Relationships between Map Format and Route Selection: Toward Improving Transit Informational Systems

by

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INTRODUCTION

Since 1973 and the Arab oil embargo, there has been a general trend of rising gasoline prices and several periods in which there was a shortage of gasoline available to the consumer. It has become important that the United States decrease its consumption of this non renewable resource. One way of decreasing gasoline use is to increase the use of public transportation. Another important reason for using mass transit include its potential for reducing traffic and air pollution. Bus companies and the government have attempted to increase bus ridership by offering discounts, special rates, special bus services, better service, and cleaner and more comfortable buses (Geller et al, 1982). These changes have met with only partial success. An alternative approach is to study the adequacy of the bus schedule in informing the potential passenger about the correct buses to take, starting and arriving times, and other bus route information. One reason that some people do not use buses may be quite simple: the schedules are incomprehensible.

One study which assessed the ease of obtaining information from bus schedules (Everett, Anderson, & Mackranczy, 1977) supported this contention. In this study, five categories of pamphlets were used, including route maps, departure-arrival information, text, advertisements, and general pamphlets. With a particular pamphlet in front of the subject, a questionnaire was given which asked the subject to plan a trip from a stated origin to a stated destination. In all, seven performance ratings were gathered. The subjects were asked what bus they would take, the departure time, the cost of the trip, what streets they would travel on, the ultimate bus stop, the length of time the trip would take, and the return trip bus.

The results indicated that the pamphlets were indeed difficult to understand. In all, 19 pamphlets from across the country were used. The ease of comprehending the pamphlets was found to vary substantially. Correct responses for the seven performance questions ranged from a low of 17 percent correct for the least clear pamphlet, to a high of 74 percent correct for the clearest pamphlet. Across all pamphlets, performance reached a low of 24 percent of the subjects correctly estimating duration of the trip, and a high of 53 percent in correctly naming the ultimate bus stop. This pattern of results led the experimenters to conclude that the pamphlets provided by the bus companies were poorly planned.

The goal of pictorial bus schedules is to present the schedule in a form that is most comprehensible to the viewer. The most comprehensible format, according to Bartram (1980), is one that is most similar to the particular form of internal representation of spatial networks made by the reader. This will minimize the recoding necessary by the viewer to make use of the external stimulus.

COGNITIVE MAPS

Theoretical Frameworks

Downs and Stea (1973) offer a clear definition of cognitive mapping.

> Cognitive mapping is a process composed of a series of psychological transformations by which an individual acquires, codes, stores, recalls and decodes information about the relative location and attributes of phenomena in his everyday spatial environment. (p.9)

Observable spatial behavior (e.g. orientation) is assumed to depend upon the individual's internal representation (cognitive map).

Lynch (1960) identified five structural elements of cognitive maps: paths, edges, districts, nodes, and landmarks. Paths (channels of movement) and landmarks, are particularly important to a pictorial presentation of a bus schedule because bus schedules represent route information and often include landmarks in a pictorial presentation. The way in which these elements are presented in a map will affect the map's clarity (similarity to internal map). This point is elaborated upon later in this introduction.

In addition to affecting a map's clarity, the way in which the environment is represented will also affect recoding between perception and action. Welford (1978) wrote that the recoding normally required between perception and action falls into two main classes: spatial transpositions and symbolic translations. The former involve mental reorientation, or rotation "in the head", of the spatial layout of a stimulus in order to make use of the stimulus. Typically, the stimulus is rotated or inverted to match an already existing internal representation, a comparsion stimulus, or a set of controls.

The second class of recoding is that of symbolic translation, whereby the subject must alter coding of the input. For example, changing a list of instructions into an internal spatial network is a form of symbolic translation.

Schedules of bus systems include a spatial network. They represent the actual physical environment in either a verbal or pictorial manner. In either case, the relationships in the environment (how the streets are oriented to one another) are represented. When the bus system is represented in the form of a timetable, a symbolic translation is necessary. The potential bus passenger must change the bus stops (street names) and buses (bus numbers) into an internal spatial network. If, on the other hand, the bus system is represented in the form of a map, and the street names and bus numbers are already represented as a spatial network, less recoding is necessary. The speed and accuracy of reading the schedule should be improved.

