This is to certify that the

dissertation entitled

MAP READING FOR ROUTE SELECTION:
LATERAL PREFERENCE, PERFORMANCE AND STRATEGIES

presented by

Kathryn Ford Thorne

has been accepted towards fulfillment
of the requirements for

Ph.D. degree in Geography

Major professor

Date 9/3/91

MAP READING FOR ROUTE SELECTION:
LATERAL PREFERENCE, PERFORMANCE AND STRATEGIES

By

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A DISSERTATION

Submitted to
Michigan State University
in partial fulfillment of the requirements
for the degree of

DOCTOR OF PHILOSOPHY

Department of Geography

1991

ABSTRACT

MAP READING FOR ROUTE SELECTION: LATERAL PREFERENCE, PERFORMANCE AND STRATEGIES

By

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Current theory proposes that spatial ability determines map reading ability. This theory is drawn from studies of map memorization and the use of thematic maps. Earlier studies have found little or no relationship between scores on tests of spatial ability and map reading for route selection and subsequent navigation.

The basis of this lack of relationship may lie in the tests of spatial ability employed in the studies. These tests may be too narrow in their focus to tap the abilities used in map reading. Alternatively, in a task as complex as reading a road map, abilities may affect only the strategies used to extract the information, not overall performance.

A broader measure of spatial/verbal ability may better reveal the basis of individual differences in map reading. This study examines lateral preference as a possible basis of individual differences in map reading for route selection. Lateral preference, or right/left brain dominance, is believed to underlie individual differences in spatial and verbal ability. Lateral preference may also influence the strategies used in problem solving.

One hundred and fifty subjects completed Dean's Lateral Preference Schedule. Forty-three subjects, selected from this pool, completed a map reading test. The test asked the subjects to locate points on a commercially available street map of Atlanta, describe a route, explain the strategy used, list useful map features, and estimate distance and travel time. Subjects were then asked to describe their travel and map reading experience and assess their map reading ability.

No relation was found between lateral preference and map reading performance. Some minor, but non-significant, trends appeared in distance estimation strategies and travel time estimations. Only two relationships proved significant: women tend to rate themselves as poor map readers, and those subjects with more travel experience performed the map reading tasks more rapidly. The gender difference in self-asssessment did not extend to map reading performance.

ACKNOWLEDGMENTS

I thank my advisor, Judy Olson, for her patient guidance over the long years needed to develop this research. I would also like to extend my thanks to my dissertation committee, Richard Groop, Jay Harmon, and Tom Carr, who steered me safely around the pitfalls of research design.

I also owe thanks to Waubonsee Community College, particularly to David Murphy and Ronald Gilkerson of the Department of Behavioral and Social Sciences who let me use their psychology students in my study and the students who participated. Holly Towrey, of the Atlanta Regional Commission, provided the traffic flow information used in the analysis. John Long and the staff of the County Boundaries Project at the Newberry Library also deserve my thanks for providing the flexible work schedule I needed to collect the data for this study.

Finally, I want to thank my family for their moral support. I especially thank my husband, Keith, for his judicious use of his "nagging rights."

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CHAPTER ONE

OVERVIEW OF THE STUDY

Introduction

Different people view road and street maps in very different ways. Some correctly consider maps to be compact, simplified representations of large complex environments. These people are quite capable of selecting routes from the flexible network of paths portrayed in a map. The map, in the hands of such a traveler, plays an important role in navigation in a novel environment. Verbal instructions based on landmarks ("Turn right at the convenience store...") are acceptable to this type of traveler. However, a trip through unfamiliar territory will usually send them to a map even if only to derive a set of instructions. This group of people, which seems to include most cartographers, uses maps with such ease that, to them, map reading is taken for granted.

Many people, however, seem to have difficulty with the spatial relations presented by a map. Some sufferers of "map phobia" also find road maps so visually complex that they seem overwhelmed by the mere appearance of an urban street map or a highway map of a populous state. These frustrated travelers may then resort to some other source of navigation information, often verbal instructions from friends or local service station attendants.

What accounts for these differences in the ability to extract navigation information from a map? What makes a good map reader good and, even more important, what accounts for the confusion experienced by a bad map reader? Does this confusion really exist or do people who have no standard of comparison simply believe that they are poor map readers?

This study examines the time required for subjects to describe a route from a commercially available street map and the number of errors made in the description. A wide range of performance measures is then examined in relation to the lateral preference of the subject. The inclusion of several performance variables examines several small ways in which spatial or verbal ability may play a role in map reading. The study also observes, in many cases for the first time, a number of the difficulties people experience in reading street maps.

Background

A widely accepted theory suggests a dichotomy between spatially adept people who like and use maps and spatially inept people who prefer verbal directions (Petchenik, 1989;

Streeter and Vitello, 1986). This dichotomy is predicated on what we know of the role of spatial ability in the formation of mental, or cognitive, maps. Thorndyke and Goldin (1983) noted a significant relationship between tests of the ability to rotate shapes mentally and the ability to memorize spatial information from a map. The Ekstrom-French kit of tests, one of which is a map recognition test, also relates map memorization to spatial ability. The tests in the Ekstrom-French kit are selected because their results consistently load on common factors, thus suggesting a common underlying ability.

Predictions based on the aspects of spatial ability measured by standardized tests, however, fail to predict adequately performance in reading road and street maps and using the information to navigate. Thorndyke and Goldin (1983) identified good and poor cognitive mappers and observed that the good cognitive mappers scored higher on spatial ability tests, but good cognitive mappers were no better than poor cognitive mappers in reading maps and navigating.

Lorenz and Neisser (1986) performed a factor analysis of scores on navigation performance and on a battery of psychometric tests of spatial ability. The analysis showed that the "environmental" variables (navigation performance) were independent of the spatial ability tests.

In an earlier study of symbol design (Thorne, 1988) the subjects seemed to have no trouble with the spatial aspects of the map reading task. Instead the subjects experienced difficulty in attending to detail such as highway ramps and dead end streets. The subjects also misinterpreted many of the symbols in very creative ways. These misinterpretations suggest that people find it more difficult to attach the correct attributes to a symbol than to determine the spatial relations between symbols.

Problem Statement

The problem addressed in this research is the explanation of individual differences in map reading for navigation. To date no studies have focused specifically on navigational map reading tasks. Previous studies have related map learning and thematic map reading to variation in performance on standardized tests of spatial ability, some using gender as a surrogate measure of spatial ability.

The small amount of information we have extracted about map reading for route selection comes from the secondary observations of these studies. Thorndyke and Goldin (1983) were specifically interested in identifying the characteristics of good map learners, not good map readers. Wulf (1978) examined the relationship between spatial ability and the ability to extract information from a wide variety of maps ranging from dot maps and air photos to state highway maps. Lloyd (1989) was examining the nature of cognitive maps when he noted differences in the magnitude and direction of errors when subjects estimated distances from mental maps as opposed to estimating distance from a map that was present on the computer screen during the estimation process.

These studies, for the most part, found little or no significant correlation between spatial ability and performance in road map reading. Such results are possibly due to the intervention of problem-solving strategies. French (1965) found that variations in strategies seemed to cause scores on some tests of cognitive abilities to load on different factors in different groups of test subjects. These strategies appeared in the performance of the visually more complex tests of spatial ability. As maps are both visually and intellectually more complex than the patterns used to test spatial ability, map reading may offer even greater opportunities for the use of alternative strategies in the performance of spatial tasks.

The measure of spatial ability used here is somewhat different from those used in earlier studies. Previous studies tested the relationship between map reading ability and the ability to mentally rotate and fold shapes or to extract concealed patterns. French (1965) suggests, however that such tests may not accurately reflect a particular ability. He observed that people with different strengths and weaknesses may draw on their strongest abilities and develop alternative strategies to solve test problems. The existence of these strategies may be reflected in the tendencies of test scores for particular items to shift factors from one group of subjects to the next.

Examination of the literature on spatial abilities indicates that hemispheric laterality may be a clearer measure of spatial ability. Studies of task performance in limited visual fields as well as physiological measures of brain activity indicate that the two hemispheres of the brain perform different types of tasks (Allen, 1982; Kosslyn, 1987).

Theories of hemispheric laterality state, in simplest terms, that the left hemisphere of the brain processes language and the right processes spatial information. The left brain performs serial processing, the right brain parallel processing. Lateral preference is not a simple dichotomy, however. The degree to which the left hemisphere dominates language processing varies between individuals. Annett (1984) has identified what she terms "bilateral speakers" in whom the right hemisphere plays a major controlling role in speech. This variation in hemispheric control of language has been put forth as an explanation of individual differences in problem solving and task performance (Beaton, 1986). Such basic individual differences may also underlie variations in map reading performance.

Assumptions

The major assumption in this study is that handedness reflects lateral dominance. "Handedness," in this case, refers to the preference for the right or left hand in a variety of tasks, not just writing. Annett (1984) has pointed out that social pressure has a strong influence on which hand one uses to write. However, few people have had their hand slapped for flipping a light switch with the "wrong" hand. Handedness is still not a completely accurate measure of lateral preference. Left handed subjects are not necessarily right hemisphere dominant; they only have a greater chance of being right dominant. The experimental design also assumes that lateral dominance is the best indicator of spatial ability. This relationship is strongly suggested by the bulk of research on lateral dominance.

The challenge, then, was to design a study that focussed on the role of lateral preference in the ability of people to extract route information from a road or street map.

Brief Description of the Study

One hundred and fifty subjects completed Dean's Lateral Preference Schedule (Dean, 1982). The scores on the Visually Guided Activities section of the Laterality Preference Schedule were stratified into three groups and fifteen subjects were to be drawn at random from each group to complete the map reading test. Only twelve subjects qualified as right hemisphere/mixed dominant so all twelve completed the map reading test.

The stratified sampling procedure ensured roughly equal representation from the entire range of scores as the full sample of 150 was heavily left hemisphere dominant, as is the general population. Forty-three subjects completed the map reading test: sixteen left hemisphere dominants, fifteen mixed dominants, and twelve right/mixed dominants. The additional left hemisphere dominant subject was tested in an attempt to reach the original target of forty-five subjects.

After the route selection task the subjects provided an immediate retrospective written protocol. The next portion of the test requested a list of map features that the subjects found particularly useful. Subjects constructed this list from memory and were not allowed to consult the map during this portion of the test.

The subjects then provided an estimation of the distance along one of the routes they had described and an estimate of the time required to traverse this distance. The last three questions asked the subjects to describe their travel experience and map reading experience and to rate themselves as map readers.

The next chapter provides a more detailed review of the literature. Chapter three describes the test procedure in detail. Chapter four presents the data analysis and results. Chapter five discusses the implications of the study results and presents conclusions and suggestions for further research.

CHAPTER TWO

REVIEW OF RELEVANT LITERATURE

In the following review of literature I first discuss the nature of map reading for navigation, particularly for route selection, and how this type of map reading differs from the more widely studied thematic map reading and the formation of cognitive maps. I then consider the findings of the existing literature on individual differences in map reading. The final sections review the relevant literature on lateral preference and differences in problem solving strategies.

The Nature of Map Reading for Navigation

The term map reading, as it is used in the literature, includes a wide range of tasks. Map reading, in some studies, refers to the encoding of map information into memory. In other contexts, map reading describes the process by which the map user changes his or her concept of the area portrayed in the map.

This study focuses on route selection rather than map reading in the broader sense. No attempt is made at this point to bridge the gap to *way finding* by asking the subject to move through the environment represented by the map. Neither will the subjects be tested for recall, or *map learning*.

The distinction between printed and cognitive maps is crucial, as much of what we have assumed about map reading is drawn from studies of cognitive maps. However, Lloyd (1989) found different patterns of errors between tasks performed using maps and the same tasks (estimates of distance and direction) performed using cognitive or memorized maps. The subjects who used printed maps consistently overestimated distances. Those who used cognitive maps overestimated short distances and underestimated long distances. He suggests that these disparate error patterns may indicate the use of different mental processes in the extraction of information from printed maps as opposed to cognitive maps.

The other source of information about map reading comes from the literature on thematic maps. Again, this literature may provide little insight into map reading for navigation. The difference between route selection and thematic map reading exists in both the procedures followed and the type of information desired.

This difference can be expressed in the terms used by Robinson and Petchenik (1976). The student studying a landform map in preparation for a geomorphology exam is very likely a *percipient*, one who wishes to obtain broad spatial knowledge from the map for long-term storage. The business woman who has just rented a car and is searching for a route from the airport to her client's office is a *map user*. She probably uses the map to form a limited set of expectations about a novel environment that will guide her from one point to another and allow her to monitor her progress. She is probably interested in only short-term storage of this information.

One of the distinctive characteristics of map reading for navigation is the need for concern for detail as much as for global information. The few researchers who have considered this type of map reading in its own right note the over-riding importance of detail. Pick and Lockmann (1983) and Hill and Burns (in Sholl and Egeth, 1982) suggest that map reading for navigation is concerned more with specific features and less with global spatial information. This observation is supported in an earlier study by the author (Thorne, 1988). To plan a route that holds no unpleasant surprises, the map reader must pay careful attention to details such as expressway access and street connectivity.

Individual Differences in Map Reading

Spatial ability and map reading

The presently accepted explanation of individual differences in map reading is that they are based on differences in spatial ability. Streeter and Vitello (1986) state that map reading "...is highly associated with normal variations in spatial ability." Based on their study of map memorization performance and self-assessment of map reading ability, these researchers estimate that approximately 64% of the general population cannot easily read road maps.

However, their study did not directly test map reading performance, other than a "map-planning test," which used a stylized grid with a few points added as "buildings" or "roadblocks." Instead they summed their subjects' responses to a number of questions regarding their ability to use maps and their enjoyment of maps. The study did find some correlations between navigational self-assessment and maze tracing, map memory, and building memory. While all these tasks are classified, through factor analysis, as spatial tasks, nothing in the study firmly ties these tasks to actual navigation performance or even map reading performance using real maps.

Spatial ability, as examined in studies of map reading and map learning, is generally what Ekstrom calls spatial visualization, "...the ability to manipulate or transform the image of spatial patterns into other visual arrangements" (Ekstrom, French and Harmon, 1979). Performance of tasks that require map learning is consistently related to these measures of spatial ability.

The link is not so clear, though, between map reading tasks and spatial ability scores. Thorndyke and Goldin (1983) found they could divide their subjects into two distinct groups--"good cognitive mappers" and "poor cognitive mappers"--based on map learning performance. These two groups differed significantly on tests of spatial ability. They did *not* differ in their ability to read a map and to navigate using the information they extracted from the map. In Thorndyke and Goldin's study the subjects navigated through a complex of buildings at the site of the experiment.

