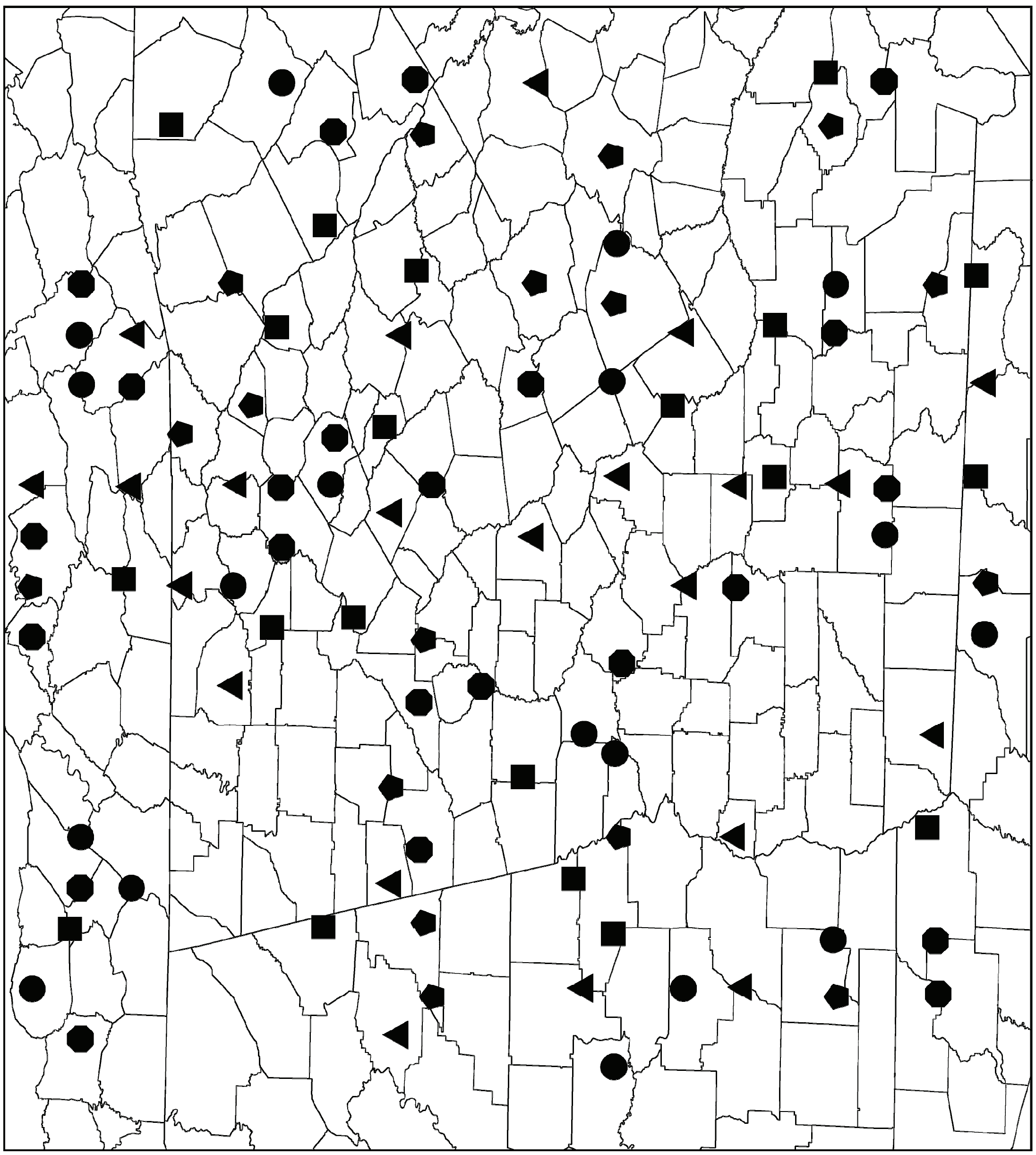
Number
of symbols

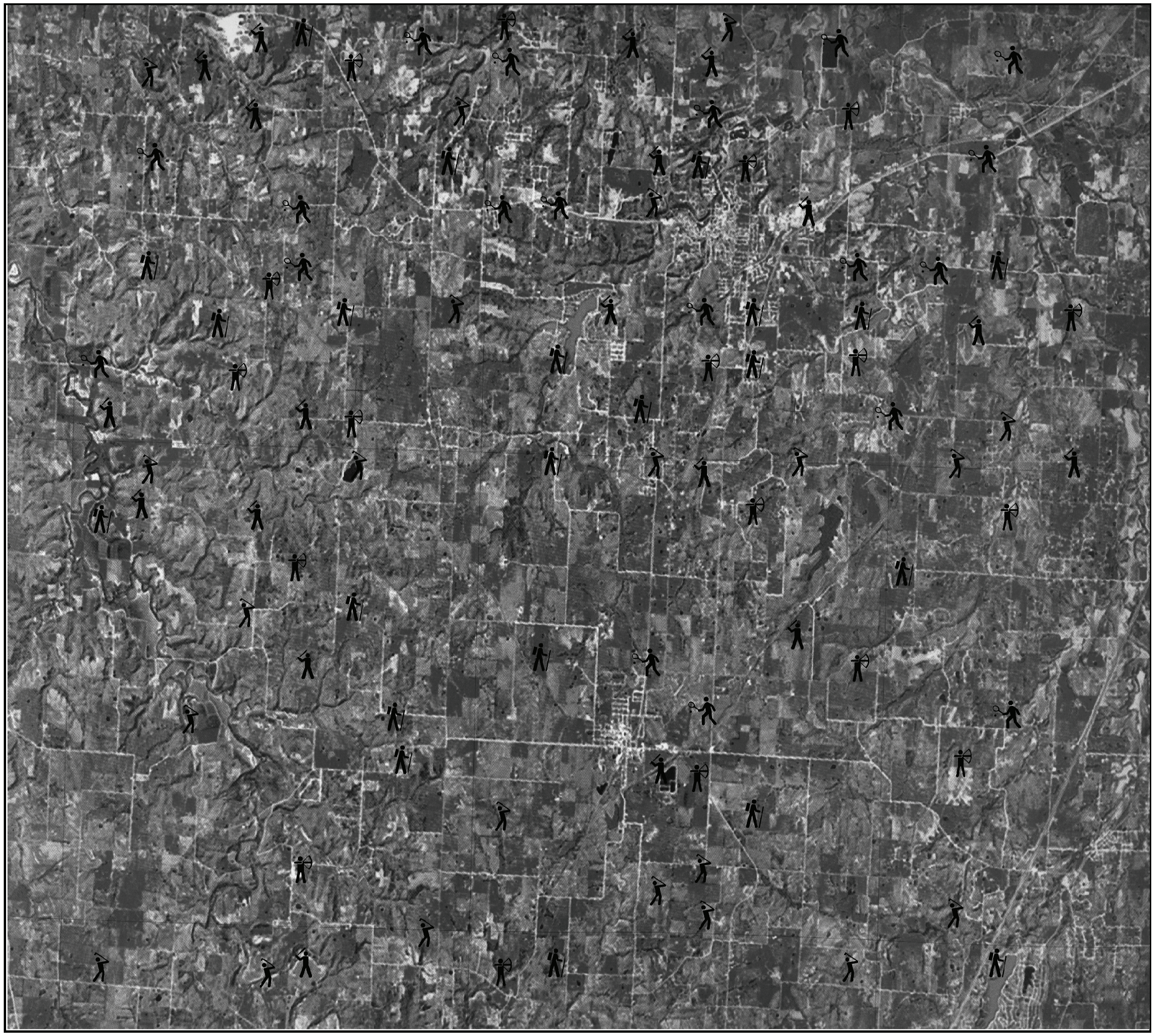
Gas station

Time Start 00:00

Time End

Number of symbols



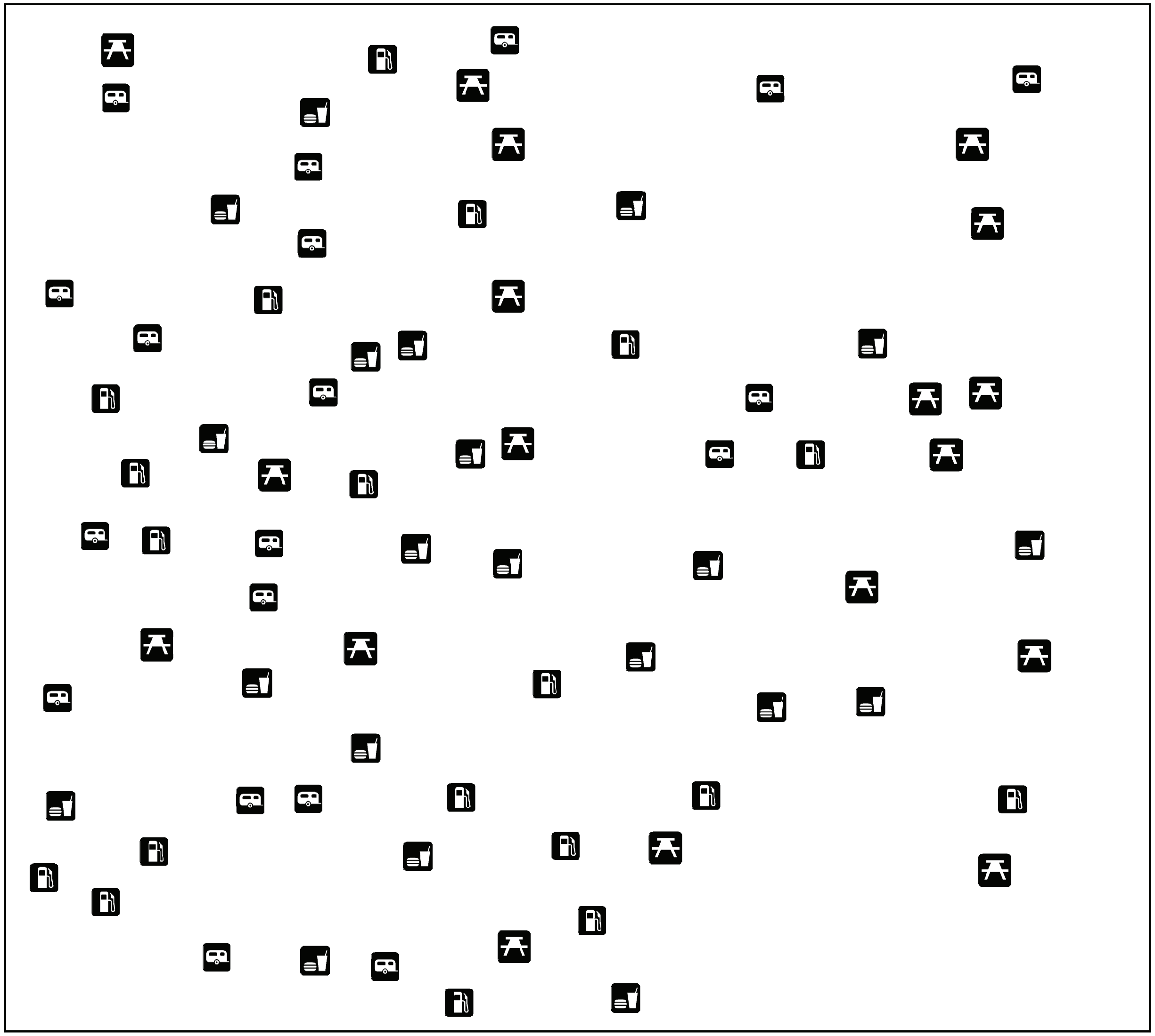


Baseball

Time Start 00:00

Time End

Number
of symbols