Spatial Descriptions. Downs and Stea (1977) differentiated between two ways of describing the location of a place. A "process description" involves giving directions on how to get to Point B from Point A. For example, telling a person to go down the road four blocks, take a right at the light, and turn left at the gas station in order to get to a theater is a process description for the location of a place. A "state description" of a place can also be given. This involves describing the location of a place with reference to landmarks known to the people involved. Telling someone that the theater is across the street from the Chamber of Commerce, and next to the fire department, is an example of a state description.

While it is generally possible to generate a process description from a state description, it is often not possible to construct a state description from a process description. This is so because a state description requires knowledge of the spatial layout of an area, while a process description does not require such knowledge, requiring only knowledge of directional cues. Again, an example should clarify this point. A person, told that the theater is across from one building and next to another (a process description), can (and indeed must) determine which roads to take and where and when to turn to get to the theater (a process description). On the other hand, a person can be given this latter information and find the theater, while not knowing what building the theater is near (i.e. a process description without a state description). A process description can be inferred from a state description, whereas a state description is not implied in giving a process description.

<u>Factors Affecting Cognitive Spatial Representation</u>

Several factors affecting cognitive maps have been investigated. One of these variables is the familiarity of the subject with an area. For instance, one line of research has indicated that heightened familiarity with an area results in a more detailed and comprehensive cognitive map (Beck and Wood, 1976; Devlin, 1976). One study (Devlin, 1976), focused upon subjects who were newly located in a town of about 40,000. Devlin asked them to draw a map of the area on a blank sheet of paper, after they had lived in town for about two and a half weeks. About three months later they were again asked to draw a map of the area. The latter maps had much more information drawn in, including more street names, more landmarks, and additional areas. The landmarks showing the greatest increase were functionally significant ones which were perceptually salient. Functionally significant landmarks are those of special importance to the subjects: school buildings for students and teachers, hospitals for nurses and doctors, restaurants, etc. In other words, places that are often used or seen.

Another study supports similar conclusions. Specifically, Beck and Wood (1976) looked at the maps drawn by visitors to European cities. The maps were collected over a period of several days. Analysis of the maps again revealed a change over time. Although the changes included sometimes progressive and sometimes degenerative changes in the elements, there was an overall growth of the system due to the increasing amount of detail (differentiation) on the maps.

Another line of research concerning familiarity with an area indicates that people's representations of a familiar environment are not truly veridical (Appleyard, 1970; Byrne, 1979; Lynch, 1960). These investigators discovered that subjects' drawings exhibited the straightening of long gradual curves, the squaring of non-perpendicular intersections, and the aligning of nonparallel streets (i.e. a schematic representation of the area).

For example, Appleyard (1970) analyzed the maps drawn by residents in Ciudad Guayana, Venezuela of their local areas and the whole city. A broad cross-section of the population was included. The most common type of error was the distortion of the roads. Appleyard reported that people appeared to structure the city in a variety of schematic ways. He believed that it was necessary, due to the disjointed nature of street systems, to simplify the structure by fitting the urban knowledge into a coherent schema. The result was the drawing of the meandering roads as straight lines.

Appleyard did not specifically tell his subjects whether to draw as accurately as possible, or to give a general picture or schematic. On the other hand, Byrne (1976) asked her subjects to draw the junction of ten pairs of familiar roads, paying particular attention to the angle at which the roads met. The true angles were 60-70 degrees and 110-120 degrees. However, the subjects' drawings closely approximated a 90 degree angle. Byrne concluded that people use representations of the environment which rely on the heuristic that junctions and turns are based on a right angle, and that these heuristics are prone to bias.

Evans (1980) concluded that, due to the influence of prototypic biases, the subjects exhibited these systematic distortions of the road network in their maps. This research was taken as evidence that the internal representation (cognitive map) of an area is distorted in the ways described. However, Evans recognized that there are certain methodological problems. One of these is the potential influence of experience with using maps and experience drawing maps on the accuracy and the complexity of hand-drawn maps.

In one study, Dart and Pradham (1967) compared Nepalese and American children in their ability to draw maps. The villagers had no experience with maps whereas the Americans had at least some experience. The drawings reflected this difference. The Nepalese children's drawings were sequential rather than spatial. That is, the maps were drawn, not to reflect the environment accurately, but to reflect the order of elements in the environment (buildings, streams) that are passed when going from one place to another. American children exhibited many more spatial and directional cues.