The relationship between map reading and spatial ability scores also varies with the type of map reading tested. Wulf (1978) found that the ability to read a highway map was much less strongly correlated with the spatial ability score than the ability to read and interpret a dot map.

Dot maps are thematic maps created to represent the spatial distribution of some phenomenon. Each dot of ink represents a certain value, for example 500 people. The dots are then clustered or scattered according to the known distribution. Dot maps are highly spatial in nature, their goal being to communicate a global representation of a distribution without concern for detail of the specific location of individual items (Figure 1). Wulf's finding provides further evidence that thematic map reading and map reading for navigation are fundamentally different in nature.

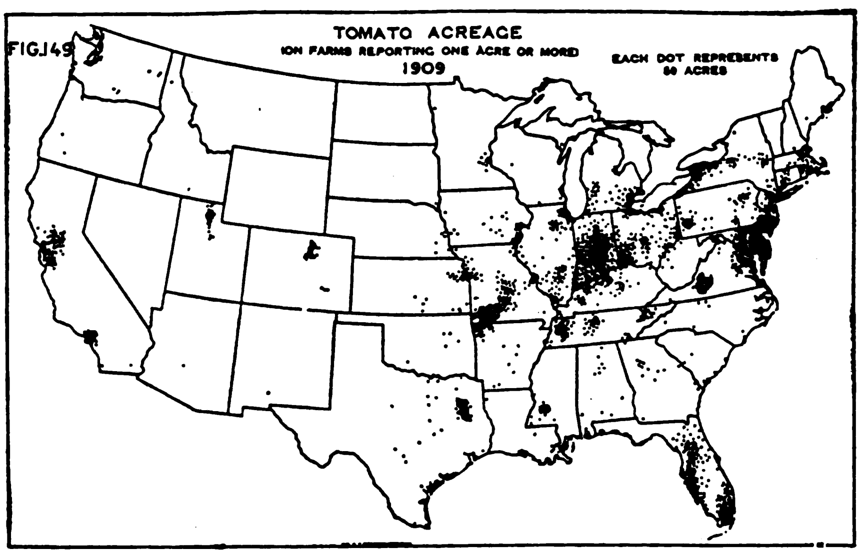


Figure 1 - A dot map (from Finch and Baker, 1917)

Wulf (1978) suggested that the difference in map reading performance between road maps and thematic maps may reflect the greater familiarity of the populace with road maps. However, Streeter and Vitello (1986) found a very low level of experience with maps of any sort among their subjects. Phillips (1979) noted that "... for most people, map reading is an important but relatively infrequent activity." Schoppoert and others in a 1960 study (in Blades and Spencer, 1987) found that only 17% of their interviewees referred to a map for navigation information. Cross and McGrath (1977) found a much higher percentage of map users (55%) in their survey. Ford (1986) found a 50% rate of map use in a survey of travelers.

It is not clear from the evidence available whether experience plays any major role in map reading. It is also unclear how well Wulf's subjects (university dormitory residents) reflect the performance of the general population. It may be that a number of her subjects had enough experience with road maps to account for the difference in scores. However, some of Wulf's road map tasks (such as determining the direction of flow of rivers) had little relevance to normal road map use and would seem unlikely to be affected by normal experience with road maps. It seems more likely that the performance differences between thematic maps and road maps may be related to the different nature of these two types of map reading.

Gender differences and map reading

A number of studies (Chang and Antes, 1987; Gilmartin and Patton, 1984; Wulf, 1978) examine gender differences in performance of map reading and map learning tasks. These studies look for evidence in the performance of map reading tasks of the expected gender difference in spatial visualization ability, defined as the ability to mentally manipulate objects.

The apparent gender difference in performance of spatial visualization tasks is probably one reason for the numerous studies of this particular ability. Maccoby and Jacklin (1974), in their review of the literature on gender differences, include spatial visualization in their short list of "fairly well established sex differences." Male superiority over females in spatial visualization peaks at about .40 of a standard deviation at age eighteen. However, the reviewers note that the majority of studies show no significant difference, hence the very minor difference noted in the review. Many of the early and often cited studies of gender differences did not even test for statistically significant differences (Caplan, MacPherson and Tobin, 1985).

There is no consensus on whether the basis of the gender difference in visualization ability is cultural (Kagan, 1982) or biological (McGee, 1979). Feingold (1988) performed a meta-analysis of spatial ability scores on the Differential Aptitude Test collected between 1947 and 1980. He found a steady decrease in the performance difference that suggests a cultural basis. Conversely, other studies have linked performance to hormone cycles (see Weiss, 1988), suggesting a biological basis.

Gender based differences found in map reading seem to vary with the task performed. Wulf (1978), rather interestingly, found no significant gender difference in performance on the spatial abilities test that she administered in her study. However, she did find a significant gender difference in "map understanding," the composite score of map reading performance on several types of maps.

In Chang and Antes' study (1987), males performed significantly better on the tasks that required the use of topographic and reference maps but not on those tasks performed with street maps. Gilmartin and Patton (1984) also found no gender difference in the ability to read street and road maps.

Chang and Antes' study (1987) raises the issue of cultural differences as an explanation of performance differences. The study was conducted in North Dakota and Taiwan. The Taiwanese females significantly out scored the North Dakotans of both genders in topographic map reading as well as in street map reading.

The consistent lack of a correlation between spatial ability (and its surrogate, gender) and the ability to read a road map suggests that variations in spatial ability, as measured by psychometric testing, may not be responsible for individual differences in map reading ability.

It may be that the spatial tests generally used do not capture the aspects of spatial ability that are important to map reading for route selection. This failure to capture the abilities used in map reading seemed clearly indicated in Lorenz and Neisser's (1986) finding of independent factors for "psychometric" and "environmental" measures of spatial ability. The instability of spatial test scores in factor analysis suggests that, perhaps, we should look deeper for variations in ability. In an effort to better understand the nature of spatial ability (and other abilities) let us next examine the literature on lateral preference and its relationship to cognitive abilities.

Lateral Preference

Laterality studies are concerned with the performance advantage of one cerebral hemisphere over the other in a given range of tasks. The task of interest in a study may range from verbal production and fine motor control to face recognition and control of emotional state.

Interest in the differential roles of the cerebral hemispheres grew out of observations, collected in the late 1800's, of the differential effects of brain injuries. Researchers found that damage to the left temporal lobe (Figure 2) almost always resulted in aphasia or loss of speech. Since the left hemisphere seemed responsible for speech, it was long considered the dominant hemisphere in "normal" processing (Beaton, 1986).

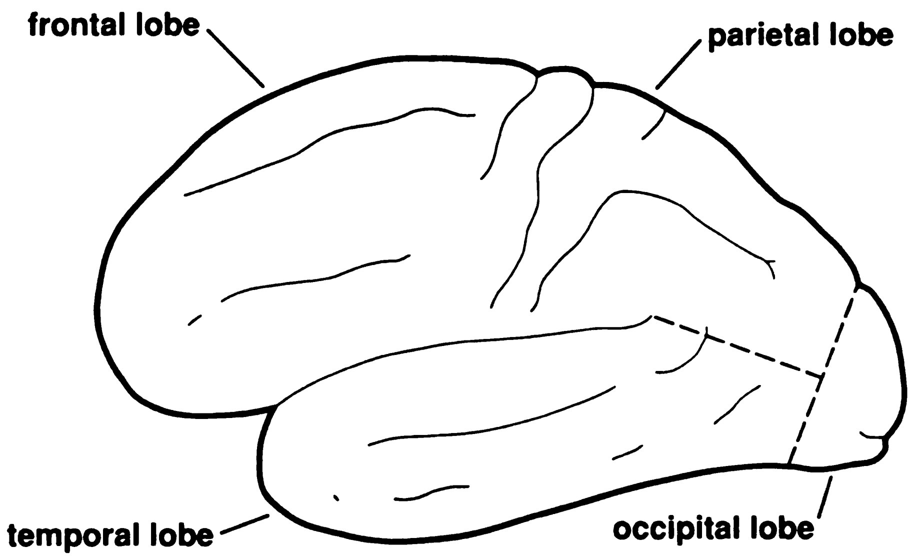


Figure 2 - The lobes of the brain (from Beaton, 1985)

In the early 1960's further research revealed that the right hemisphere was actually superior in non-verbal processing (Beaton, 1986). This revelation spurred a new interest in laterality. In 1982, Allen estimated that three to four articles on laterality were published each week.

Numerous methods exist for the evaluation of hemispheric activity. The oldest method is the observation of the results of brain damage and the postmortem examination of the structure of the brain. Modern physiological measures include measures of cerebral blood flow and electrocortical activity. A number of non-physiological measures are also used: visual half-field studies, dichotic listening, lateral shift of gaze during cognition and measures of handedness (Levy, Heller, Banich, and Burton, 1983).

The assumption that handedness reflects lateral dominance for a specific task is reinforced by physiological measures. Both EEG and cerebral blood flow measures in right handed individuals show increased left hemisphere activity for verbal tasks and increased right hemisphere activity for spatial tasks (Levy, Heller, Banich, and Burton, 1983). Note that this increased activity is observed in right handers. Evidence suggests that the right hemisphere has some degree of language function (Corballis, 1983) and that this function may be enhanced in some left handers, whom Annett (1984) refers to as "bilateral speakers."

The existence of such bilateral speakers is one indication that lateral dominance is not a clear cut right/left issue. Careful observation of task performance reveals that handedness is not a dichotomy as would be expected but rather a continuum (Annett, 1984; Beaton, 1986). Some people use the right hand consistently for all tasks, others vary hand use for tasks such as throwing a ball, opening jars, and using scissors.

The discovery of the extent and nature of individual differences in lateral dominance has led to a shift of favor from simple, structural theories of laterality to information processing models (Allen, 1982; Beaton, 1986). The unilateral, structural models suggest that the hemispheres are highly specialized--the left manages verbal tasks and the right, spatial. Bilateral interaction models, particularly information processing models, suggest that not only are the hemispheres much more flexible than they previously were thought to be but tasks are not always clearly verbal or spatial.

Allen (1982) suggests that tasks are not unitary entities but are composed of subprocesses. These subprocesses are then distributed to subprocessors located in either hemisphere. The more complex the task, the greater the flexibility in allocation of the subprocesses. In a bilateral interaction model these subprocessors would be split between the hemispheres. Thus it would be difficult to categorize a complex task as verbal (left hemisphere) or spatial (right hemisphere).

The allocation of the subprocesses is quite likely controlled by the strategy employed by the subject (Beaton, 1986). Segalowitz (1984) notes a strong relationship between lateral dominance and strategy or style of problem solving. However, the causal nature of this relationship is not yet clear (Segalowitz, 1984).

Kosslyn (1987) suggests a useful information processing model for the control of visual search procedures in which a right hemisphere, global processing mechanism controls the location of an "attention window." A left brain, detail processor then identifies the content of the window. Learning and thus individual differences would result from a "snowball mechanism" that decreases resistance along frequently used neural pathways. The subject's favored strategies over time would determine which hemisphere becomes dominant for most tasks.

Researchers still disagree over the exact nature of lateral dominance. Psychologists have developed two classes of bilateral cooperative interaction models: positive interaction and negative interaction or inhibition (Allen, 1982). In positive interaction, the hemispheres work together to process information. In this case, mixed laterality for language may actually hamper spatial processes as part of the capacity normally allocated to spatial processing is consumed by language processing (Annett, 1984). This model predicts that a highly dominant left hemisphere in verbal processing clears the right hemisphere for processing spatial information.

On the other hand, some studies show strong evidence that the dominant hemisphere suppresses activity in the non-dominant hemisphere (Levy, Heller, Banich, and Burton, 1983). In an inhibition model, a person with a strong preference for the right hand would have difficulty with spatial processes due to the suppression of all activity in the right hemisphere by the dominant left hemisphere. Under the inhibition model, a subject with mixed dominance (mixed hand preference) would perform better on spatial tasks as the right hemisphere is less strongly suppressed by the left hemisphere and so is freed to perform spatial tasks.

Inhibition by the dominant hemisphere might explain the large proportion of the population that is believed to have difficulty with spatial tasks (64% according to Streeter and Vitello, 1986). About 90% of the population is right handed (Hassett, 1984). About 97% of right handed people and 68% of those with mixed and left hand preference are left hemisphere dominant for language (Corballis, 1983). In these people, activity in the right hemisphere would be suppressed. It is not clear exactly what types of activity are suppressed by the dominant hemisphere in this case. It may be that the verbally dominant left hemisphere only suppresses verbal activity in the right hemisphere (Beaton, 1986; Corballis, 1983).

However the dominant hemisphere expresses its status, lateral preference may not have an overriding effect on the final product of complex tasks such as extracting information from a road map. The ability to develop alternative strategies with practice (Kosslyn, 1987) and the flexibility of allocating subprocesses (Allen, 1982; Kosslyn, 1987) may explain the failure of the attempts to link road map reading to the performance of spatial tasks. Map reading may be a different type of task for different people, a varied combination of verbal and spatial activities.

Consider, for example, the following list of "right hemisphere" tasks gleaned from the neuropsychological literature on task performance by brain damaged subjects (Corballis, 1983): figure-ground differentiation, visual synthesis, visual location, judgments of the direction of a line, memory for familiar environments, visuoconstructive ability, mental rotation, and maze learning. All these tasks seem similar to those performed in map reading and navigation. However, two studies of navigation in brain damaged subjects do not support predictions based on performance on spatial tests.

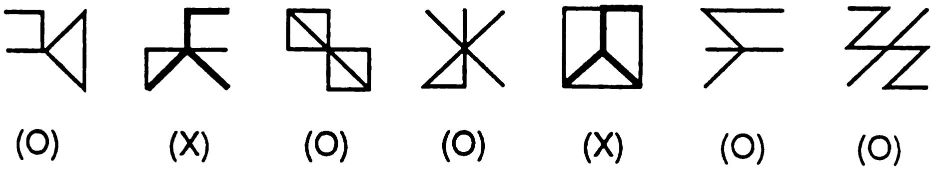
Semmes (with Weinstein, Ghent, and Teuber, 1955) administered a navigation test to subjects with damage to one or both parietal lobes. Neuropsychological studies had indicated that spatial information is processed in the right parietal lobe (Figure 2) (Benton, 1985). The experimenter asked the subjects to follow a route between dots painted on the floor as represented on a map that the subject carried while navigating the course. Semmes found that subjects with left parietal damage performed just as poorly as those with right or bilateral damage. The only significant difference in performance existed between the control subjects and all types of brain damaged subjects. Ratcliff and Newcomb (in Benton, 1985) repeated Semmes' experiment and found that subjects with bilateral posterior injuries performed poorly.