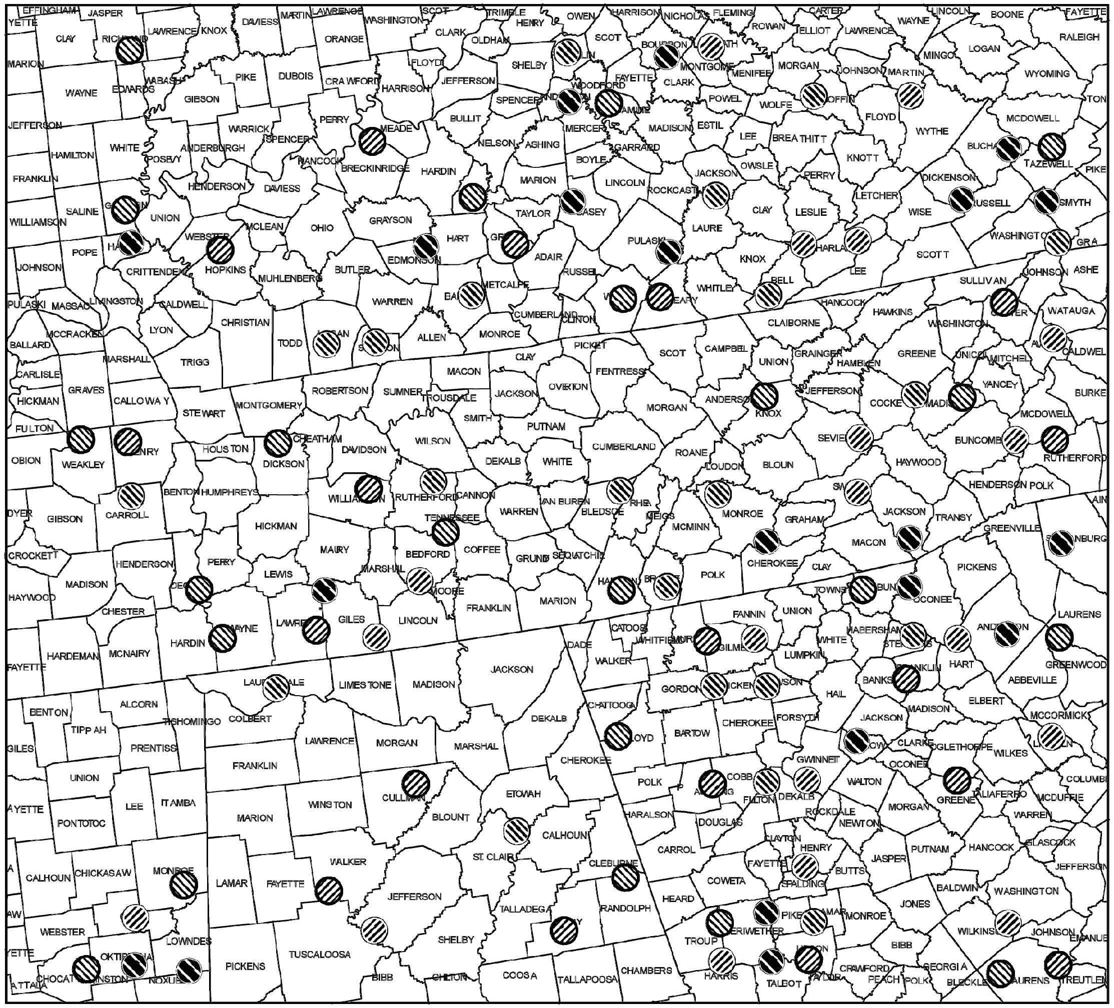


Picnic Area

Time Start 00:00

Time End

Number of symbols



Golfing

Time Start 00:00

Time End

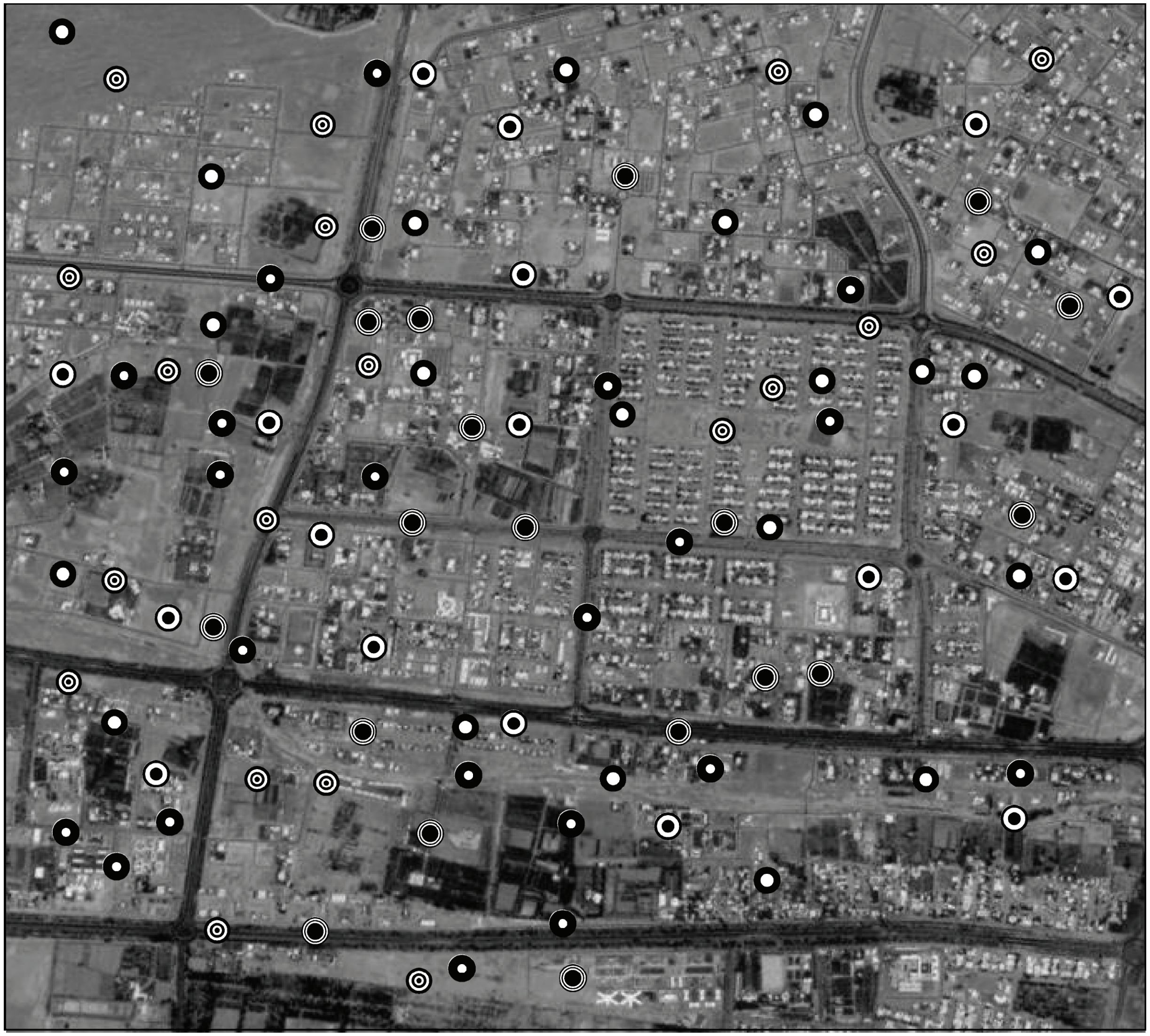
Number of symbols

Archery

Time Start 00:00

Time End