These results, in addition to other research (Beck and Wood, 1976) indicate that map experience enhances the ability of the subject to accurately draw the map area. Thus, the distortions in the drawings found in the previously mentioned studies may have been methodological artifacts. It may be that distortions are the result of inexperience with using maps or with map drawing.

As Golledge (1976) pointed out, when a subject is asked to sketch or map an area, both the recall and artistic ability of the individual affect the drawing of the map. In order to make a meaningful interpretation of a drawn map, the nature of the geometric transformation from the stored environmental knowledge to the external reproduction must be assessed. This applies particularly when attempting to extract the metric and geometric information from sketched material (e.g. the accuracy of road presentation). In practice, however, a geometric translation is difficult.

One of the advantages of the map drawing procedure, Appleyard pointed out, is that by analyzing the subjective map, information can be obtained about urban perception. Spatial relationships which are very difficult to verbalize can be pictured through maps. However, Appleyard makes clear that maps may not directly reflect internal cognitive maps.

> That they (maps) do not indicate visual imagery, however, makes it important to devise other survey methods to fill out exactly how people structure their cities. (p116).

As Appleyard and Golledge acknowledge, the information that is included in a map is not necessarily a true reflection of the actual internal representation.

The research is fairly consistent in indicating that as familiarity with an area increases, knowledge of the detail of that area also increases. It has not been determined whether or not that information, if included on a map, would facilitate the readability of a map. The present research was designed to test this.

The research investigating the effects of familiarity on cognitive maps has generally involved obtaining data about internal spatial representations from subjects' map drawing. The studies reviewed suggest that internal representation of the external environment may be exaggerated and distorted in that the essential features of a map (i.e. intersections, directions of roads) are stressed. However, due to the limitations of the drawing methodology, other more indirect ways of determining how the environment is internalized must be performed (Byrne, 1979). The study described in this paper investigated the nature of cognitive mapping using an alternative method to map drawing, which was based upon Bartram's 1980 study of spatial information comprehension. His research attempted to extract internal representations more indirectly, as opposed to the more direct methods of the previously cited research.

Bartram compared four types of bus route presentations: two kinds of lists of bus stops (alphabetical and sequential) and two kinds of map drawings of the bus routes "road" and "schematic. Of interest to the present discussion are the maps. The road map was an accurate representation of the area, in which all twists and turns of the roads were portrayed. The schematic map simplified the crucial spatial relationships; curved roads were straightened and all irrelevant information was excluded.

On each map were seven bus routes, the bus stop names and the route numbers. The experimenter pointed to a location and named a second location. The subject was required to first point to the destination, and second name the buses he would have to use, including transfers, to get there.

The results yielded no differences among the four bus route presentations for the time it took to point to the destination. The time to determine the correct sequence of buses was less for the maps than for the list. There was also a difference between the two maps. The time to pick the correct bus route was faster for the schematic (simplified) map (15.26 seconds) than for the road (realistic) map (23.26) seconds.

Bartram interpreted these results to indicate that more recoding is necessary to understand the road map than the schematic map. According to Bartram, information about places and relationships between them is normally represented internally in a form analogous to a spatial network, and more specifically, in a schematic network.

The subjects in this study were unfamiliar with the area represented by the maps. However, as was mentioned, research has indicated that one's cognitive map increases in detail and specification as the familiarity with the environment increases. As has also been suggested, one's cognitive map may also reflect the area more veridically as familiarity increases.

One previous study did compare subjects familiar with an area to subjects unfamiliar with the area along several map-reading dimensions. Specifically, Everett et al (1977) detected no relationship between familiarity and performance, the latter being measured by the seven ratings previously mentioned. The mean performance scores of the subjects familiar with the city were compared to the subjects who were not familiar with the city, yielding no difference in scores.

However, the data collected in the Everett et al study were collected on one city. The subjects were either familiar with the area, as determined by self-ratings, or they were not. A within-subjects design was used in the present study. Specifically, two different areas were shown to each subject, one familiar and one unfamiliar, and the two areas were compared for the same subjects. Everett et al's experiment was a between-subjects study, in which the same area was compared. In addition, Everett et al pointed out that there was a relatively small number of subjects possessing the moderate to high level of familiarity (18 percent of the total number of subjects). They specifically suggested further study with a more balanced sample of subjects.