These unexpected results seem to suggest that map reading and navigating may be "whole brain" tasks. As map reading is a much more complex task than most of the tasks used in assessing spatial ability, map reading may offer even more latitude for variance in the allocation of subprocesses. Thus damage to any of the portions of the brain that process information may hinder map reading and navigation performance. It is then not surprising that map reading ability seems not to correlate with measures of spatial ability. This allocation of subprocesses is the information processing terminology for what we normally call strategies.

Individual Differences in Strategies

Inconsistency in factor composition of scores on psychometric tests of cognitive abilities led French (1965) to hypothesize that different subjects solved the test problems in different ways. Through questionnaires and interviews, he determined that there was a dichotomy in problem solving styles. French designated the dichotomy as "systematizing" versus "scanning." The subjects who practiced a systematic strategy devised explicit rules to apply to the tasks. These rules used details of visual images to solve visual/spatial problems. When subjects used such reasoning to solve embedded figure problems (Figure 3), this task left the space-visualization factor and loaded instead on a reasoning factor.

French's observation has been replicated. Shore and Carey (1984) studied spatial problem solving in gifted children and found a similar dichotomy. Those children who scored above the median on both the Block Design and the



figures containing the target figure are marked with an "X"

Figure 3 - Embedded figure problem (from Eliot and Smith)

Vocabulary tests of the Wechsler Intelligence Scale for Children used an implicit spatial strategy to perform the rod and frame test, which asks subjects to adjust a rotating rod so that it is vertical to the floor regardless of the orientation of the surrounding frame. These spatially gifted subjects could not clearly express how they had solved the test problem. Children who scored above the median on verbal ability with only an average score on the spatial ability test were still able to perform well on the rod and frame test. However, these children expressed strategies. Some were even observed to talk their way through a solution during the test.

Shore and Carey (1984) collected a retrospective protocol, asking for a report of the problem-solving procedure after the task was completed. The fact that those subjects who seemed to use a spatial strategy could not explain how they solved the problem suggests that they did not verbalize, even "mentally" during the procedure. Ericsson and Simon (1984) suggest that information that is not verbalized is not moved from short-term memory to long-term memory. Therefore, this unvocalized information would not be available for a retrospective protocol and "spatial thinkers" would have very sparse information on their strategies.

The expected variation in strategies has been observed in studies of map reading and of way finding. Griffin (1983) identified four different strategies assembled from the subtasks listed in Table 1. These strategies were used by his subjects to compare a map of political units with a distorted representation (Figure 4). The most successful strategy, both in speed and accuracy, used the center of the map as an anchor and constructed a chain of units as a guide to the target unit. This would qualify as a detailed verbal "analytic" strategy as the subjects were able to identify distinct steps in their problem solving process. The least successful and yet most spatial strategy searched comparable locations of the two representations.

Blades and Spencer (1986) found variations in the strategies that subjects used in way finding. Some subjects noted left and right turns and the number of blocks between turns. Others were careful to note street names with less emphasis on counting blocks. These results were collected in a pilot study and the published report includes no information on error rates.

Table 1

Map Reading Tasks and Procedures (Subprocesses)
(from Griffin, 1983)

Task	**Observed Procedures**
Establish a reference system	select central unit select prominent boundary unit select visually significant unit near target unit directly transfer spatial position from display to distorted display

Task	**Observed Procedures**
Search	develop a chain of topological relations to measure distance between units determine angular relations between units search along boundary of display and work inward to target

Task	**Observed Procedures**
Matching	match a pair of display units to act as a reference point match shape of target unit

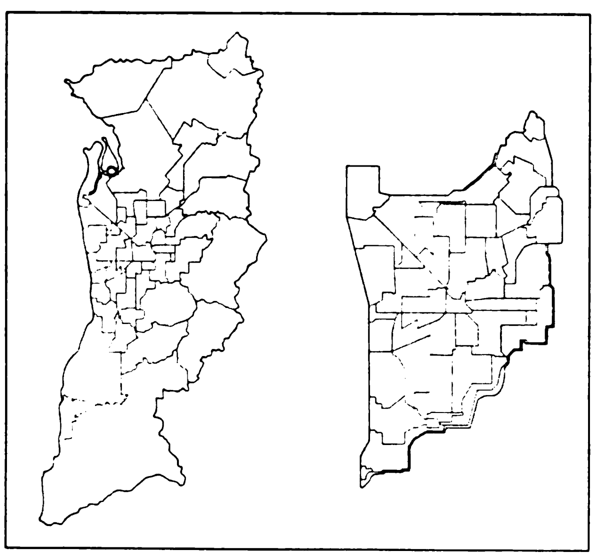


Figure 4 - Map and cartogram used in Griffin's study

Thorndyke and Stasz (1980) conducted a detailed study of map learning strategies. They defined good map learners as those who learned 90% of the map elements presented after a maximum of six two-minute study sessions. These good map learners were significantly more likely to use systematic and memory directed sampling in allocating attention, and rehearsal, counting, imagery, pattern encoding and relation encoding in encoding the information. Poor map learners were more likely to use random sampling to allocate attention.

Experienced map readers did not necessarily possess effective map learning strategies. Two of the experienced subjects ranked third last and last in map learning performance. A further experiment found that subjects trained to use effective strategies recalled significantly more map elements than control groups who received neutral training, or no training. However, training in effective strategies did not erase differences in map learning performance. Subjects who scored high on visual memory gained much more from the training than those who scored lower on visual memory.

Variations in procedure also appeared in a pilot study for the test developed for this study. Subjects used either "global" or "detail oriented" strategies to perform a distance estimation task. Subjects were asked to give the distance in miles across a map segment. Some subjects visually estimated the width of the segment and compared it to the bar scale. Others added up the mileage notations between the intersections of a road that ran the width of the inset.

Variation in strategy clearly plays a role in map reading and map learning. The identification of strategies poses a difficulty, however. Blades and Spencer (1986) question the validity of verbal protocols; it is not clear that subjects are really solving the problems in the way they think they are. These authors suggest that choice of strategy may be revealed by the type of errors made by the subject rather than in the verbal protocol. Probably the safest course is to examine both the protocol and the errors.

People do vary in the way they store information about their environment. At least three different types of information have been identified (Freundschuh, 1988; Kuipers, 1982; Thorndyke and Golding, 1983). Though the terminology varies, the categories are consistent. The first category of spatial learning consists of the recognition of landmarks in the environment. In the next category landmarks are integrated into sets of verbal instructions that will take navigators from one landmark to the next. The third category adds bearings and distances. The people in this category can navigate simply on the knowledge that their destination is "over there somewhere."

Relation to the Current Study

The literature seems to suggest, then, that left hemisphere dominant people would develop a verbal, serial, detail oriented approach to map reading problems. Right hemisphere dominants would perform better using a spatial, parallel processing, non-detail approach with major emphasis on overall relations.

Kosslyn has presented the most clearly elaborated mechanism through which individual differences in lateral preference influence performance. His concept of a right hemisphere driven attention window and a left hemisphere identification device adapts very nicely to a possible explanation of map reading.

A right hemisphere dominant map reader would be quite adept at guiding an attention window around the map on the basis of gross features such as area tints or major highway patterns. However, this right hemisphere dominant map reader may pay for this ability with a deficiency in attention to detail. A left hemisphere dominant would be less adept at allocating attention across the reach of the map but much better at attending to details.

Kosslyn's theory accounts very nicely for variations in strategy in its snowball mechanism. In this explanation, early successes in problem-solving establish pathways between subprocessors. These pathways are then used in preference to alternatives. As a pathway is used, resistance along the pathway decreases, making it more attractive to future use. Thus someone who, at an early age, successfully derived a verbal solution to a spatial problem would be biased toward verbal approaches to novel spatial problems such as map reading.

Successful map reading combines elements of both types of information processing. Therefore, those map readers who can successfully employ both the attention window and the identification device may have the best overall performance. This possibility suggests that mixed dominance subjects may indeed be the best map readers. They may sacrifice a small amount of processing speed but benefit by missing fewer details.

Hypotheses

Consideration of the nature of different map reading tasks and the nature of the neurological systems responsible for spatial and non-spatial processing as depicted in bilateral information processing models of laterality suggests the following research hypotheses:

> Subjects whose laterality test results suggest a right hemisphere (spatial) bias will perform the map reading tasks using spatial information. These subjects will:

Require less time to complete the map reading tasks

Make fewer errors of reversed directions, either cardinal or egocentric.

Make more errors of missed details

Use cardinal directions in their route descriptions.

Subjects whose laterality test results suggest a left hemisphere (verbal) bias will use verbal information to perform the map reading tasks. These subjects will:

Require more time to complete the map reading tasks

Reverse directions instructions, either cardinal or egocentric (left and right)

Make fewer errors of missed details

Use egocentric rather than cardinal terms in their route descriptions.

The best overall map reading performance, with the most rapid performance and the lowest number of errors of either type, should be achieved by those subjects who fall into the mixed lateral dominance category on the screening test.

CHAPTER THREE

RESEARCH DESIGN AND EXECUTION

The first step in the data collection was the screening of a number of potential subjects to select a group from each category of lateral dominance. Selected subjects then completed a map reading test including a retrospective written protocol. The test booklet contained a number of additional questions, the answers to which may allow exploration of alternative models such as those in which map reading performance is based on map reading experience, self-assessment of map reading ability, or gender differences. The collection of a wide range of variables also increases the chances of observing important differences in map reading practices.

Main Independent Variable

The main independent variable was lateral preference. Prospective subjects completed Dean's Lateral Preference Schedule. This group-administered test measures hemispheric dominance for six categories of tasks: general handedness, visually guided motor activities, eye preference, ear preference, strength, and foot preference. Evaluations of this self-report inventory reveal a correlation of >.80 with performance for each item requested and a test-retest coefficient of .91 (Dean,1982;1989).

This multi-task inventory should provide a better measure of lateral dominance than does a simple observation of which hand is used for writing. Handedness for such tasks as writing and eating is subject to social pressures, which pollute these observations as measures of laterality (Annett, 1984).

The different segments of the Lateral Preference Schedule, at least for the participants in this study, are not strongly correlated with one another nor with the total test score. For the 150 subjects screened for this test the correlation of the Visually Guided Activities score with the total score was only .195. However, the scores on this segment of the test--Visually Guided Activities--are most closely related to physiological measures of laterality (Dean, 1988). This measure of reaching, pointing, and grasping also seemed likely to best capture the tasks encountered in map reading for route selection. Thus the Visually Guided Activities score rather than the total Lateral Preference Schedule score determined a subject's laterality category for my purposes. Rather curiously, the Visually Guided Activities score tended more toward mixed dominance whereas the General Handedness section of the

Lateral Preference Schedule indicated a clearer left or right preference.

The test manual for the Lateral Preference Schedule provides guidelines for categorizing responses. The nature of the score distribution precludes the classification of responses by the usual statistical means, which assume normally distributed data. The distribution of scores in the standardization sample is bimodal: a large number of subjects were left hemisphere dominant, a second mode appears in the right hemisphere dominant range, with the rest of the respondents scattered in the mixed range.

The manual therefore provides "prototype profiles" to suggest categorizations. To construct these profiles, scores are calculated for each segment of the test for hypothetical subjects who consistently answered right mostly, left mostly, or right and left equally. Subjects whose scores for each segment of the test fall below the "right mostly" score are classified as right handed, left hemisphere dominant. Subjects whose scores fall above the "left mostly" score are classified as left handed, right hemisphere dominant. Subjects whose scores lie between the two, scattered about the "equally" score, are considered to have mixed hemispheric dominance.

These boundaries between categories are somewhat arbitrary, as they must be, since standardized scores cannot be used to divide a bimodal distribution. In this study, the categories served simply as a guide to subject selection. The subjects were selected at random from the strata suggested by Dean's prototype profiles. A totally random sample would, based on the Visually Guided Activity scores, have provided a preponderance of mixed dominance subjects.

The arbitrary nature of the category boundaries and the failure to find any subjects in the right brain dominant category encouraged an alternative approach to the data analysis. The dependent variables were regressed against the Visually Guided Activities score where appropriate. When the analysis required the construction of a contingency table, the Visually Guided Activities scores were split at the median to provide two categories.

Subjects

The composition of the subject pool for many map reading and psychological studies is the target of criticism. Critics suggest that many studies examine the characteristics of university undergraduates, not the population at large.

In an attempt to address this criticism this study tested community college students in two sections of an introductory course in psychology. While these students are still probably not representative of adults in the general population, they should provide a broader pool of subjects than could be found in university courses as the entrance standards are less stringent for community colleges and the costs much lower.

The volunteer effect is another pitfall to be avoided in recruiting subjects. If subjects are recruited on a strictly volunteer basis, those who enjoy map reading are more likely to respond. The students earned extra credit for completing the screening test (five points in one section and ten in the other). This chance to gain points probably attracted some of the more reluctant map readers.

Subjects for this study needed some familiarity with the demands of navigating on roads and streets. Therefore, only licensed drivers eighteen years and over were tested. The other limit on choice of subjects was the diminished visual acuity some people experience in late middle age. Some of the subjects in the pilot test had difficulty reading the names on the map without a magnifying glass. The use of a magnifier would tend to modify the map reading process and introduce new variables. Therefore, subjects were asked if they experienced any difficulty focusing on fine text. None of the subjects who participated in the study (maximum age thirty-three) noted any visual difficulty.

One hundred and fifty prospective subjects completed Dean's Laterality Preference Schedule. This test was administered to the students in their course sections as part of their regular class meeting. One subject who was absent on the day of the screening test yet still wanted the extra credit was tested alone. Each test sheet was marked with an identification number immediately after the completion of the test. This number served to label the data for the rest of the study.

These subject numbers were sorted into three separate computer files set up according to the ranges suggested by Dean for left, mixed, and right dominance. Fifteen subjects were selected at random from each of the two files for the left hemisphere dominant and mixed dominant subjects. Only twelve mixed/right dominant subjects completed the screening process so all twelve were used in the map reading study.

These 12 subjects' scores fell on the right hemisphere dominant side of the "always equal" score. None of the screened subjects scored in the right hemisphere dominant range, at least on the Visually Guided Activities section of the test. The three files of selected subject numbers were combined into a single file, sorted into numerical order (by their assigned subject numbers) so that the ID numbers were no longer grouped by laterality category, and printed. This procedure generated a list of subjects to be contacted for further testing without revealing the lateral preference of the subjects to the experimenter during the data collection.

Two of the selected subjects were only seventeen years old. These subjects were replaced with others from the same lateral preference category. Two volunteers were included from the screened subjects due to the difficulty of contacting two of the randomly selected subjects. The final balance of the subject pool was as follows: fifteen subjects from the left hemisphere dominant range, sixteen from the left/mixed dominant range, and twelve from the mixed/right dominant range.

The subjects selected for the map reading test ranged in age from eighteen to thirty-three; eighteen were female and twenty-five were male.