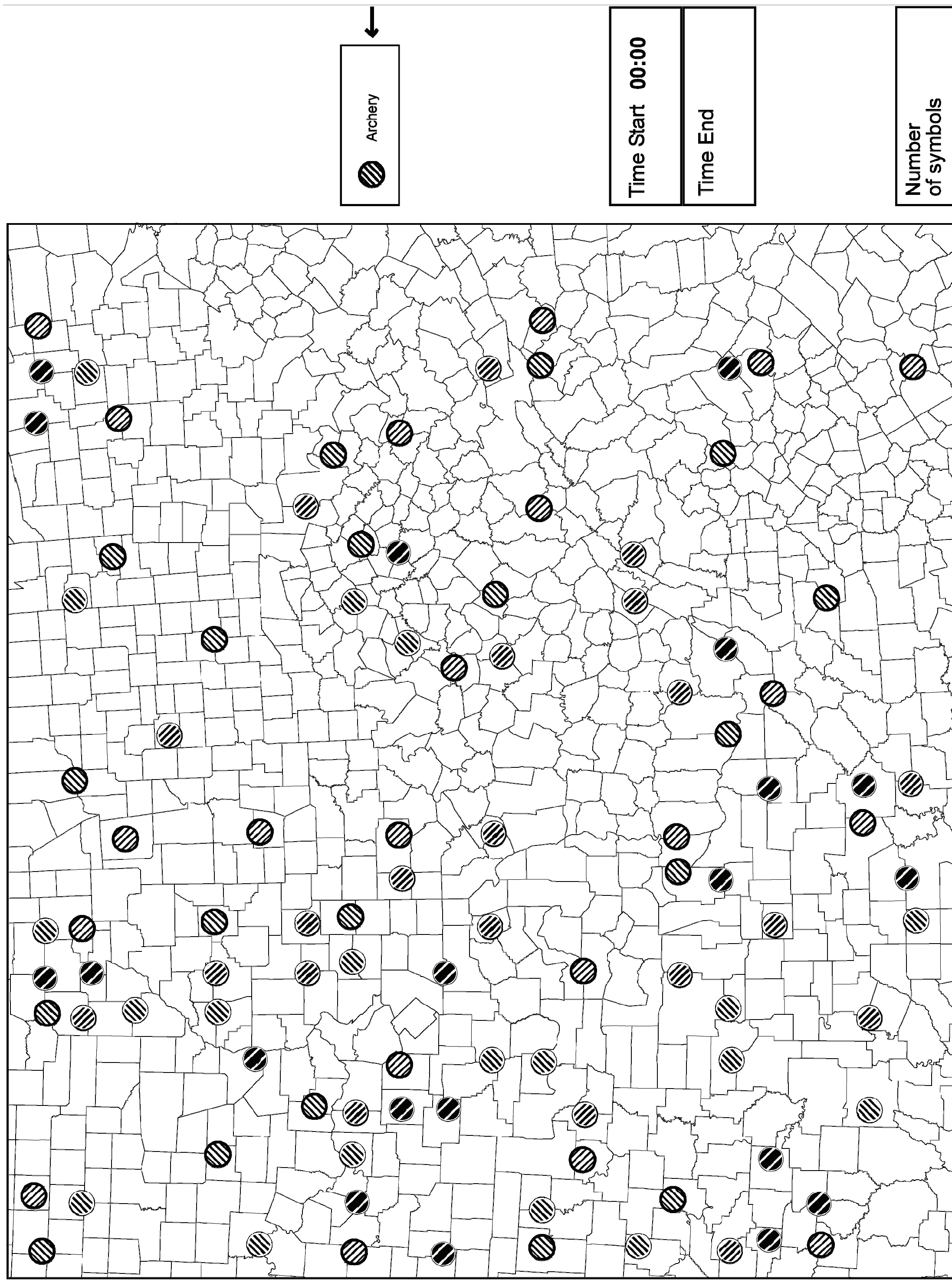
Number
of symbols



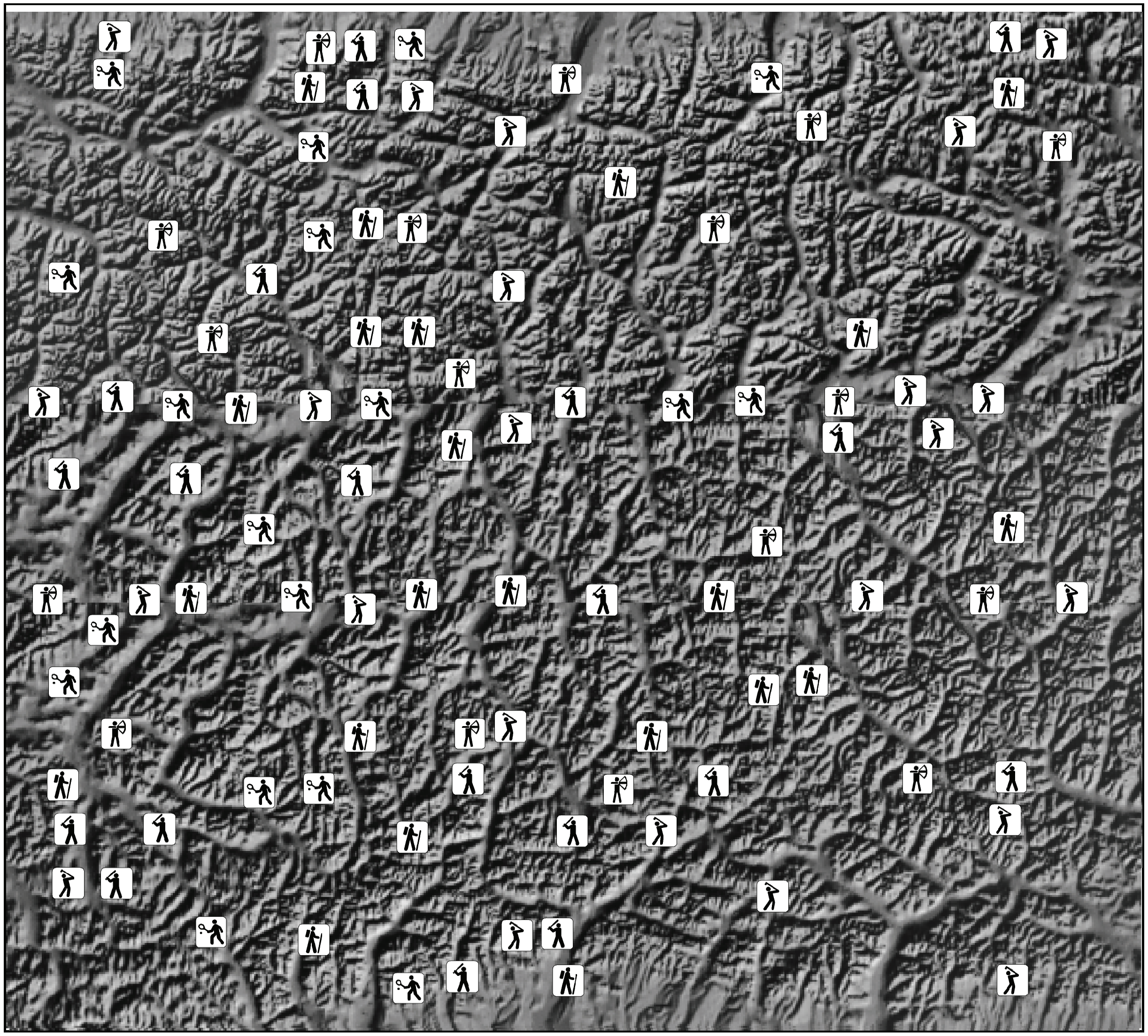
Hiking

Time Start **00:00**
Time End

Number of symbols



Archery
Time Start 00:00
Time End
Number of symbols

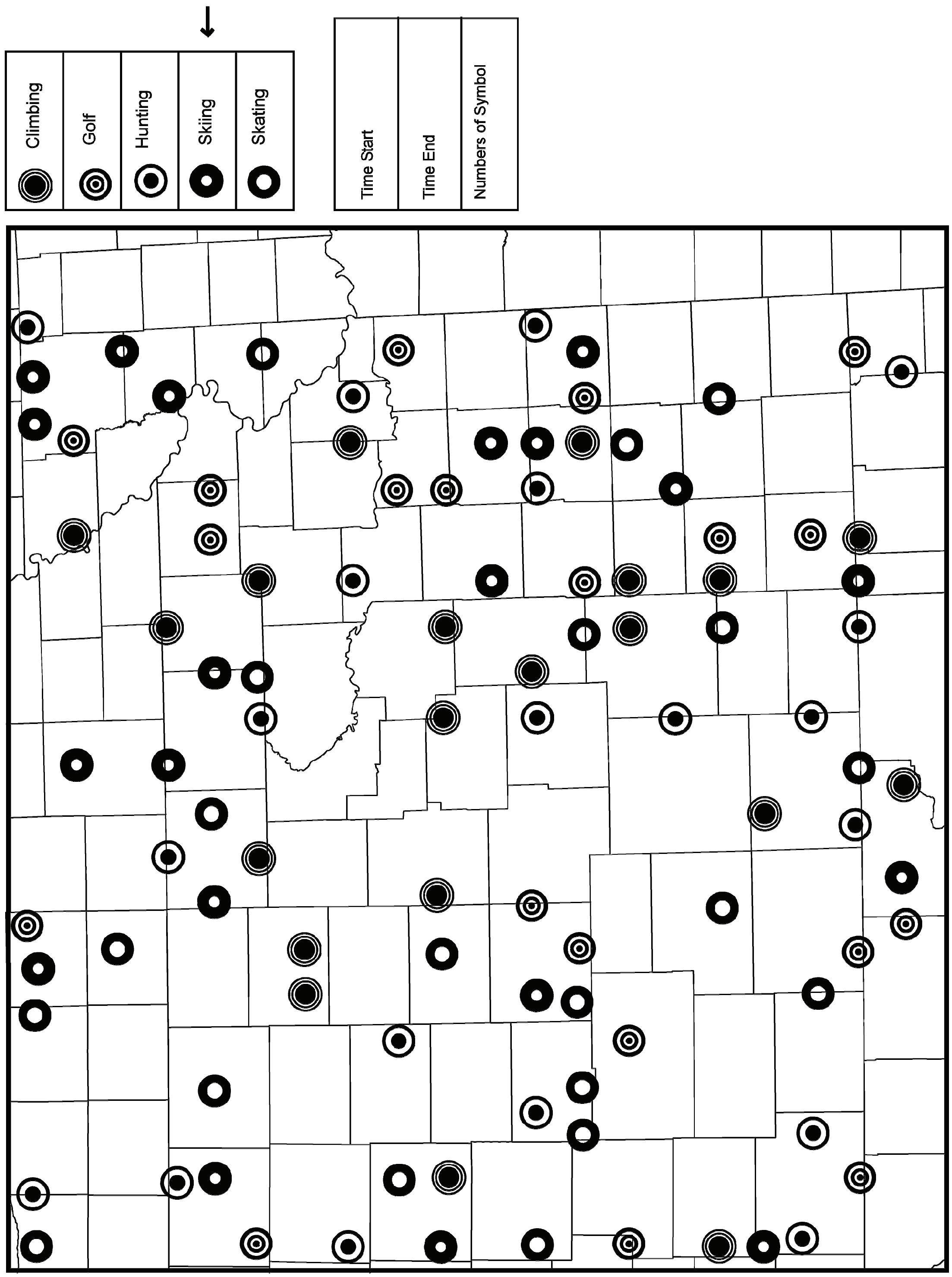


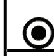