It is important to compare a familiar with an unfamiliar area along these two dimensions of detail and road structure because a relevant contribution will be made toward our knowledge of how cognitive mapping differs under differing circumstances. In addition to providing evidence concerning how one's environment is perceived, this research may alter the way the external environment is portrayed to the map reader.

Two important variables of cognitive maps have been discussed: detail and accuracy (or realism). Bartram's maps confounded these two variables. The road map included both extra detail and a veridical road network. The schematic map not only included a simplified road network, but also left all extra detail out. The study reported here included four maps such that these two variables could be assessed independently (see Table 1).

Each map included the names of the streets on which the bus routes traversed, the bus route numbers, and the roads themselves. The first and second map included roads presented in a veridical manner.

Table 1

The eight maps presented to each of 40 subjects

	Blacksburg		London	
	Veridical	Simplified	Veridical	Simplified
Low-Detail	One	Five	Two	Six
High-Detail	Three	Seven	Four	Eight

Maps three and four displayed the roads in a similar fashion (veridical). These two maps included several additional roads, road extensions, and landmarks (including buildings, parking lots, etc). Functionally significant landmarks, shown by past research (Devlin, 1976) to be peceptually salient to people familiar with an area (e.g. school buildings), were stressed. These can be seen on the maps.

No extra detail was included on maps five and six. The roads, however, did not accurately reflect their true properties. That is, curves were straightened, intersections were made at or near right angles, and roads were presented more parallel than they really were.

The final two maps, maps seven and eight, also included non-veridical roads: for these maps the roads were distorted to the degree discussed. At the same time, the above mentioned detail was included. Landmarks and other points of reference, even though they were not necessary to determine the correct bus route, were included.

Past research has revealed that subjects' performance on a number of perceptual and intellectual tasks was related. These stylistic tendencies have been designated cognitive styles. Under the broader label of cognitive style is the more specific designation field-dependence-independence, which refers to the ability to overcome an embedding context (Witkin et al, 1971).

Tests for field dependence require the person to separate an item from the field---it is necessary to break up a field configuration to do this. It had become apparent that this is quite similar to what is required when a subject attempts to both locate points on a map and to determine bus routes between points. The subject must separate the information relevant to the solution of the task (bus stops and bus routes) from the irrelevant information (landmarks, unimportant street names, etc).

The subjects were required to complete an additional task, a test designed to measure the test-taker's level of field dependence, entitled the Group Embedded Figures Test (GEFT), designed by Oltman, Raskin, and Witkin. It is a perceptual task, requiring the person to find a simple figure, which is embedded into the pattern of a larger, more complex, figure. The simple figure is shown on a separate page. The subject must trace, in pencil, the simple figure on the complex figure.

Individuals tend to be consistent in their perceptual functioning from test to test. As reported in Witkin et al (1971), field dependence has been related to susceptibility to illusions, performance in mirror-tracing tasks, and an auditory-visual conflict situation, among other variables.

It was expected that high field-independence would also be positively related to the map-solving task described in this study.

METHOD

SUBJECTS

The subjects were male and female students from Virginia Tech. It was required that the subjects had completed at least two-years of their studies at Virginia Tech in order to participate in the experiment. This was necessary to ensure that the subjects were at least somewhat familiar with Blacksburg. The actual length of time in Blacksburg was recorded.

APPARATUS

The only mechanical devices used in the experiment were two stopwatches, capable of keeping time to a hundredth of a second.

STIMULUS MATERIALS

Two cities were mapped; Blacksburg, where Virginia Tech is located, and an unfamiliar area, based upon a section of London used in Bartram's study. This map was changed considerably to correspond in size, shape, and complexity to the Blacksburg map so that it had become a fictional city. This area will still be referred to as London. Bartram used a different color for each route in his "schematic" map but only one color for all routes in his "road" map. He therefore confounded color of the bus route with the type of map. The maps that were used in this study had the routes designated by number only, not by color. Specifically, the maps all had black print on a white background. In all there were the four types of maps previously described in Table 1, each city having one of each type. All eight maps (four for each city) can be seen in Appendix A.