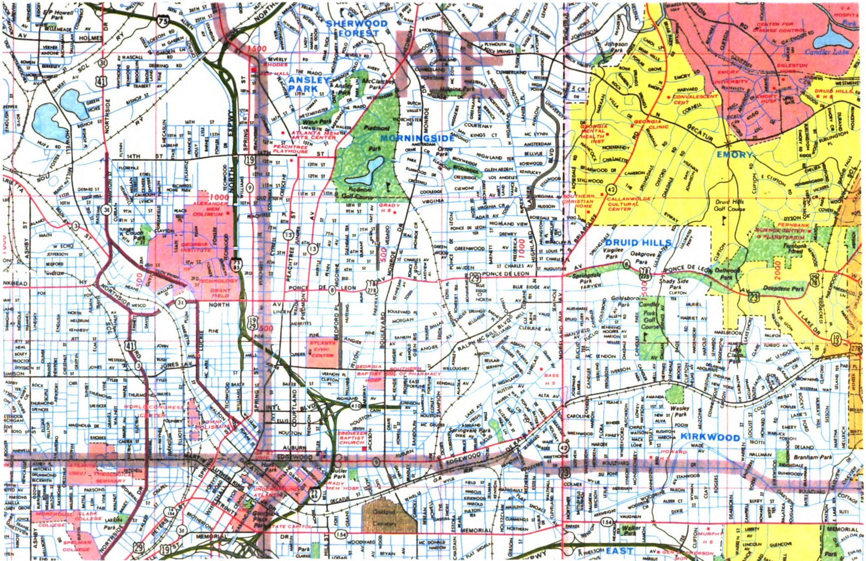
The Map Reading Test (see Appendix)

Each subject completed the map reading test in an individual meeting with the experimenter. Most of these tests were administered in an unused classroom in the building where the psychology class met. The last few tests were administered in a conference room at the community college library. The testing spanned six weeks with a one week break while the students were on spring vacation.

In each meeting, the subject took a seat across the table from the experimenter with ample space to spread out the map. The subject read the one page instruction sheet and indicated that he or she understood the tasks. The subject then unfolded the map and began to search for the destinations mentioned in the instructions. When the subject unfolded the map the experimenter started a tape recording. The tape ran until the subject completed the route descriptions.

The subjects were allowed to complete the map reading tasks without aid or interruption from the experimenter, though a number requested aid during the process. There was one exception to this policy, however. If, after five minutes, the subject still had not located and searched the downtown portion of the map, the experimenter pointed out the downtown. This adjustment of the procedure allowed collection of the rest of the data in the experiment, which may not have been possible had the subjects been allowed to quit in frustration. Due to this policy, however, we no longer know the extreme range of time required for map reading. One of the early subjects, tested before the adoption of this policy, needed twenty-nine minutes to complete the route selection task. Removal of these subjects who received assistance from the data base really made no change in the regression of performance time against lateral preference. It seems likely, therefore, that this assistance had no overall effect on the results.

Selection of a map for this study required careful consideration. The Rand McNally map of Atlanta served as the stimulus for the map test (Figure 5). Atlanta met the criteria set forth for the selection of a city. It has a compact shape that allows more flexibility in selecting directions for the "test route" than would a linear city. It has a network of interstate highways that offered the subjects a choice of travel on expressways or surface streets. It has no other major linear features such as a



From Atlanta Road Map © 1990 by Rand McNally Company R.L. 90-s-50

Figure 5 - Portion of map used in this study

major river or a coastline that would add an unwanted variable to the route descriptions. It also has both grid and non-grid street networks. Most important, it is a long way from the subjects being tested. Only one subject claimed any familiarity with the city, and he insisted that the map was "all wrong" because the route to the World Congress Center was not as he remembered.

The map test asked subjects to plan a route between designated points. The subjects described the route as if they were telling a driver how to proceed to a destination. Taping these descriptions had two advantages. First, it collected a complete audio record of the process including verbal expressions of confusion, dismay, and indecision. Second, the tape provided a timing device (about four and a half seconds elapse with each inch of tape that passes the read/record head). This timing device was found to be quite accurate and certainly suitable for time spans of five to thirty minutes such as were measured in this study.

The subjects next attempted to write a description of how they made their decisions. The protocol revealed the different goals of the map readers, an important consideration in evaluating map reading performance.

In the next step, the subjects listed, without referring to the map, the information they found most useful in their route selection decision. It was hoped that these lists would serve as an indicator of "heeded information" (Ericsson and Simon, 1984).

The last section of the test asked the subjects to look at the map again and estimate the route distance between the first destination and the final destination and to estimate travel time. This estimation indicated the subject's understanding of the environment through which he or she expected to travel.

The measurement of interest here is the deviation of this estimate from the estimated traffic speed provided by the Atlanta Regional Planning Commission. An average speed was calculated from the official estimate for the type of road the subject traveled for each portion of the route. These averages were then combined to provide an average speed over the entire route. These averages were calculated for both peak and off peak traffic (Table 2). The subjects' travel time estimates were then converted to miles per hour using each subject's estimated distance and compared to the official travel speeds.

Table 2

Road Type	**Off-Peak Speed**	**Peak Traffic Speed**
Freeway	55	40
Arterial(high design)	28	25
Arterial(med. design)	25	22
Arterial(low design)	22	20
Collector	18	16

The last segment of the test asked for a brief description of the subject's map reading and travel ex

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experience and a self-assessment, on a scale of one to six (poor to excellent) of map reading ability.

Dependent Variables

The major dependent variables then are the time required to locate the points and select and describe a route, and a count of errors. The measurement of performance time is quite straight-forward. The number of inches of tape that ran from the time the subject unfolded the map until he or she completed the route descriptions was divided by the inches that passed the read/write head each minute. The result of this division was the number of minutes required for each subject to complete the map reading task. The number of inches per minute depended on the quarter of the tape in which the route description fell, the divisor in the calculation, therefore, varied accordingly.

There were two general types of errors: detail errors and spatial errors. Detail errors are those where the subject tried to access or exit a limited access highway where there was no ramp, missed the name of a street, or failed to notice a discontinuity in the route. Many subjects described a route that led to the name of the destination rather than to the point symbol. This was also counted as a detail error.

The simplest detail error to count was the choice of a non-existent exit ramp. Even this tally was somewhat complicated in the downtown area. Some access ramps show up only on the inset. If the subject selected such an exit from the main map, this selection counted as an error. However, if the experimenter's notes indicate that the subject used the inset to plan the route, the selection was considered correct. If the subject went back to the interstate the same way he or she entered the downtown, on a non-existent ramp, the ramp error was counted twice. This method of defining errors assumes that the subject looked at the intersection again when selecting the return trip, though this may not always have happened.

Name errors were usually counted as detail errors. If the subject would have missed a turn because he or she was looking for the wrong name, the error was considered in the calculation of the approach ratio. For example, if the name of the street the subject was following changed and the subject failed to notice, the error probably would not cause the subject to get lost. The correct name, however, is crucial when searching for a cross street.

Subjects often failed to realize that one road could have a name and several numbers. The selection of the name or any one of the numbers was considered correct. Subjects often referred to state and US highways as interstates. This was not considered a name error, though perhaps it should have been, in that if subjects are looking for a limited access divided highway, they may miss the road they actually want to follow.

Spatial errors are those where the subject reversed the proper directions in describing the route. There are actually two types--word errors and spatial errors. In word errors, for example, the subject said "right" but from the succeeding instructions it is clear that the subject meant to turn left. In the other type of error, the succeeding instructions indicate that the subject actually meant to turn the wrong way. Only one subject actually committed this second type of error.

The most general measure of route planning success is the approach ratio. This ratio is calculated by dividing the straight line distance left to the destination when the subject made an error by the distance between the beginning of the route and the desired destination (Figure 6). Only errors that would necessitate revising the route were used to calculate the approach ratio. For example if a subject, who had planned to get on the expressway where no ramp exits, were actually to attempt to travel the designated route he or she would have to leave the planned trajectory at this point and search for an access ramp.

This ratio provides an estimate of the map reader's ability to avoid the pitfalls of route selection--a subject who made a fatal error only "one inch" from the destination successfully negotiated more intersections than the subject who ran through a dead end street within a block of the starting point. What is not reflected in this measure is whether this success was due to map reading prowess or shear good fortune in the initial departure from the starting point.

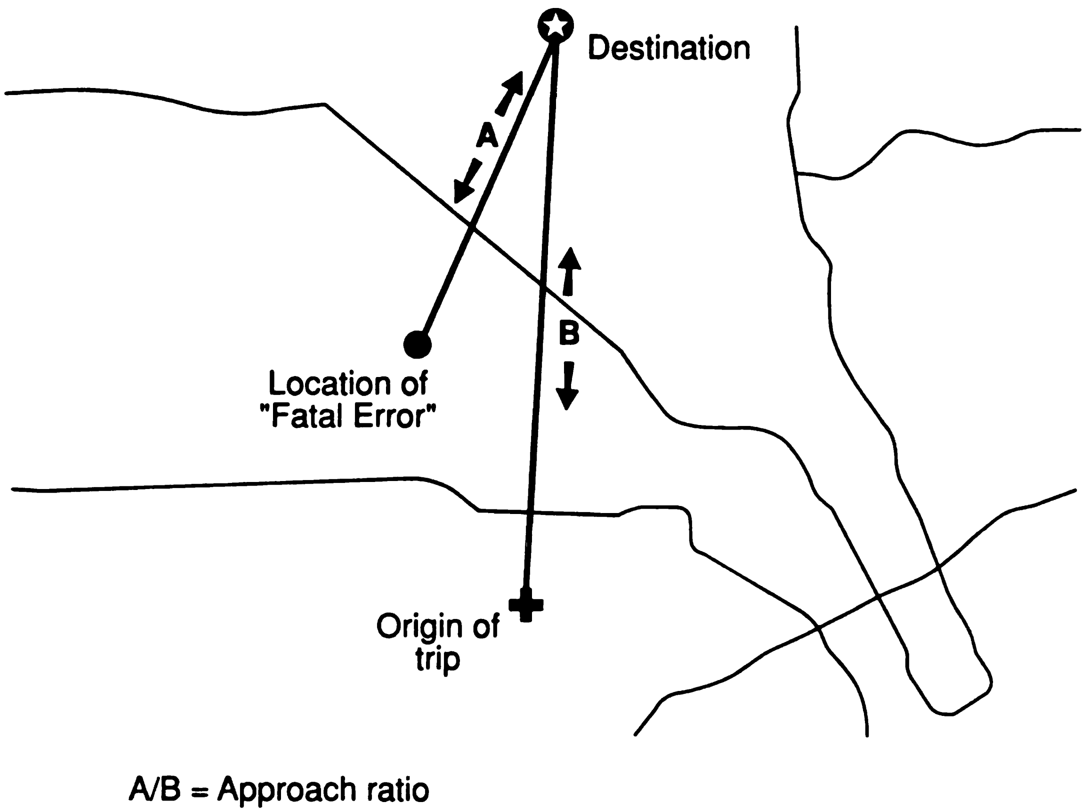


Figure 6 - The calculation of the approach ratio

Strategies

The original design of the study called for the extraction of strategies from the retrospective written protocol. Based on the characteristics of left and right dominant information processing the strategies should have fallen into two categories. There were actually three types of responses. Two categories fell out along the major highways/straight line navigation dimension. The third category was a totally different type of answer. Subjects in this third category actually provided a strategy i.e., they gave a step-by-step description of the problem solving procedure. Some even noted the tricks they used to solve the route selection problem.

For subjects who gave the third type of protocol, the route selection process was cognitively penetrable. The other subjects had difficulty understanding the question, perhaps because they had no idea of how they solved the problem.

Of course the other alternative is that the subjects are simply answering different questions. It seems, however, that the subjects who described a route preference rather than a problem-solving process were confused by the question, possibly because they were unaware of their own problem-solving process.

The subjects also indicated an implied strategy--whether they used the index to locate points or simply performed a visual search. Use of the index may have covered a multitude of spatial sins. Subjects who had no spatial search strategy and no idea how to develop such a strategy could rapidly locate the destination through the index. The method of estimating distance also proved a further indication of strategy. Some subjects were quite meticulous in measuring the distance. Others simply gave a visual estimate.

Several aspects of strategy were then examined. First, did the subject express a strategy? Second, did the subject use the index at any point? Third, did the subject physically measure off the scale or lay off the distance visually?

Data Collection Summary

The completion of the data collection portion of the study provided a promising independent variable and a selection of dependent variables.

The independent variable, lateral preference, seemed likely to capture some of the same abilities as those required by map reading for navigation: pointing, reaching, throwing a ball to a target, and general visual and kinetic interaction with space. This measure of a subject's potential for spatial comprehension should also be free of the influences of strategies. One theory of development of lateral preference does suggest that lateral preference actually results from a preference for spatial or verbal strategies early in life. The origin of preference, however, is of little importance to this study. At the moment, my major interest is in the reflection of lateral preference in performance and strategies.

The subjects, it is hoped, provided a fairly broad representation of the general public despite having been pulled from the somewhat selective confines of a community college.

The test instrument yielded a series of potentially revealing measurements gathered in a relatively natural setting. The following section analyzes these observations of map readers' goals, strategies, and performance to determine whether these aspects of map reading do indeed vary with lateral preference.

CHAPTER FOUR

DATA ANALYSIS AND RESULTS

The data analysis is broken into two major sections. The first section examines the results for each stated hypothesis. The hypotheses predict the relationship of simple performance variables to lateral preference. The second section examines the additional variables collected in the course of the map reading test.

Few of the data supported regression analysis as the dependent variable was often a yes/no answer rather than a range of responses. In most cases the data for the dependent variable--lateral preference--was split at the sample median for chi square analysis against the data on experience, strategies, and other classed information. Performance time and detail errors were also split at the median for analysis against these secondary variables.