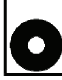
Archery

Time Start 00:00

Time End

Number
of symbols


Climbing
Golf
Hunting
Skiing
Skating
Time Start
Time End
Numbers of Symbol

 Baseball	20
 Snack bar	23
 Trailer site	19
 Gas station	22
 Baseball	15
 Picnic Area	18
 Golfing	22
 Archery	17
 Hiking	18
 Archery	19
 Archery	17
 Skiing	20

Appendix 2

Examples of Backgrounds and Symbols

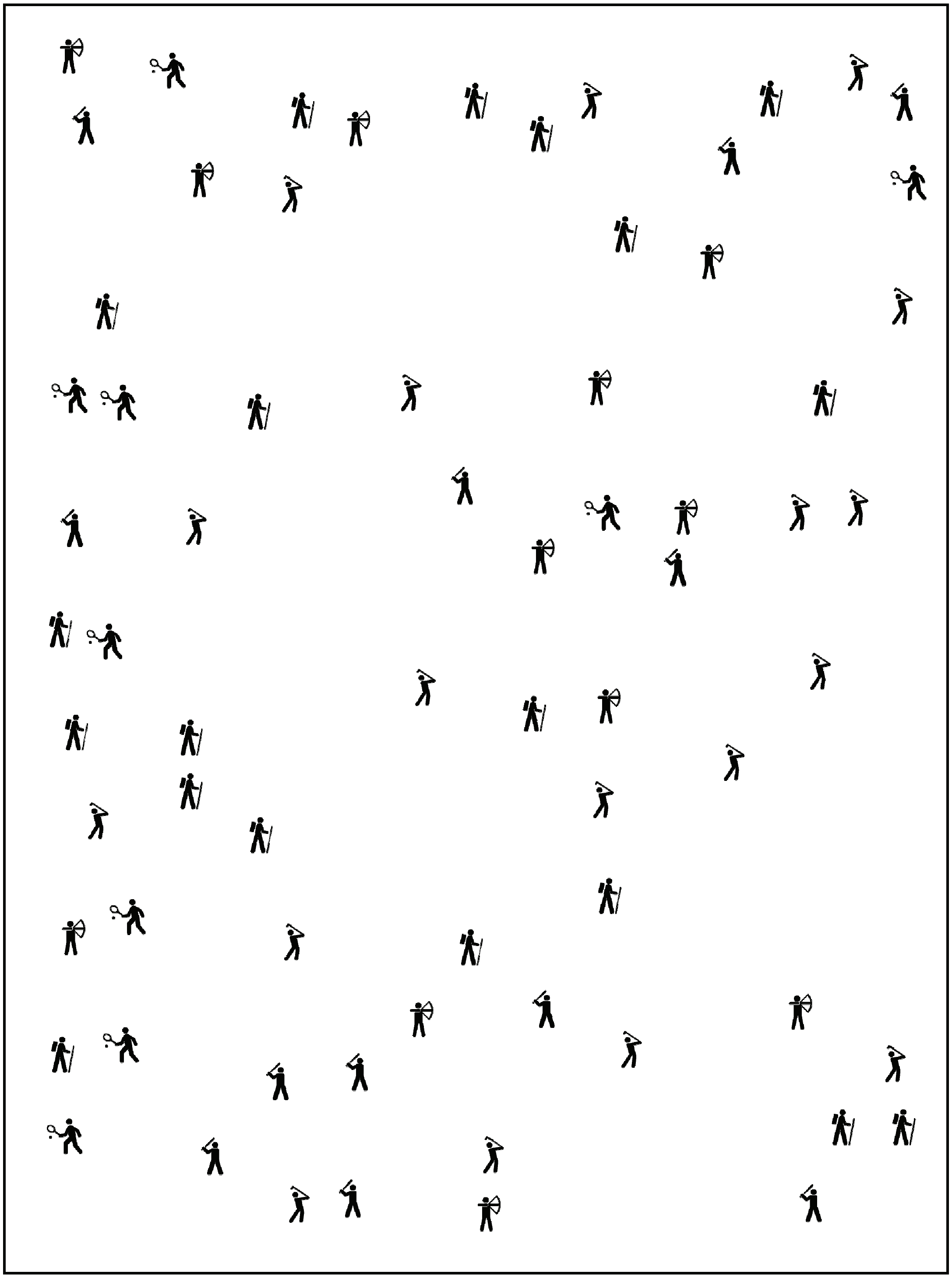


Figure 1. Example of the white background with complex pictorial symbols.