It was important that the maps for both cities were of similar complexity. If not, differences between cities could be due to map complexity, rather than city familiarity. Therefore, the maps were developed to have the following in common:

1. The maps were of comparable appearance---same height, width, and road layout.

2. Each had the same number of street names(35).

3. Each had the same number of bus routes (8).

4. Each had the same number of bus stops (location points) (43).

5. Each had the same number of bus route intersections (Two bus routes on the same bus stop) (23).

6. Each had the same number of intersections served by only one bus (20).

7. Each had the same number of bus routes with ten stops (1), nine stops (1), eight stops (4), and seven stops (2).

8. There were the same number of bus route designations on each map (66).

9. The four maps with high detail each had the same number of additional streets (4), additional sections of already named streets (5), places (7), and buildings (12).

While the two cities still did not have identical maps (which was not possible), these nine conditions should have ensured that they were comparable.

Other materials used during the experiment included an 18 by 24 inch road map of Blacksburg, Virginia, in which an inch represented 1600 feet, (provided when the subjects were asked to locate the 10 places in Blacksburg), a questionnaire (as shown in Appendix G), and 40 GEFT booklets (one for each subject).

PRETEST

To provide for a fair interpretation of the effect of the independent variables (familiarity, detail, and road structure) on the dependent variables, the four Blacksburg maps were of the same complexity as the four London maps. If the complexity between these maps differed, then any differences in scores could be attributable to differences in complexity rather than to the familiarity of the area represented by the maps. To this end, the maps of London were drawn with Blacksburg in mind, with the goal that the complexity of the road layout be similar between the two. The following pretest demonstrated that this was indeed the case.

The experimental design was a 2 X 2 X 2 factorial. The first factor was that of the familiarity of the city being mapped; a familiar city was mapped (Blacksburg, Virginia), as was an unfamiliar city (London, England). The second factor was the manner in which the roads were presented; the road structure. One level was the simplification of the roads in the ways described (simplified map), the other level was non-simplification (more realistic map). The third factor was whether extra detail was included in the map---either extra detail was present, or it was not included. Thus, there were a total of eight treatment conditions.

All eight maps were presented at one time in a random array, to each of 20 volunteer subjects. All writing, road names, places, and bus numbers were removed from the eight maps to ensure that no bias resulted from knowledge of the place represented on the map. (Therefore, in the pretest the high-detailed maps included only extra roads and road extensions). The subjects were requested to rate each map's complexity, on a scale of one to seven, one being least complex, seven being most complex. The subjects were told to look at all eight maps simultaneously before making any ratings, and to rate the maps in terms of their complexity in comparison to the other maps. They were also told that the same rating may be given to more than one map. The mean complexity ratings for each map can be seen in Table 2.

A 2 X 2 X 2 analysis of variance on the variables of familiarity, detail, and road structure revealed that there was no main-effect of familiarity---that is, the complexity ratings for the four Blacksburg maps were no different than for the four London maps ($F(1, 19)=1.12$, $p=.30$). In addition, a look at each pair of maps (familiar vs. unfamiliar) indicated that at each level of the factors of detail and road structure, the Blacksburg and London maps were judged to be of equal complexity. (A Duncan's post hoc comparison was used, with a .05 significance level). The other two main effects were also tested by the analysis of variance. First, as expected, the four high-detailed maps, those including extra roads, were seen as more complex than the four low-detailed maps (5.20 vs. 3.01; $F(1, 19)=175.53$, $p<.01$). Secondly, as also expected, was the result that veridical maps, those including all twists and curves in roads, were rated as significantly more complex than simpli-

Table 2

Mean rating of each map's complexity,
(1 = least complex, 7 = most complex)

Road Structure	Detail	Blacksburg		London
Veridical	Low	3.35	=*	3.60
	High	6.05	=*	5.55
Simplified	Low	2.55	=*	2.55
	High	4.75	=*	4.75
Total (Mean)		4.18	=*	4.04

* $p > .05$

fied maps (4.64 vs. 3.57; $F(1, 19)=21.47$, $p<.01$). There were no significant interactions between the three factors. The present experiment was performed in part to determine whether the more complex maps, in terms of detail and road structure, aided or hindered map reading, this finding to be related to the subjects' internal representation of the map's area, and familiarity of the area. These complexity results were used to help explain the results of the experiment.