Performance variables

The most general measure of performance, the approach ratio, showed no relationship with lateral preference (Figures 7 and 8). The r^2 was .000 for the approach to the

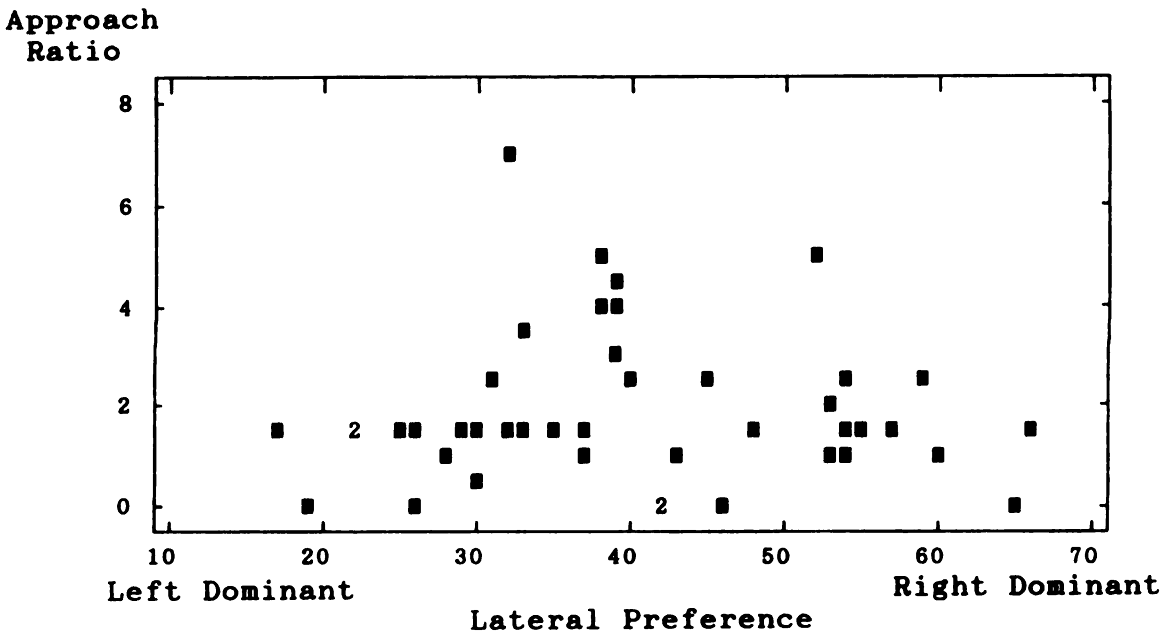


Figure 7 - First approach ratio and laterality

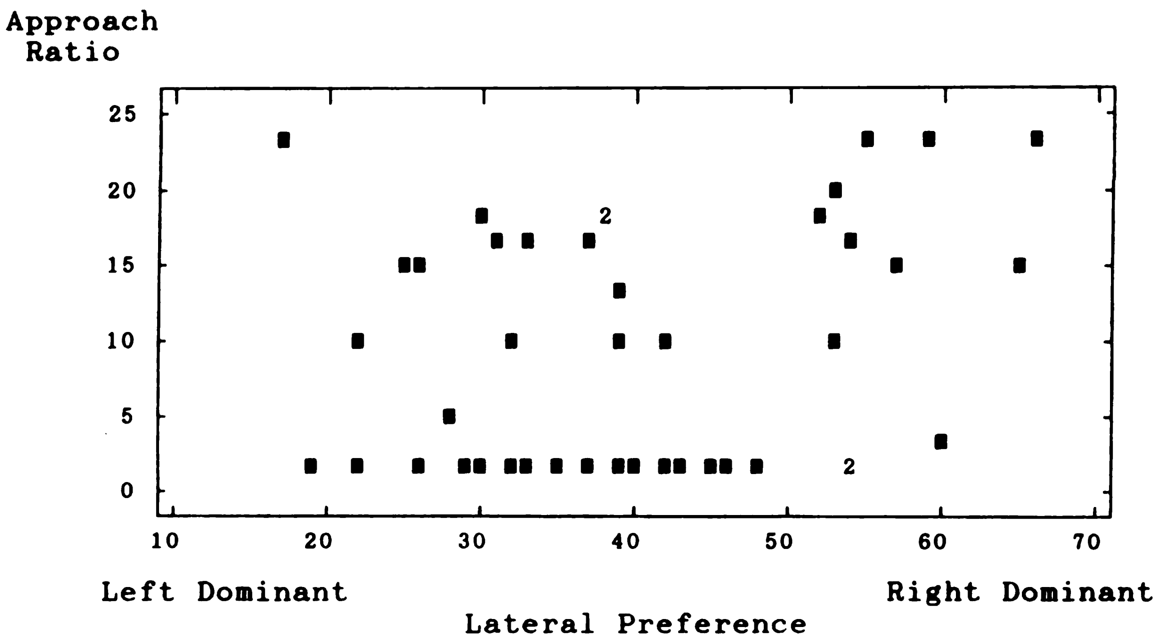


Figure 8 - Second approach ratio and laterality

first destination and .049 for the approach to the second. As expected then, the overall performance was unrelated to lateral preference.

The four formal hypotheses address the performance variables that were expected to vary with lateral preference: time required to complete the task, number of details missed, confusion of cardinal or egocentric directions, and use of geographic terms rather than egocentric terms.

Hypothesis one

Right hemisphere dominants will require less time to complete the map reading tasks

A regression of performance time against the score on the Visually Guided Activities suggests there is no linear relationship between lateral preference and speed in map reading with an r^2 of .001, an F of .024 and p of .876. The scatter plot shown below (Figure 9) suggests that, contrary to expectation, subjects with mixed dominance performed relatively poorly. Subjects to either end of the scale were about equal in map reading speed.

Hypothesis two

Right hemisphere dominants will miss more details in the route.

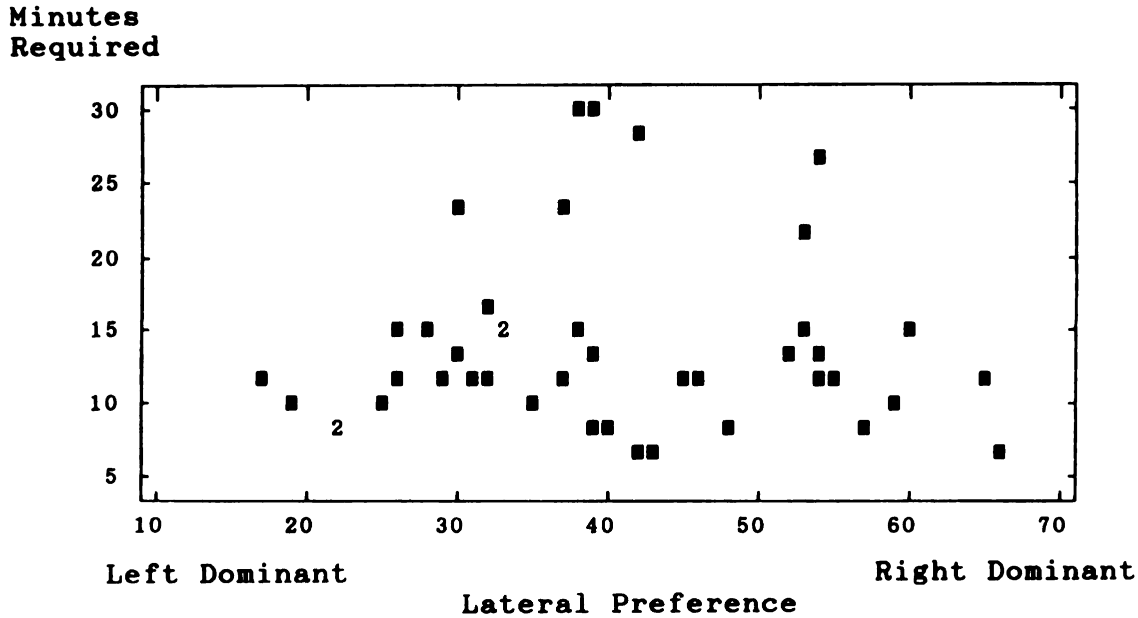


Figure 9 - Performance time and lateral preference

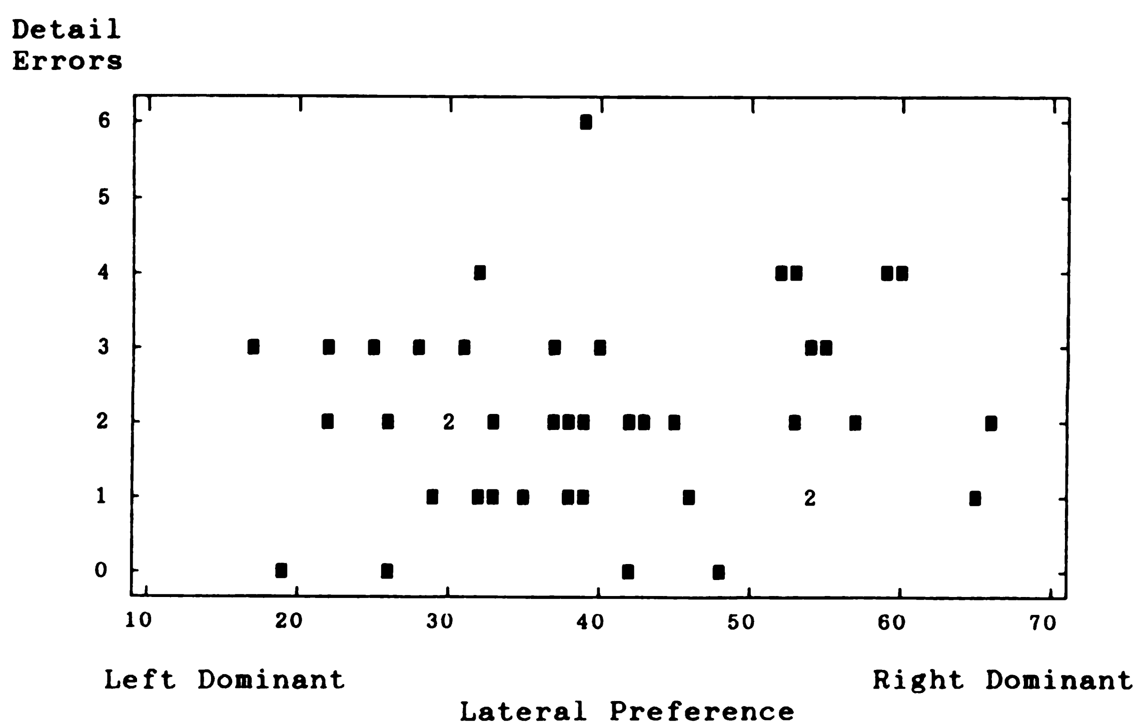


Figure 10 - Detail errors and lateral preference

Again, regression against the Visually Guided Activities Score suggests no relationship between laterality and performance (Figure 10). The r^2 is .014, the F .571, and p .454. In this case, there is an outlier in the mixed dominance range.

Hypothesis three

Right hemisphere dominants are less likely to confuse direction words in describing the route.

Though there was no significant difference in performance between the left and right dominants (X^2 = 1.983, p = .159), there is at least a visible trend here. Only about one-third of the subjects reversed direction words in their route descriptions. However, the right hemisphere dominants seem to have a slight advantage in performance as only about one fourth of these subjects reversed words while nearly half of the left hemisphere dominants reversed direction words (Figure 11). A large enough sample size might well show a significant difference.

Word reversal means only that the subjects said the wrong word. Word reversal does not necessarily indicate spatial confusion as most of the subjects who reversed words proceeded quite smoothly toward their goal if one observed the street names given in the description and the finger tracing of the subjects. Only one subject actually described a route that led in the wrong direction.

	Left Dominant	Right Dominant	Total
No Reversal	12	17	29
Reversal	9	5	14
Total	21	22	43

Figure 11 - Direction word reversal and laterality

Hypothesis four

Right hemisphere dominants will use more geographic terms in their route descriptions.

This table also shows a visible yet non-significant ($X^2 = 1.431$, $p = .232$) trend but opposite the hypothesized direction. Over two-thirds of the left hemisphere dominants used geographic terms while only slightly more than half of the right hemisphere dominants used geographic terms (Figure 12).

	Left Dominant	Right Dominant	Total
Egocentric	5	9	14
Geographic	16	13	29
Total	21	22	43

Figure 12 - Word type and laterality

Alternative explanations

Strategies

The subjects in this study were asked to describe how they selected the routes. Nineteen subjects actually expressed a problem solving strategy (see Figure 13). The rest simply expressed a preference for either the most direct route or a route that followed major roads. There is no relationship between the expression of a strategy and lateral preference (X^2 = .196, p .658).

The question that follows from this observation is "Did the expression of a problem-solving strategy relate to an improvement in map reading performance?" A Mann-Whitney U test shows no significant difference in performance times of the two populations--those who expressed a strategy and those who did not.

	Left Dominant	Right Dominant	Total
No Strategy	11	13	24
Strategy	10	9	19
Total	21	22	43

Figure 13 - Expression of strategy and laterality

Gender, self-assessment and performance

A great deal of interest has been expressed in whether or not women can read maps. Given this immense interest, questions on gender and self-assessment were included in the map test booklet. Again the results do not match popular expectation.

A X^2 analysis of gender and performance time reveals no difference (X^2 = ,239, p = .625). About half of the women fell above the median and about half fell below. The men's scores had the same distribution (Figure 14a). This distribution is virtually duplicated in the analysis of detail errors (X^2 = .559, p = .455) (Figure 14b). The analysis of word reversals suggests that women are slightly more likely to reverse direction words (7 out of 18) than men (7 out of 25). This trend is in no way significant, however, with a X^2 of .565 and probability of .452 (Figure 16c). Again, it must be noted that word reversal is exactly that. Only one subject actually indicated spatial confusion rather than simply misspeaking the directions.

The X^2 analysis of self-assessment and gender yielded the only statistically significant results of gender analysis, and they are very significant: X^2 = 12.165, p = .000. Women are extremely likely to rank themselves below "fair" in map reading ability. Men are as likely to rank themselves above "fair" (Figure 15).