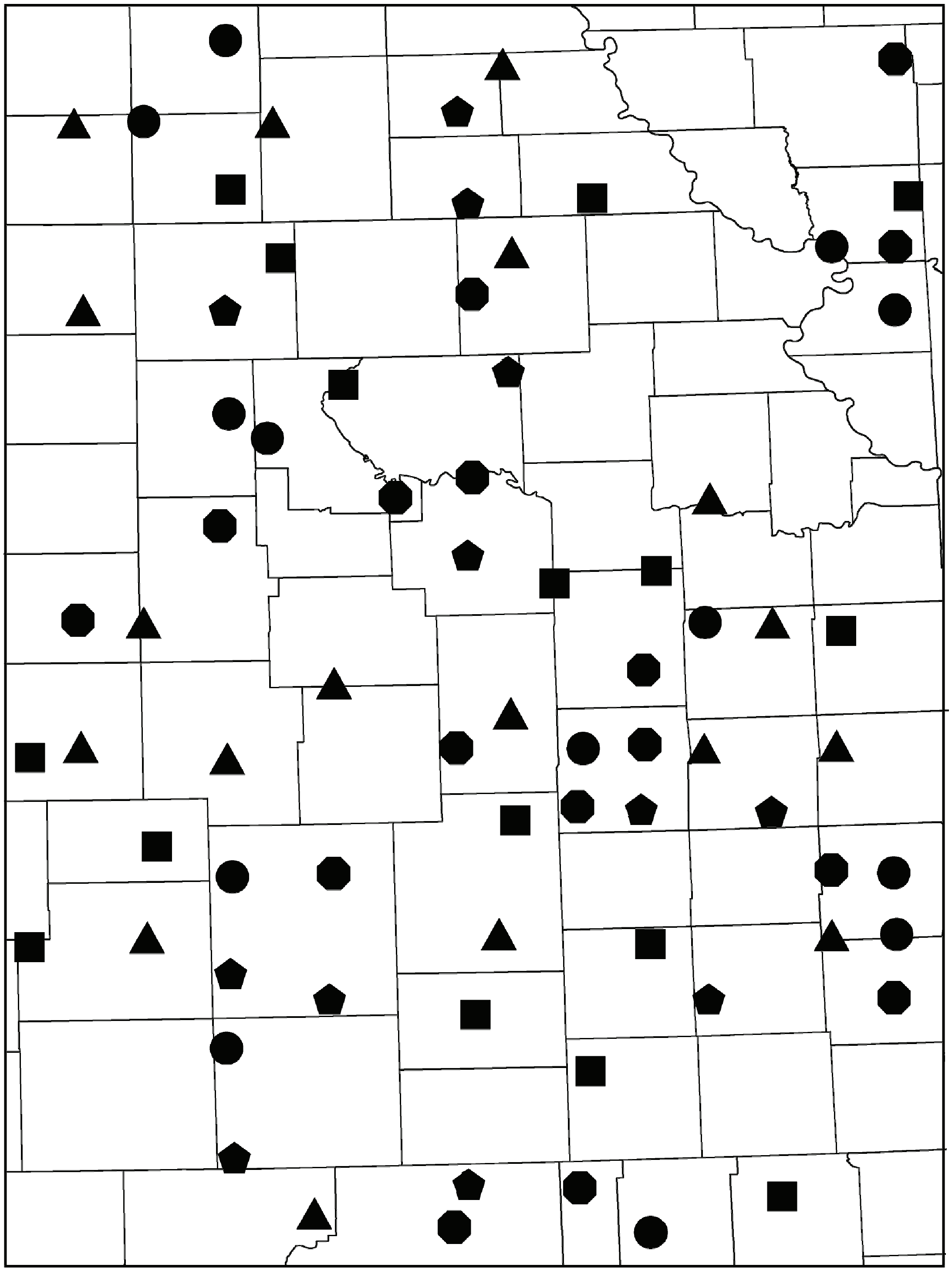


Figure 2. Example of the regular linear background with simple geometric symbols.