DESIGN

A 2 X 2 X 2 factorial design was employed, with the same three factors as in the pretest (Familiarity X Detail X Road Structure). Thus, there were again eight treatment conditions.

40 subjects were presented each of the eight maps, making the experiment completely within subjects. There were two very important advantages to this. The first advantage was that subject differences did not mask true differences between experimental conditions. When comparing the results between maps, only the differences between the maps themselves contributed to differences in scores, since each subject was tested with each map. If the subjects were tested with only one of the two cities or only one of the four

kinds of maps, the subjects would be different when comparing results across cities, or across maps, respectively.

A second advantage was that by presenting all eight maps, the subjects should not have become accustomed to any one of the maps. If only two or only four of the maps had been presented, several trials with each, the subject would likely have become familiar with the maps, artificially improving his/her score.

A modified Latin Squares design with randomized blocks was used to counterbalance the order of presentation of the trials to ensure that there was not a trial order effect. This design can be seen in Appendix B. This particular design was chosen so that one of each block of eight subjects would receive a different order of the eight maps. In addition, this design ensured that each map followed every other map four times and preceded every other map four times. In this way, any possible map order effect should not have biased the results.

PROCEDURE

In individual sessions, the subjects were presented with one of the eight maps and were told that it represented a bus route system for either Blacksburg or an unfamiliar city. They were given a pair of locations, the departure point and destination of a bus trip, printed at the top of the page, and told that they must find and indicate these two points by marking the map. In addition, the subjects were asked to indicate the bus route one would need to use to get from the departure point to the destination, again by marking on the map their response by drawing the bus route, as well as writing down the bus number next to the map. It was also made clear that one could travel between two immediate points only if the same bus stopped at those two points. The actual instructions, which the experimenter read out loud while the subject read silently, are shown in Appendix C.

Both stopwatches were started when the subject was given a map with the two intersections written at the top of the page. When two intersections had been circled by the subject, the experimenter stopped the first stopwatch, the second watch still running. This time was considered location time. The subject then immediately determined the bus route to be taken, again marking his/her response by drawing the route on the map, as well as writing down the bus numbers next to the map. When this was completed, the second stopwatch was turned off. This total time minus location time was the time the subject took to determine a bus route. The map was then taken from the subject, and the next map was presented. (The subjects were told to work as quickly as possible, but to try to minimize errors).

One practice trial was performed using a completely different map, but simpler than those used during the actual experiment (see Appendix D). After each trial, the map was taken away and a new one presented, with a new task. In all, there were two trials for each map, for a total of 16 trials. The 16 pairs of intersections are shown in Appendix E.

It was necessary that the eight pairs of intersections selected for each familiarity area be of equal difficulty. To do this, intersections were chosen such that the most optimal route, as defined by the number of buses between the two intersections, were the same for both sets of intersections. Thus, each area had the same number of pairs of intersections in which the most optimal bus route included two buses (1), and three buses (7), for a total of 23 buses. In addition, the total number of bus stops used for each of the eight routes was 63. Therefore, any differences between familiar areas are due to the different routes chosen by the subjects, not the intersections presented by the experimenter.

After the sixteenth trial had been completed, the subjects were asked to rank order the four Blacksburg maps and the four London maps (the order of city presented randomly), according to preference of use for the city represented. In addition, possible differences or similarities between preferences for a familiar and an unfamiliar area were recorded.

After rating the maps, subjects were shown a road map of Blacksburg. Ten places in Blacksburg were mentioned orally to the subject, one at a time. The ten places were chosen such that all sections of Blacksburg were represented (north, south, east, and west). The subject was asked to point to the place's location if known, or to tell the experimenter that the place's location was unknown. If the subject pointed to within approximately one-half of the location on the map (800 feet in real distance), it was scored as a positive location, this number (0-10 places) treated as a continuous variable. This measure of the number of correct places located in Blacksburg was obtained to provide a second measure of familiarity with Blacksburg--- an independent measure of familiarity to the length of residence (see Appendix F for the 10 places).

A questionnaire was given to the subjects (as shown in Appendix G), designed to obtain information pertaining to the experiment. The subjects reported their familiarity with bus schedules, their familiarity with the area of

Blacksburg represented on the map, their believed familiarity with the area represented from the strange city, and how long they have lived in Blacksburg. In addition, the subjects reported their most frequent mode of transportation around Blacksburg.