	Female	Male	Total
Below Median	10	12	22
Above Median	8	13	21
Total	18	25	43

(a) Performance time and gender

	Female	Male	Total
Above Median	8	14	22
Below Median	10	11	21
Total	18	25	43

(b) Detail errors and gender

	Female	Male	Total
No Reversal	11	18	29
Reversal	7	7	14
Total	18	25	43

(c) Direction word reversal and gender

Figure 14 - Map reading performance and gender

	Female	Male	Total
Below Fair	14	6	20
Above Fair	4	19	23
Total	18	25	43

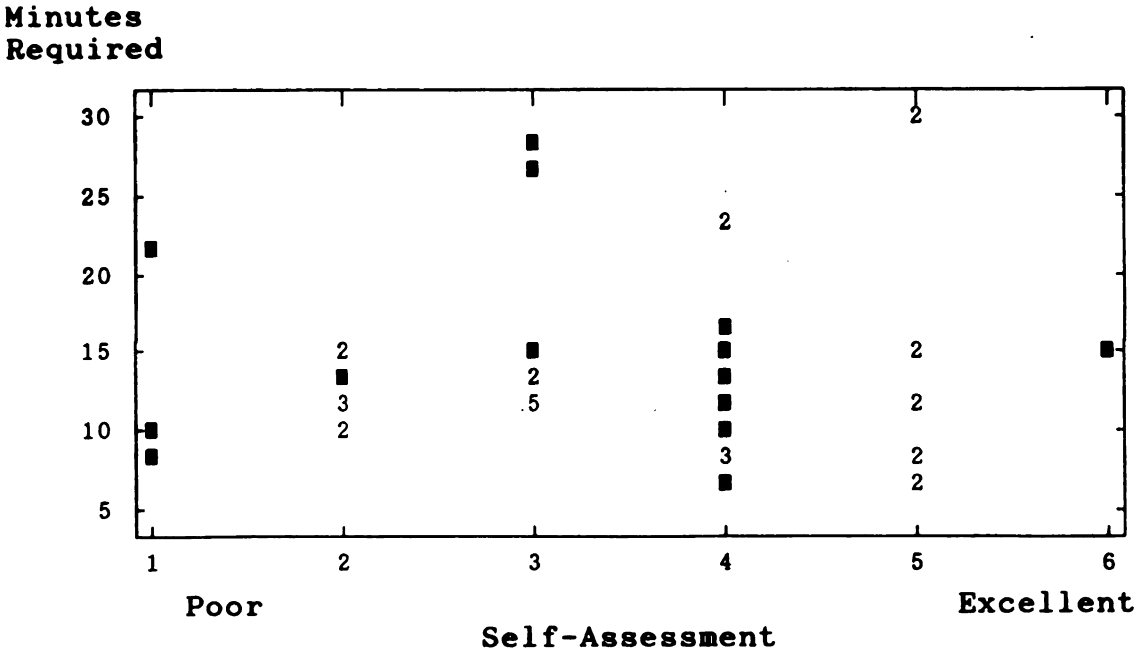
Figure 15 - Self-assessment and gender

Again, the important question is how this relates to map reading performance. A regression of performance time against self-assessment suggests that self-assessment has no influence on map reading speed, r^2 = .004 (Figure 16a). The analysis of missed details again shows no significant relationship, r^2 = .027 (Figure 16b). The very slight positive slope of the regression line seems due to a single outlier.

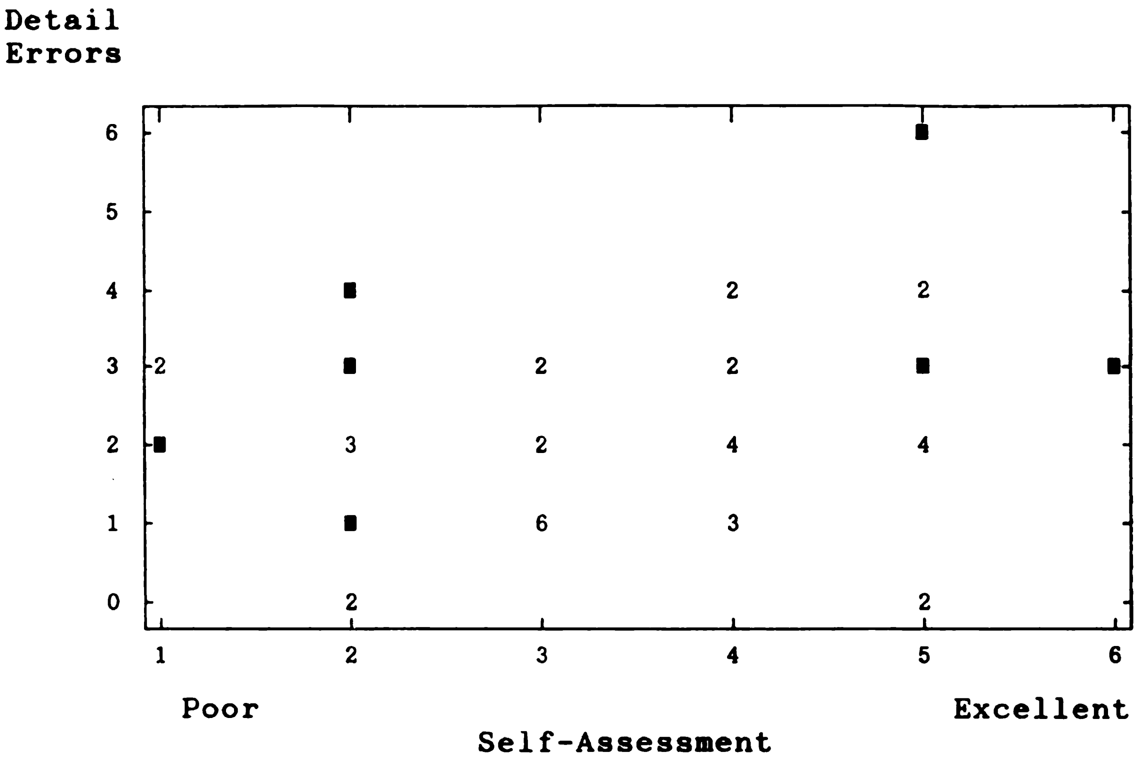
Travel and map reading experience

These variables seemed likely to explain variations in map reading ability given the failure of laterality to do so. Subjects gave a brief description of their travel experience. The experimenter then classified the level of experience as some or none. Even this dichotomy is somewhat arbitrary. A few of the subjects said that they had accompanied their parents on vacations but had slept most of the time while in the car. This hardly seems to qualify as travel experience that would enhance their navigation skills, so these subjects were classed with those having no travel experience. One subject was dropped from the analysis of travel experience because he gave an unclassifiable response to the question.

A significant difference exists in performance time between well traveled and inexperienced subjects (X^2 = 4.887, p = .027) (Figure 17). No visible trend appeared in



(a) Performance time and self-assessment.



(b) Detail errors and self-assessment.

Figure 16 - Performance and self-assessment

the analysis of detail errors and travel experience (X^2 = .171, p = .679) (Figure 18).

	No Experience	Experience	Total
Below Median	1	21	21
Above Median	6	14	21
Total	7	35	42

Figure 17 - Performance time and travel experience

	No Experience	Experience	Total
Below Median	4	17	21
Above Median	3	18	21
Total	7	35	42

Figure 18 - Detail errors and travel experience

Differences in map reading experience again failed to indicate significant differences in map reading performance (X^2 = .005, p = .942). In fact, the visible trend here is counter to expectations. A small majority of those with map reading experience were above the median in performance time, indicating slower performance, while 75% of those without experience were below the median (Figure 19). Map reading experience did not seem to aid in picking up the details of the route (X^2 =.005, p = .942) (Figure 20). Right dominants seemed slightly, but not significantly, more

likely to have map reading experience (X^2 = .734, p = .391) (Figure 21).

	No Experience	Experience	Total
Below Median	4	18	22
Above Median	4	17	21
Total	8	35	43

Figure 19 - Performance time and map reading experience

	No Experience	Experience	Total
Below Median	4	18	22
Above Median	4	17	21
Total	8	35	43

Figure 20 - Detail errors and map reading experience

	Left Dominant	Right Dominant	Total
No Experience	5	3	8
Experience	16	19	35
Total	21	22	43

Figure 21 - Map reading experience and laterality

Additional Performance Variables

Distance estimates

The subjects, with a few obvious exceptions, performed quite well in estimating the distance to be driven. The median error was 1.75 miles (Figure 22). Twenty-five percent of the estimates were within one mile of

```
  0 Q 000122225667779
  1 M 003566788
  2   145
  3   0025
  4                        Minimum         0.0
  5 Q 6                    1st Quartile (Q)0.7
  6   1                    Median (M)      1.8
  7   6                    2nd Quartile (Q)5.9
  8                        Maximum       991.0
  9   5
 10
 11
 12   7
 Outside Values
 15   4
 17   3
 31   2
 37   6
 95   3
290   0
991   0
```

The first column indicates the magnitude of errors in whole numbers. Each digit to the right is the first decimal value of an individual observation.

Figure 22 - Absolute error of distance estimates

the correct distance as measured by digitizing each route. The actual distance, depending on the selected route, ranged from 6.9 to 13.7 miles.

The outliers were quite astounding, however. One subject estimated the distance at 300 miles (a 290 mile error), another at 1000! Both these subjects claimed to have map reading experience. However, neither was aware of the presence of the map scale. They both seemed to have the impression that they were looking at a map of the entire state of Georgia rather than just of the city of Atlanta. One other also seemed unaware of the presence of a scale; however, his estimate was a somewhat less exaggerated 105 miles.

The examination of the use of the scale provided one of the few nearly significant results of the study with a X^2 of 2.805 and a p of .094 (Figure 23). Left dominant subjects tended to mark off the scale along the edge of a piece of paper or along the barrel of a pen and actually measure the distance. Right dominants would look at the scale and "eyeball" the distance. Left hemisphere dominants tended to underestimate the distance. Right hemisphere dominants (X^2 of 3.360, p of .186) seemed to overestimate the distance (Figure 24). The absolute errors of the right hemisphere dominants tended to be greater (mean of 19.5 miles without the 991 mile outlier) than the absolute errors of the left hemisphere dominants (mean of 7.5 miles).

	Left Dominant	Right Dominant	Total
Did not Mark	8	14	22
Marked	13	8	21
Total	21	22	43

Figure 23 - Scale use and lateral preference

Some of the subjects were confused by the presence of two scales on the map sheet--one for the body of the map and one for the inset. Seven subjects (three left hemisphere dominant and four right hemisphere dominant) began to calculate the distance on the body of the map using the scale of the inset. These subjects, since they were at least aware that they needed a scale, were guided to the proper scale. About half of these subjects had some prior map reading experience.

	Left Dominant	Right Dominant	Total
Underestimated	13	9	22
Overestimated	8	13	21
Total	21	22	43

Figure 24 - Distance estimation error and laterality

Travel time estimates

The subjects generally performed well in the travel time estimates as well as in distance estimates. They tended to estimate speeds closer to peak traffic conditions. The median deviation from observed speeds for offpeak conditions was 12 MPH. The median deviation for peak traffic conditions was 10 MPH error (Figure 25). The average speeds were calculated using the distance estimates of each subject so these speed estimates are not polluted by distance estimation errors as they would be if calculated using the actual measured distance.

There is a definite, though non-significant, trend in travel time estimation errors by lateral preference (off peak errors X^2 = 2.012, p = .364, peak traffic errors, X^2 = 4.112, p = .128) (see Figures 26 and 27). Left hemisphere dominants seem to underestimate the time required suggesting that they expect to achieve a higher speed throughout their trip. Right hemisphere dominants seem to overestimate travel times, hinting that they are rather pessimistic about the driving conditions.

0		0111
0		2233
0	Q	44555
0		67
0		89
1		001
1	M	2233
1		4455
1		7
1	Q	8999
2		0011
2		
2		55
2		
2		
3		
3		2

Outside Values
30

Minimum	0.5
1st Quartile	5.5
Median	12.0
2nd Quartile	19.0
Maximum	308.3

(a) Absolute error for off-peak travel

0		0000111
0	Q	222233
0		445
0		67
0		99
1	M	0001
1		233
1		45
1		6
1	Q	888
2		
2		333
2		5
2		889

Outside Values
31

Minimum	0.2
1st Quartile	2.8
Median	10.0
2nd Qartile	18.0
Maximum	311.3

(b) absolute error for peak travel

Figure 25 - Error in travel time estimates (MPH)

	Left Hemisphere	Right Hemisphere	Total
Missing	1	1	2
Above Median	7	12	19
Below Median	13	9	22
Total	21	22	43

Figure 26 - Off-peak travel time estimates and laterality

	Left Hemisphere	Right Hemisphere	Total
Missing	1	1	2
Above Median	7	14	21
Below Median	13	7	22
Total	21	22	43

Figure 27 - Peak travel time estimates and laterality

Transcription length

I classified the transcriptions The were classified as long or short depending on whether they ran more or less than half a page. There were few borderline cases. The subjects either carried on what amounted to a conversation with the experimenter or stared silently at the map and then delivered a route description. The left hemisphere dominants seemed equally likely to chatter or to remain silent. Fewer right hemisphere dominants talked while examining the map. The results are presented in Figure 28 (X^2 = 1.122, p = .289).

	Left Hemisphere	Right Hemisphere	Total
Long	10	7	17
Short	11	15	26
Total	21	22	43

Figure 28 - Transcription length and laterality

Heeded information

It is interesting simply to examine what the subjects found memorable among all the pieces of information printed on the map. Subjects were not limited to listing the single most memorable type of information but could list as many items as desired. There seemed no pattern related to laterality. The only good candidate is the preference for the inset. Six subjects noted that they found the inset of the downtown area useful. All six were right hemisphere dominant. Nine subjects, six of whom were right hemisphere dominant, noted the usefulness of the area tints. The same distribution held for the nine subjects who noted the importance of the colored fills for the major roads. Only one subject listed both of these items. Nine subjects also found the bold and colored type on the map a useful aid.

Again six were right hemisphere dominant and three left hemisphere dominant.

The indexes were the big winners in the memorable aids category. Twenty-seven subjects listed the index in answer to the question. These subjects were about evenly divided between left and right hemisphere dominants.

The trailing categories were landmarks (2 subjects, 1 and 1), on and off ramps (1 subject, right dominant) and the quadrant direction letters (NE, SE, etc) (one subject, left dominant).

Index use

Only twelve subjects completed the route selection task without using the index. The non-significant trend was that left hemisphere dominants preferred to use the index (X^2 = 1.601, p = .206) (Figure 29). Five of the twelve who did not use the index completed the route selection task in less than the median eleven minutes. Three of these five were left hemisphere dominant. Of the remaining seven who finished above the median, six were right hemisphere dominant.

	Left Hemisphere	Right Hemisphere	Total
No Index	4	8	12
Index	17	14	31
Total	21	22	43

Figure 29 - Index use and laterality

Geographic concept

Subjects who located the downtown area without assistance from the experimenter were considered to have a good geographic concept of a city. A number of subjects went directly to the index and so did not really demonstrate this quality. If the subjects searched for five minutes without concentrating on the downtown area, the experimenter pointed it out.

Of the thirty-one subjects who used the index, six turned to it quite late, having already had the downtown area pointed out. Two of these were right hemisphere dominant, four were left hemisphere dominant. Eight of the twelve subjects who did not use the index seemed to possess this good geographic concept. Six of these eight were right hemisphere dominant.

It is important to note that several subjects did not realize that the inset *was* an inset. These subjects would be directed to the inset when they looked up the downtown destination in the index, then proceed to describe a route that crossed the inset neatline and proceeded toward the second destination. At this point, the subjects were interrupted and directed to the true location of the downtown area.

Route preference

Thirty-two of the forty-three subjects expressed a preference for a direct route rather than one which detoured to follow main roads. This preference was unrelated to lateral preference (X^2 = .193, p = .661) (Figure 30).