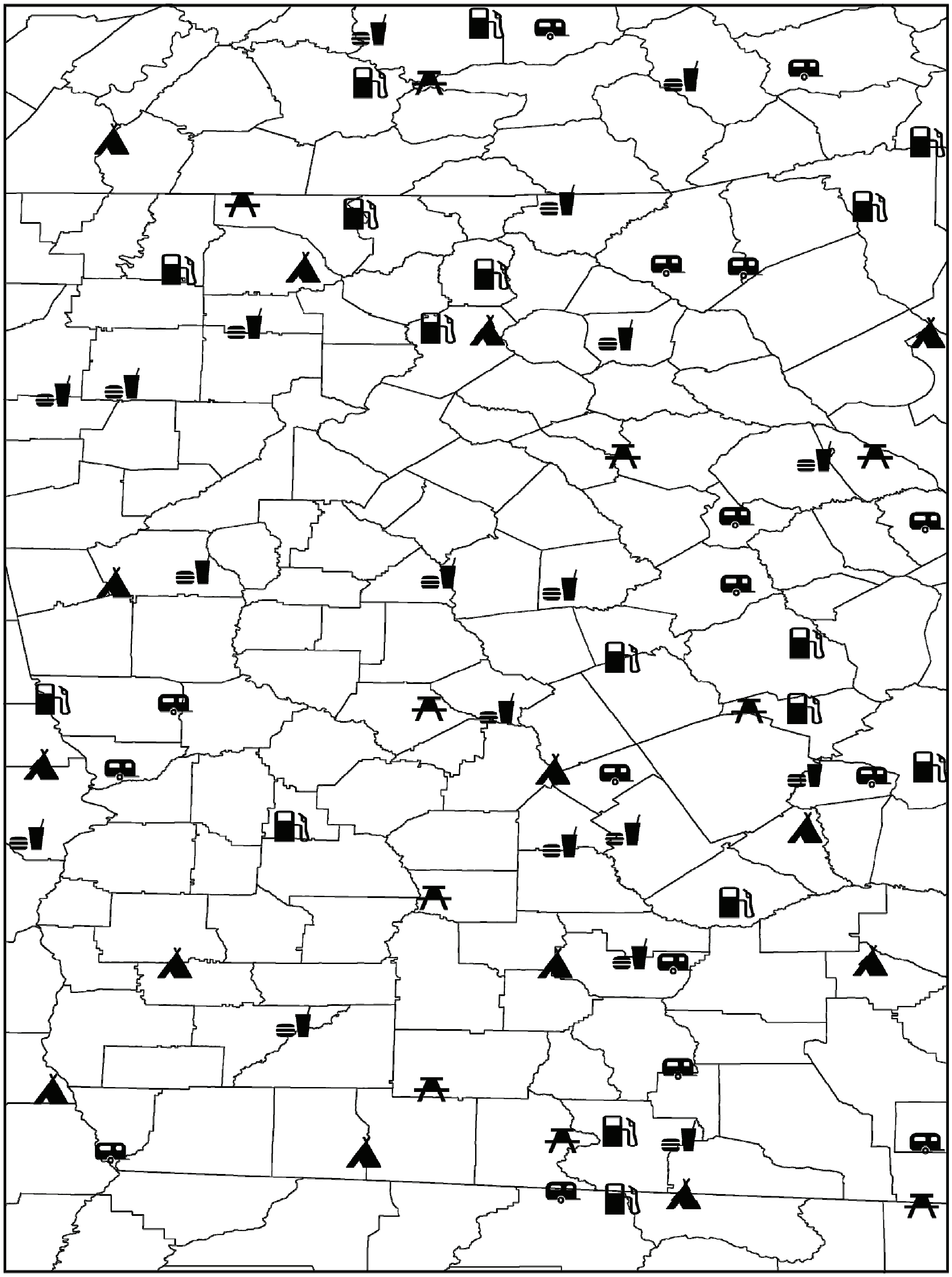


Figure 3. Example of the irregular linear background with simple pictorial symbols.

Figure 4. Example of the New Imagery background with complex pictorial symbols.

Figure 5. Example of the shaded relief background with simple pictorial symbols.

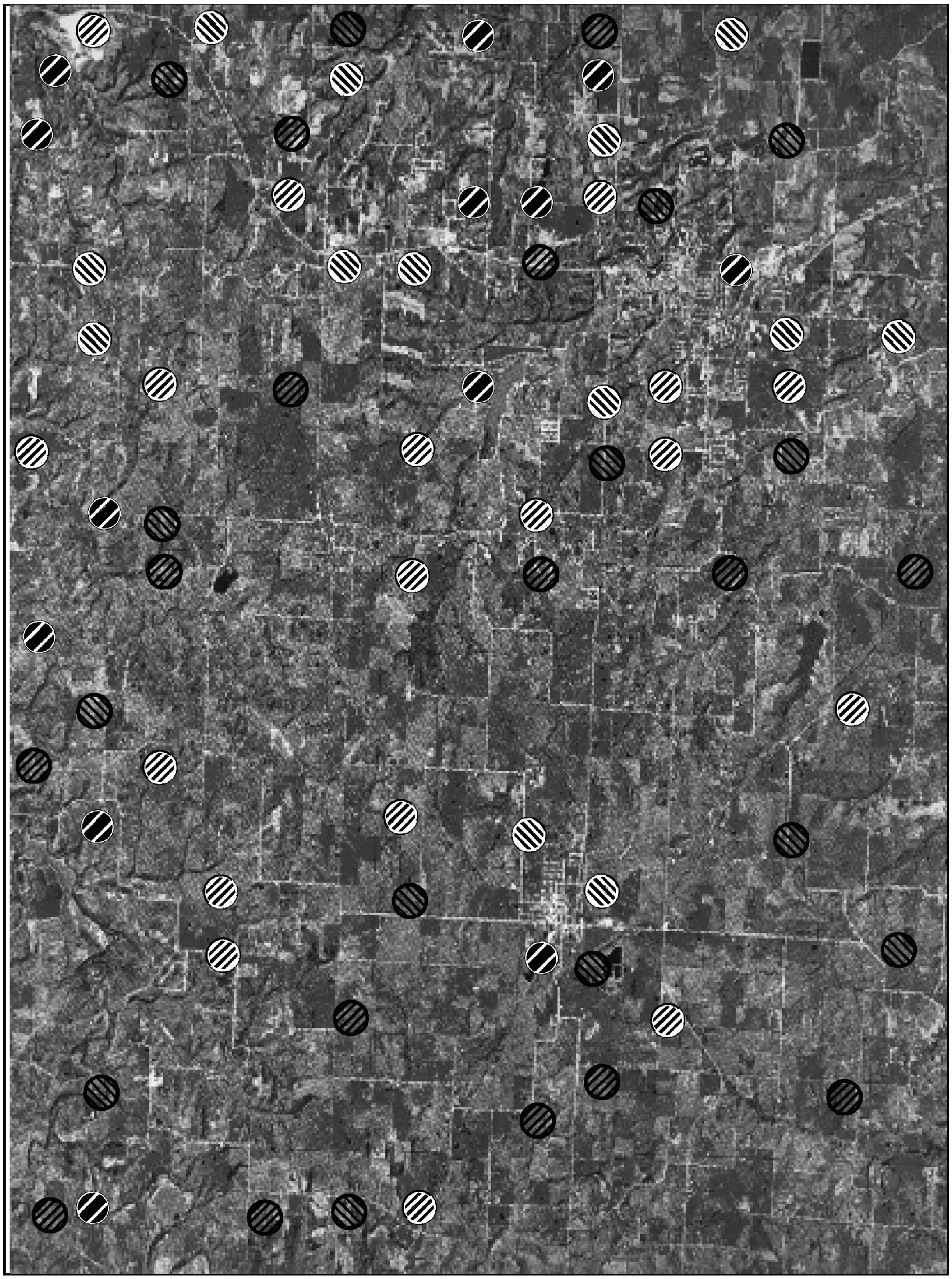


Figure 6. Example of the old imagery background with complex geometric symbols.