	Left Hemisphere	Right Hemisphere	Total
Direct	15	17	32
Main	6	5	11
Total	21	22	43

Figure 30 - Route preference and laterality

Successful route selection

Most of the subjects selected a route that probably would, with a little adjustment and some help from directional signs, have led them to their destination. Only two subjects might have had major difficulties. One lost track of her destination and headed off in the wrong direction. One other subject was confused by the symbology and described a route that followed a grid line for about half the distance to the destination.

In general, the subjects were able to extract a workable route from the map. Only two failed to describe a route that would take a traveler at least the majority of the distance towards the destination and aim the traveller in the right direction to reach the goal. The performance time (the elapsed time from the unfolding of the map to the completion of the route description) ranged from 5.4 minutes to 29.3 minutes with a median of eleven minutes.

The number of missed details ranged from zero to six with a median of two. Though many subjects reversed right and left in their descriptions, only one subject showed true spatial confusion, pursuing a route that led 180 degrees from the destination in the last leg of the journey.

CHAPTER FIVE

DISCUSSION

The results of this research were rather surprising. While the use of strategies was expected to decrease the differences between right and left dominants in the overall performance measures, some differences in the specific variables were still anticipated. The analysis actually does not support the rejection of the null hypothesis for any of the hypothesized relationships.

The only significant relationships found were between self-assessment and gender, and between travel experience and performance time. Self-assessment did not affect map reading performance.

Only the small matters of marking off the scale and estimating distances, varied with lateral preference. Even these variations were, for the most part, very slight, and non-significant, with only moderate variation from expected frequencies in the chi-square analysis. Additionally, some of the chi-square analyses may be questionable due to the small size of some of the categories.

These secondary considerations and stylistic variations, however, seem to hold some promise in explaining map reading practices and so will be discussed first. The next section will examine some possible explanations of the failure of the formal hypotheses to address significant differences in performance.

Secondary Variables

Gender and self-assessment

It is not really surprising that women think they are poor map readers. The reason for this belief is clear in the remarks of several of the female subjects "My boyfriend (husband, father) tells me I'm a terrible map reader." The male subjects also tended to make self-denigrating remarks about their map reading ability. However, when asked to write down a rating, the men almost invariably rated themselves fair or better, the women rated themselves poor to fair.

What is surprising is that self-assessment did not carry over into map reading performance. A potential explanation for this failure appears, however, when one considers that accurate self-assessment requires some standard of comparison. How many people have ever carefully watched a number of other people read road maps with an eye toward judging their own performance? The women are simply recording what they have been told, usually repeatedly.

These results may explain Streeter and Vitello's (1986) findings that such a large portion of the population has difficulty reading road maps. Their particular study used self-assessment as its only measure of map reading ability and tested an all-female sample. The tendency of women to underrate their map reading abilities may have, in this case, led to misestimation of map reading ability in the general population.

Most subjects, male and female, thought they performed poorly due to the seeming inordinate amount of time that map reading requires. This impatience, rather than the lack of a particular cognitive ability, may be at the root of the complaints about the difficulty of reading maps. The majority of the errors seemed to result, not from spatial confusion, but from the failure of the subject to trace the route carefully to check for dead end streets, one-way streets and name changes.

Distance estimation

The stylistic variation with lateral preference is most evident in this task. Left hemisphere dominants seem, in nearly significant numbers, more likely to somehow mark off the scale and measure rather carefully. Right hemisphere dominants tended to look at the scale and then visually estimate the distance along the route.

This difference has a quite predictable effect on the nature of errors in estimation. The left hemisphere dominants tended to come up short, probably because they failed to account for the sinuosity of the route. The right hemisphere dominants tended to over-estimate the distance.

Overall performance, however, was quite impressive, particularly when one considers the complexity of the routes between the two points. Over twenty-five percent of the subjects were within one mile of the measured distance along their routes as determined by the experimenter. Depending on the directness of the route, of course, this constituted about a 10% error. Fifty percent were within two miles of the measured distance.

Travel time estimation

It might be expected that travel time errors should parallel distance estimation errors. However, travel times were computed for the distance the subjects thought they would be traveling, not measured distance, so errors in the two estimates should be independent. Left hemisphere dominants, however, tended to underestimate travel times, while right hemisphere dominants rather consistently overestimated the time required.

Again, this pattern is difficult to explain. Perhaps the spatial subjects have a greater appreciation of the difficulty of urban travel and therefore err on the side of caution. This possibility contradicts what we expect from the study of the literature, however. Left hemisphere travelers are expected to lack confidence and to allow extra time for navigation difficulties encountered along the route. Right hemisphere travelers are expected to breeze through complex environments without errors.

Both types of subjects gave estimates that better fit peak traffic conditions than off peak. This may have been due to the reputation that Atlanta has gained as a city of snarled traffic.

Experience

Travel experience seems to have a beneficial effect on map reading performance. These results must be viewed with considerable suspicion, however, due to the low number of subjects without travel experience. Only about one sixth had no travel experience. In most of the analyses too many cells had too low a frequency for us to make inferential statements with any confidence.

Travel experience may have lent some speed to the map reading process. Of seven subjects who were classified as having no travel experience, six took more than the median time required to extract the route information from the map.

This trend faded in the examination of detail errors. There was virtually no difference in error commission.

The other difficulty in this analysis (the first being the unequal numbers of subjects) is the evaluation of travel experience. The distinctive characteristic between "some" and "none" in this case was whether the subject had traveled out of state by car.

This classification is somewhat arbitrary. It serves to separate the subject who had wandered over several states on his own from the one who had never even been farther than Chicago, 40 miles away. However, this criterion does not pick up the pizza delivery man or the construction worker who continually have to refer to a map to make deliveries or find new building sites. Further, how does one classify the subject who took regular vacations with his or her family but claims to have slept the majority of the time spent in the car? The assignment here to the no-experience category was rather arbitrary.

Map reading experience was somewhat easier to evaluate, perhaps because map reading implies at least some activity on the part of the subject whereas being carted along on a family vacation does not necessarily require any participation in navigation. Subjects were considered to have map reading experience if they had classroom training or used maps regularly in their work.

The subjects had picked up map reading experience in a surprising number of ways. Some were delivery men, workers seeking building sites, limousine drivers. Others had military or scout training. Some had map reading in a driver education course. A few even remembered reading maps as part of a geography course in primary or secondary school. Still, a surprising eight out of forty-three claimed to have no map reading experience at all!

A faint majority of these eight were *below* the median time required to complete the route selection task yet above the median in detail errors. Perhaps their lack of familiarity with the task led them to rush through it unaware of the need for caution and attention to detail. The weak beneficial effect of map reading experience on map reading performance was a disappointment. However, quality of map reading experience is difficult to measure. Given the fact that only five subjects out of forty-three referred to the legend and several took quite some time to discover the index, most experience seems to be of poor quality and fails to familiarize people with the more useful aspects of road maps.

Lateral preference may play an indirect role in the relationship of travel and map reading experience to performance. The faint trend observed in the map reading experience data suggests that right hemisphere dominants may be more likely to have experience with maps.

Heeded information

The survey of "useful" information proved quite interesting. For example, only one subject found useful the display of access ramps, a feature that is presumably indispensable in route planning. The map also contained large, screened letters indicating the quadrants of the map NE, SE, SW, and NW. One would have thought these letters would be quite useful to map readers who felt insecure about cardinal directions but, again, only one subject noted them in the list.

Right hemisphere dominants seemed to gain the most from the visual aspects of the map design. Nine subjects found each of the following to be useful: bold and colored type, area tints and colored route fills. In each case, six of the nine (not the same nine subjects, incidentally) were right hemisphere dominants. Six subjects, all right hemisphere dominant, thought the inset of the downtown area was useful.

Geographic concept

The misinterpretation of the inset may be part of a problem noted in several subjects, the lack of a good geographic concept of a city. In spite of being told that the first destination was located in the downtown portion of the city, many subjects searched the entire map. A few actually seemed to grasp that the downtown area would be at the intersection of several major roads and would have the greatest density of streets. This ability may be related to lateral preference, as it fits the "profile" of a right hemisphere task--it is global, spatial, and parallel in nature. However, given the findings of the present study, this assumption needs to be tested. The design of the current study did not provide consistent observations of this particular search behavior.

Other subjects could not act on these clues but decided that there must be an easier way to locate a point on a map. These subjects began to explore the marginal information and soon discovered the index. From this point on they seemed to have little difficulty with the tasks.

Index use

Both types of subjects found the index quite useful. Twenty-seven subjects included the index in their list of useful features. Half were right hemisphere dominant, half left.

The use of the index may have masked performance differences related to lateral preference. As noted above, several subjects seemed to lack effective search strategies. However, once these subjects abandoned the search and resorted to the index, they exhibited little difficulty in completing the map reading tasks.

The only problem observed in the use of the index was the tendency of the subjects to look up an item without checking the heading of the index. The index was subdivided by both topic and geographic area. A number of subjects assumed that the map had only one all-inclusive index. These subjects looked for Magnolia street in the index for a suburban town only to conclude that the street was not indexed. When they expressed confusion and looked further afield, they noticed the bold faced index headings and completed the lookup task correctly.

The subjects also experienced difficulty in selecting the item in the index. A few looked up the Centers for Disease control in the hospital index and were directed immediately to their destination. Most looked up Clifton road. Subjects sometimes looked in the wrong section of the index, which provided a section for each suburb, and found themselves referred to a portion of Clifton road in a suburb far south of their destination. In this part of the urban area, Clifton is only a minor, winding residential street rather than the major thoroughfare it becomes in the northern reaches of the suburbs. These subjects then described a route that wound through minor streets for quite a distance to approach their destination.

These difficulties suggest that the index is not necessarily the perfect starting point for the route selection task. However, it does provide a way to complete the task for people who may otherwise be effectively stymied by the visual search for a place described only as a downtown location. This alternative approach is often not considered in discussions of map reading ability that emphasize visual search techniques. There is very likely more than one way to successfully extract almost any information from a map.

Formal Hypotheses

A reconsideration of the independent variable

The failure of the formal hypotheses to reveal significant performance differences among the lateral preference groups indicates that the Laterality Preference score may not be an appropriate explanation of map reading performance. For the dependant variables observed in this study, it would at least take a larger number of subjects to confirm any tendencies observed, suggesting that the differences in performance between groups are small relative to the variation within the groups. Alternatively, the observations made in my study were not the ones that would reveal differences related to lateral preference.

Another possibility is that the Laterality Preference Schedule is not a good surrogate measure of spatial ability even though the Schedule is significantly related to physiological measures of brain hemisphere activity observed to correlate with spatial and verbal tasks. The right hemisphere is found to excel at the following tasks: figure-ground differentiation, visual synthesis, visual location, judgments of the direction of a line, memory for familiar environments, visuoconstructive ability, mental rotation, and maze learning (Corballis, 1983). Current theory, which suggests that these are some of the tasks performed in map reading for navigation, governed the selection of the Laterality Preference score as the independent variable in this study.

Yet another likely possibility is that the limited range of lateral preference of the subjects precluded the examination of true "right hemisphere" performance. No strongly right hemisphere dominant subjects showed up in the 150 people screened for participation in the study. The scatter plot of performance time seems surprisingly symmetrical. Those at the right dominant end of the scale perform about the same as those at the left dominant end, those in the middle slightly poorer. It may be that this right dominant trend toward greater speed would continue in strongly right dominant subjects, if such subjects could be found.

It seems that right dominants, at least as classified by the Visually Guided Activities segment of Dean's test, are quite rare, since none appeared in the sample of 150. Even if these right dominants do prove to be gifted map readers, we still need to be concerned with the difficulties experienced by the more common mixed and left dominant map readers.

The slight, but not significant, trend toward poorer performance by the mid-range subjects is also difficult to explain. These results suggest that perhaps the positive interaction models of hemispheric dominance are correct. In such a model, the less dominant spatial hemisphere is not suppressed. In less strongly lateralized individuals, however, the right hemisphere may devote some of its capacity to verbal activities, thus leaving less capacity for spatial activities. This inefficient allocation of tasks may be what slows performance in these subjects.

Whatever was behind the higher performance times of the mixed dominance subjects failed to affect their ability to attend to details. The lower performance level does not appear in the data on detail errors.

It is difficult to tie theories of lateralization to the results of the Laterality Preference Schedule as the scores vary so greatly from one section to another. A subject may be right dominant for eye use, mixed for visually guided activities and left dominant for ear use.

The General Handedness section of the test showed much stronger lateralization than the Visually Guided Activities section used in this study. In fact the General Handedness scores fit the expectation generated by the literature on laterality. The majority were left hemisphere dominant, many were right hemisphere dominant and a few were mixed.

The Visually Guided Activities scores were used in this study because they have been observed to correlate more closely with physiological measures of hemispheric activity. In addition, these tasks seem to better approximate the tasks performed in map reading and navigation.

The Visually Guided Activity scores of the subjects in this study were, like the scores of the standardization sample published in the test manual, mostly in the mixed laterality range. This concentration in the mixed range of scores suggests that much of the literature on handedness, which uses a simple observation of the hand used for writing and other easily observable tasks, uses a measure that is affected by socialization and should be employed with caution in forming hypotheses about lateralization. Mixed laterality would be difficult to detect using observations of these tasks.

Some of the subjects may also have been careless in filling out the schedule. However, observing the subjects as they completed the questionnaire, I am convinced that they were thinking over their answers and trying them out. The room was full of people crossing their arms or reaching for non-existent items to see what "felt right." One must also consider that these were students in a college level psychology class who, for the most part, took a genuine interest in the study.

A final possibility is that, as stated in the introduction, perhaps map reading is simply too complex to be classified, as a whole or even in the components observed in this study, as a spatial activity. The variations according to spatial ability may indeed only exist in small portions of the overall task. For example, if all the subjects were forced to visually estimate distance, a clear relationship with laterality may appear with the advantage going to the right hemisphere dominants. Conversely, if a collection of subjects were asked to select the continuous route from a test set of complex routes with small discontinuities, left dominants may perform best.

The true relationship of map reading to laterality may be that, left to their own devices, map readers compensate for their deficiencies over the whole scope of map reading tasks. The results of this study strongly suggest such a possibility.

Language style

There was a slight trend in the use of geographic terms. However, this trend was, contrary to expectation, toward left hemisphere dominants using geographic terms--north, south, etc. The literature suggested that right hemisphere dominants would be more confident about relating the map to the real world and thus using cardinal directions. "Verbal" people are supposed to be less confident about space and to use egocentric terms--right, left, up, down, etc. This contrary trend is hard to explain. Perhaps the use of geographic terms by left hemisphere dominants simply demonstrates the verbal subjects' facility with language.

The fact that, in all but one case, the route descriptions and actions of the subjects reflect no other signs of spatial confusion suggests that "direction reversal" may simply be semantic confusion. Anecdotal evidence suggests that people who have this difficulty in giving directions have no difficulty in navigating themselves.

This semantic confusion may be a memory retrieval mistake similar to that observed in large families where a parent calling out a child's name often comes up with the wrong name on the first try. It is important that we separate word from deed in considering these types of errors.

Right hemisphere dominants also differed slightly from left dominants in that they were less likely to talk while solving the map reading problems. The verbal people were equally likely to talk or not talk during the procedure. The transcripts contain mostly conversation, anecdotes or complaints, however, rather than clear evidence of problem solving, i.e., talking one's way through the procedure. This particular problem solving behavior seemed much more evident in Shore and Cary's (1984) study than in this study.

Strategies

The differences between right and left hemisphere dominants should have been most obvious in the strategies. The distinguishing characteristic of those who expressed a strategy was that they listed a series of steps that they followed to select the routes. The only variation seemed to be in the number of steps described. Most strategies were quite sparse.

Those who did not express a strategy only gave their reasons for selecting the particular route, either a desire to follow the main roads for the sake of simplicity or to find the most direct route. Of the thirteen who expressed an analytic strategy, nine were right hemisphere dominant.

Yet again, this is contrary to the expectations drawn from the literature. Shore and Carey (1984) found that their spatially gifted students were unable to verbally express a strategy. French suggested that verbal strategies were the way in which verbally gifted subjects compensated for a lack of spatial ability. The "verbal" subjects in my study were the ones who failed to express a strategy.

The problem in collecting a strategy may lie in the phrasing used to request the protocol. However, even a slight rewording of the phrase in answer to queries by the subjects failed to elicit a protocol. The majority of the subjects seemed to have no idea what was expected of them at this point. They fell back on giving their reasons for choosing a particular type of route rather than turn in a blank page. On the other hand, those who gave a protocol, in some cases, gave quite a detailed description of the procedures they used to locate the destinations and select routes between them. For example, consider the following:

1. I got familiar with the map. Also in getting familiar with it, I tried to look for the certain streets.

2. I used the index to find the street, Magnolia, to get to the W.C.C.

3. Once I found it I was supposed to track the next point from there. I use a mental picture of the pattern of the streets to quickly find the W.C.C. again in the different location on the map to go to the next point (*locate the inset on the body of the map)*.

4. I found Clifton Rd. I take Clifton all the way to (C.D.C.). From there I connected the most possible strait (sic) line with streets.

On the whole, however, the written protocols proved a disappointment as a way of tapping the strategies used by the subjects. If all subjects could have responded in the detail shown above, this study would have revealed a great deal about how people go about reading road maps. However, the above example was very much the exception rather than the rule.

Summary and Conclusions

The major conclusion that can be drawn from this research is that spatial ability, as represented by performance on the Lateral Preference Schedule, has no overall effect on map reading ability as measured in this research. The differences (tendencies) are limited to variations in small subtasks such as distance and travel time estimation, and even these differences were not significant for the small number of subjects used here. Also, gender related differences in spatial ability played no role in navigational map reading, other than in self-assessment.

For the most part, the subjects were quite capable of extracting a usable route from the map. Even though they would not have been able to drive the exact route they had described, they generally were close enough that they could follow signs or simply proceed along nearby roadways. It is impossible to assess the success or failure of route selection without actually observing the process of navigation in the environment, but the important prerequisite, route planning from the map, was a task which most people could perform reasonably well.

Perhaps the most common problem, overall, was the mis-identification of road types. The subjects seemed to grasp the idea of the graphic representation of a hierarchy. However, they failed to use the legend to confirm their interpretations. Therefore, they failed to look for access ramps because they were unaware that they were planning to travel on a limited access roadway. Conversely, they wondered whether they could "get off" at a given street when traversing a four lane, divided street with grade crossing.

The problems of map readers in route selection, then, seem to be a matter of applying correct labels as much as they are problems of locating points in space, at least in the route selection stages. The major difficulty observed in the study was the determination of the attributes of symbols, not their spatial relations.

The opposite may hold true in orienting the map and matching the map to the environment during navigation. However, we have no research available at the moment to confirm the importance of spatial ability in these tasks. Research on map orienting and map matching may itself yield surprising results as has this research.

Suggestions for Future Research

Perhaps, instead of concentrating on memory for spatial information, we should test and attempt to improve the overall match of the map reader's expectations to the environment through which he or she plans to travel.

Training in map reading, rather than adjustments to map design, has been suggested as the best solution to map reading difficulties. Careful study of performance gains from training in map reading may reveal that people prefer different strategies. A student who normally applies a verbal strategy to problem solving may gain little from being taught a spatial strategy. Conversely, a student who prefers spatial strategies may find a verbal strategy complex and overly detailed for the matter at hand. Perhaps we could gain much by learning to teach more tailored strategies in map reading instruction.

At the very least, research concerning "training" must include task-relevant instruction. A course in map reading that includes such activities as drawing profiles from topographic maps and learning about population distributions from maps is unlikely to influence performance in reading street maps. Even a few minutes of street map reading with feedback and guidance might have far more influence and would be worthy of research (Olson, 1975).

Research should also be carried out to determine just how well people navigate in the environment with map in hand. The currently published studies seem only to treat navigation from memory, which is probably not at all the same set of tasks.

It would be interesting to see whether the 10% error figure observed in distance estimation holds for routes of varying lengths on maps of different scales. It also would be interesting to ascertain what portion of the population shares spatial concepts of the two subjects who thought that a single map could show individual city blocks yet still show points 300 to 1000 miles apart without interruption of the image.

The most promising variation observed in the study was one not captured in the recorded variables. This is the variation in mental set. Expressed another way, mental set is the willingness, or lack thereof, of a subject to discard an ineffective strategy and try an alternative solution. Some of the worst performers were subjects who had no effective visual search strategy yet kept searching the map in a seemingly random manner. Some of the best performers, on the other hand, were subjects who briefly scanned the map, abandoned the visual search, and proceeded to use the index. A formal study of the relationship between mental set and map reading performance may reveal the basis of important individual differences.

One of the difficulties in designing this study was the need to base the design on assumptions borrowed from psychology and from studies of other types of maps. Results indicate that these assumptions were inappropriate to map reading for route selection.

Petchenik (1985) noted the difficulties in the application of the results of map design research due to the inappropriate assumptions made by the researchers. She notes a conclusion drawn about the need for "more daring" use of color to portray elevation in maps for children without any consideration of whether such colors even suggest elevation to the young users of the map.

The same inappropriate assumptions seem to appear in the design of studies of map reading tasks. The desire for clean experimental design constrains us to assign specific tasks for the subjects to perform. However, we may find the results of such studies less than useful in predicting map reading success because, left to their own devices, subjects would have selected alternate methods to gain the same information.

This study was particularly untidy in its open ended in design. However, this loose structure revealed a great deal about the flexibility of map readers, more than most studies would allow because of their designs. The observations recorded in this study should suggest more appropriate tasks and questions for future studies.

Implication for Map Design

The improved training that is commonly suggested as a remedy to the map reading problems of the traveling public is difficult to implement. It is difficult to reach most map users for training, however. In addition, in this study at least, training proved ineffective in improving map reading performance.

Instead of, or in addition to, increased attempts at training, some attempt could be made to provide a highly visible guide to the full extent of the marginal information available on the map. Almost without exception, the subjects in this study opened the folded map and immediately began to scan the map image. If a "table of contents" were prominently displayed on the cover of the folded map, perhaps more people would be aware of such valuable marginalia as indexes, legends, scales, and insets. Alternatively, a brief "quiz" on the map cover might stimulate awareness of these elements. Any increased awareness induced by the map's design might improve map reading more than attempts at "training" in any conventional sense of that term or even of the task relevant variety. Training and design improvements, however, improve map reading performance in different and complementary ways (Olson, 1975) and one approach (training for example) should not be discarded in the belief that the other approach (design improvements) can compensate.

A "guide to map reading procedure" also deserves a prominent position on the map cover. If inexperienced map readers were guided to the index, then to the proper inset, then to the body of the map, they could save much wasted time. Map readers should also be encouraged, once they have assembled a likely looking network of lines, to check the legend to confirm that those lines are roads. They should then trace the lines and check carefully for breaks in the lines and examine the nature of the intersections. These simple measures would prevent most of the errors committed by the subjects in this study.

Implications for Navigation System Design

The desire to understand competence in map reading takes on new meaning when discussing vehicle navigation systems. The questions raised in the design of such systems are a driving force behind the current lively interest in map reading.

The need for safety is the first concern expressed in discussions of navigation systems. Any discussion of CRT displayed maps installed in passenger cars engenders images of drivers careening along the road with their gaze fixed on the screen. Evidence from the users of the existing ETAK map-based vehicle navigation aid suggests that, for whatever reason, this is not the case. It may be that the users of the ETAK system are self-selected good map readers and that system designers still need to be deeply concerned about the safety of the "average map user." Given the lack of relationship between self-assessment and map reading performance, it seems more likely that users of the ETAK system are average map readers who receive just the assistance they need from the system. It is probably the appropriate design of the system rather than the "giftedness" of the users that explains the safety record of the system.

One bonus that automated systems offer is the chance to design "remedial software" for people who find maps confusing. To design such software, we need information on the tasks that poor map readers find difficult and the abilities that they lack (Vicente, Hayes, and Williges, 1987). This remedial approach to software development may tap a great potential of automation--the ability to alter the nature of a task in such a way that information becomes available to a broader audience.

Some researchers have suggested that the greatest good for the greatest number may be served by extracting information from a digital data base and presenting only the resulting verbal instructions to the driver. This argument is based on the noted deficiencies in spatial ability in the driving public as well as on expressed preferences. Gilmartin (1986) suggests that "verbal" people might prefer verbal directions. Petchenik (1985) found that 1/2 to 1/3 of the driving population would indeed prefer verbal instructions. People also seem to navigate more efficiently with verbal/audio instructions compared to a paper map (Streeter, Vitello, and Wonsciewicz, 1985).

The verbal nature of the difficulties experienced by these subjects suggests that, perhaps, our energies in navigation system design have been misdirected. Most attention in academic research has been given to the automation of route selection and description on the grounds that people could not manage the spatial aspects of route information and should therefore be provided a strictly verbal description. The subjects in this study, however, had no difficulty with spatial relations but could not correctly identify the attributes of a given symbol and seldom referred to the legend.

It is likely, however, that both verbal and visual/spatial information may be useful. These complementary types of information have varying value at different points in the map reading and navigation process and may be alternated in an iterative process of information extraction.

Some people may even use a map only to construct a verbal description of the route. For example, in planning a drive to a distant point for a leisurely dinner the map reader may select a major route out of town, then detour past a scenic lake to the restaurant, then return via the interstate after dark. If the map reader jots down a few notes she need not refer to the map again that evening. She has, however, planned a much richer and more satisfying route than could be obtained from phoning the restaurant to ask verbal directions.

This richness is yet another argument against a purely verbal presentation of navigation information. No reasonable amount of verbal instruction can transmit the variety and volume of information that can be presented by a well designed map. If, as Shore and Carey (1984) suggest, people can redefine tasks to draw on their strongest abilities, it is possible that the "spatially deficient," with a little help, can still extract the needed information from maps.

Learning also takes place in map reading. As a map reader searches the map, perhaps guided by the computer, he or she "exercises" neural pathways that may seldom be used under other circumstances. In this way, exposure to maps may be a rare opportunity to aid the development of spatial ability.

Perhaps, instead of insulating the user from the spatial relationships by providing only verbal directions, we should let travelers select a route from a map that shows only a sparse framework of roads, thus exposing them, in a relatively painless manner, to the global spatial characteristics of the map. The automation effort could then concentrate on route description. The overlooked attributes of the symbols could be emphasized and the route selection could be critiqued. In this way, obvious errors such as planning to travel the wrong direction on a one-way street or needlessly traverse a congested surface street rather than an expressway could have been avoided.

The resulting rich and accurate description could then override the false expectations built up by the map user. This is indeed the true task of a road map, to provide the traveler with an accurate set of expectations against which to monitor his or her progress.

If people learn that they can rely on these expectations, they may become more confident and efficient map readers and navigators. If they repeatedly encounter aspects of the environment that do not match expectations they will continue to lose their way and their confidence in their ability to understand the map and to maneuver in a novel environment.

We may also wish to tailor systems to different navigation styles. Some proposed systems leave the user completely out of the decision-making process. Experience with automated systems has shown that the user needs to be included in the process so that he or she continues to monitor the system. Absolute faith in automated systems is blamed in such accidents as the shooting down of the Iranian airliner, "...operators tend to put too much faith in the computer's judgment and take a relatively passive role in analyzing and integrating new data" (Bower, 1988). Likewise, accidents could result, on a smaller scale, from leaving the user out of the decision making loop of a car navigation system.

Petchenik (1989) noted that we need to know more about *real* intelligence used to navigate in automobiles before we can model artificial intelligence or build expert systems to perform these tasks. We probably will learn only a limited amount about map reading from carefully controlled experiments driven by theories of spatial learning. What is needed are studies of map reading itself. Only by pulling the process apart and examining it carefully can we truly begin to understand map reading and the questions raised by the implementation of new technology. In this way we can develop theory to guide the development of powerful automated systems for the provision of geographic information.

APPENDIX

APPENDIX

Data Sheet

Subject #_______

Tape start_______

Time test started______

Use legend	yes	no
Used index	yes	no
Used insets	yes	no
Finger trace	yes	no

Third page--take map away

Eye shift	L	R
	L	R
	L	R

Time finished_______

Tape end________

Comments:

MAP READING TEST

This is a study of how people read street maps. I would like for you to pretend we are on a business trip to Atlanta from Chicago. As we approach the belt highway on Interstate 75 I hand you a map of the city and ask you to direct me.

It is 1:00 on a weekday afternoon and we have two stops to make: first the World Congress Center, which we know is on Magnolia Street in downtown Atlanta, then the Centers for Disease Control (CDC), which are on Clifton Road near Emory University just east of the city of Atlanta. Please describe for me the route I should follow.
(Your description and comments will be taped.)

Without looking back at the map, list any information that you found particularly useful in planning the route.

Next try to describe, in the space below, how you made the route selection decisions.

Now look back at the map and find the distance we had to travel between the World Congress Center and the Centers for Disease Control. Write the distance on the blank below

____

Estimate how long it would take to drive from the Congress Center to the Center for Disease Control. Write the answer on the blank below.

____

Information About You

Age:_______ Gender: Male Female

Briefly describe your travel experience (family vacations, business trips, etc)

Briefly describe your experience with maps and your travels (classwork, scouting experience, etc).

How do you rate yourself as a map reader?
(circle the best number)

Poor			Fair			Excellent
1	2	3	4	5	6	7

LIST OF REFERENCES

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