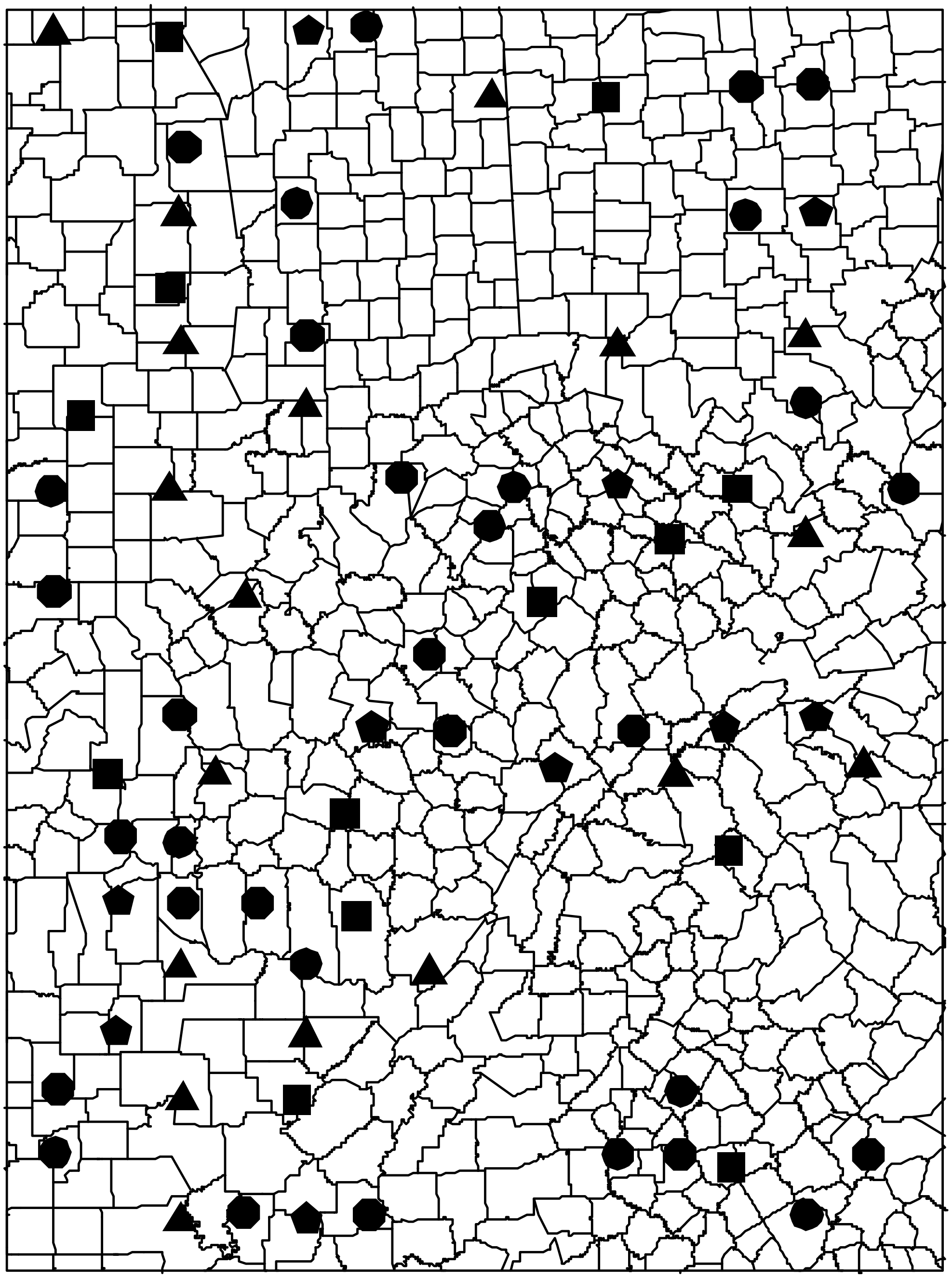


Figure 7. Example of the dense linear background with simple geometric symbols.

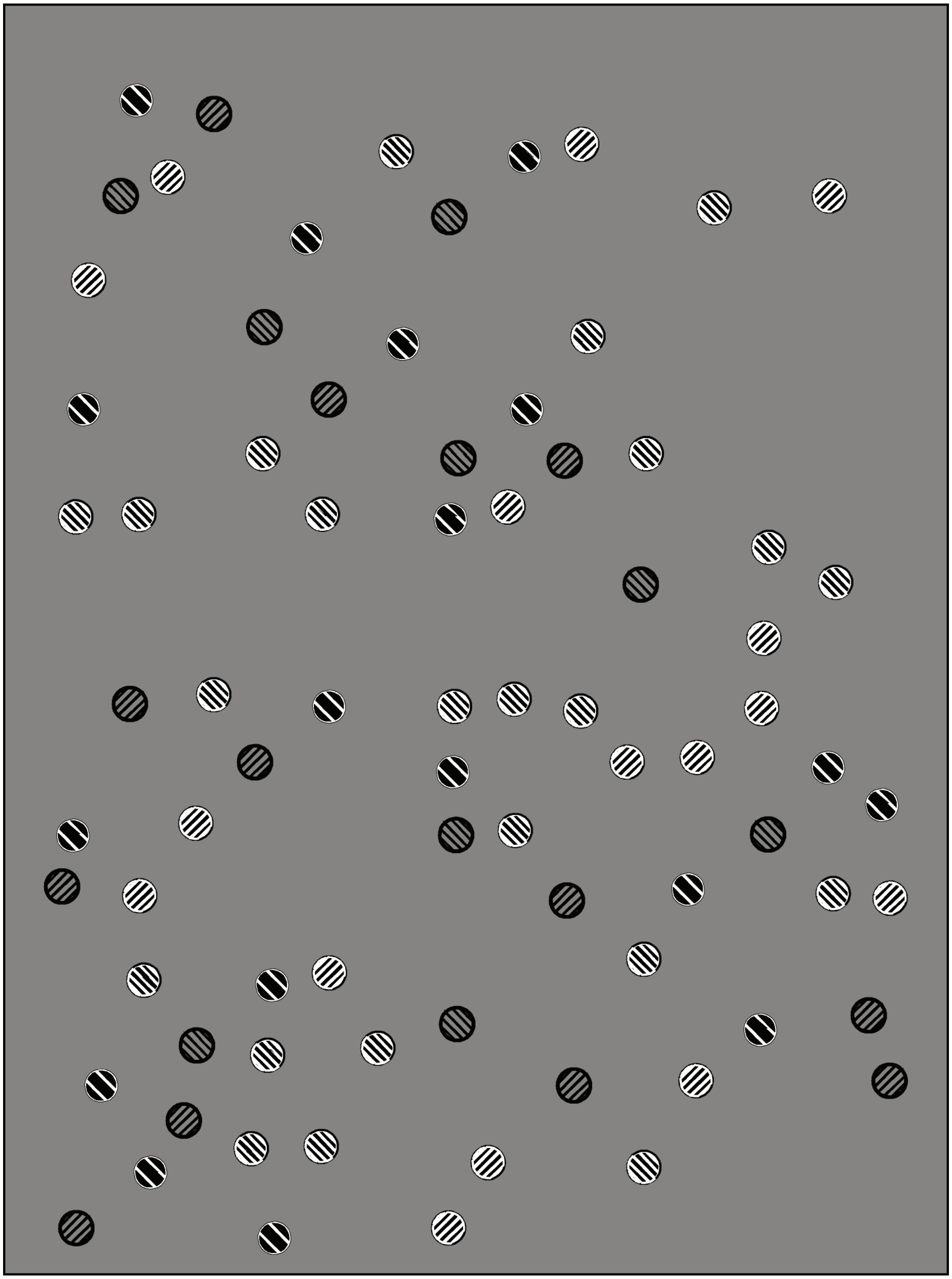


Figure 8. Example of the gray background with complex geometric symbols.