The last task the subjects completed was the booklet of the embedded-figures test. There were a total of nine practice trials (including 2 examples) with the next two sets of nine counting toward the total. On the basis of this test, each subject was given a field dependent score, 0-18, which, like the number of places located, was treated as a continuous variable. The entire session took from 45 minutes to one hour.

RESULTS

DEPENDENT MEASURES

The experiment involved basically two tasks. The first task required the subject to locate and circle two intersections on a road map of a bus schedule. There were two dependent variables measuring performance of this part of the experiment. One was the time the subject took to complete this task. The second was the number of intersections correctly located.

The second task of the experiment required the subject to determine a bus route which would allow the subject to travel between two particular intersections, and write down the bus numbers. The time to complete this task was obtained. Additionally, two dependent variables measured the efficiency of the bus route chosen by the subject: 1) the number of bus stops 2) the number of buses. Greater efficiency was defined as traveling between the two intersections in the shortest possible number of bus stops and buses. Refer to Table 3 for an outline of the definitions of the dependent variables.

Five subjects were included for each of the eight orders of map presentation determined by the Latin Square design used in this experiment. It was therefore possible to test

Table 3

The five dependent variables

I. Locating Two Intersections

1. Time: Time to locate the two intersections (location time).

2. Accuracy: Number of intersections located correctly, per map (0, 1, or 2).

II. Determining Bus Route

1. Time: Time to determine bus route between the two intersections (bus route time).

2. Efficiency: a. Number of bus stops in the bus route selected by the subject, including departure and destination bus stops.

   b. Number of buses in the bus route selected by the subject---how many different buses were used to travel from the departure intersection to the destination intersection.

for order effects. A one-way analysis of variance was run on each of the five dependent variables. The independent factor was map order, the eight orders being the eight levels of that factor. For each dependent variable, the results indicated that there were no main effects of order for any dependent variable (all $\underline{F}$s(7, 32) yielding $\underline{p}$s>.05). The Latin Square design was therefore effective in counterbalancing the order of map presentation.

Type of Error

A total of 640 observations were obtained (40 subjects X 8 maps X 2 trials). For 81 of these trials, the subject would not reach the destination given to him/her using the bus route that s/he had drawn. There were two sources of this error, defined as follows: 1) the subject circled at least one wrong intersection (69 trials) and 2) the drawn bus route used a road untravelled by a bus (12 trials). When either of these errors occurred (i.e. the subject would not reach the destination given to him/her by using that bus route), it was labelled a destination error.

No scores were obtainable for the two efficiency measures of number of bus stops and number of buses in the bus route when a destination error had occurred, because there was no correct bus route between the two intersections. The two time measures were still obtained, although for incorrect routes only. These times could only be included if it was shown that they were not significantly different than the times obtained on the rest of the trials. A t-test comparing the times for the 81 erroneous trials with the 559 others indicated that both locating the intersections and determining a bus route took a significantly greater time for the erroneous trials than for the trials with no destination errors ($t(80, 558)=4.30$, $p<.01$, $t(80, 558)=2.20$, $p<.05$, respectively. Therefore, the trials on which a destination error occurred were eliminated from further analysis.

A second type of error occurred when the subject located both intersections correctly and had a correct bus route drawn on the map (the route would successfully take the subject from the departure point to the destination point), but the bus numbers which were written down were incorrect. That is, the bus numbers associated with the drawn route were different from the bus numbers the subject wrote next to the map. This was termed a <u>translation</u> error, of which there were 64. This type of error did not necessitate exclusion of the data for that trial because the bus route, as drawn by the subject, was correct. The error was in the translation of the drawn bus route to a written form.

As already mentioned, there were two kinds of errors made during the location of the street intersections and the determination of the bus route: destination errors and translation errors. The distribution of these errors, across maps, is shown in Table 4.

A chi-square one-sample test was performed on each set of errors. For destination errors, the chi-square indicated significant effects of familiarity ($\underline{X}^2(1)=13.44$, $\underline{p}<.01$) and road structure ($\underline{X}^2(1)=11.86$, $p<.01$), but not detail. The London maps (the unfamiliar area) resulted in more destination errors than the Blacksburg maps (the familiar area), and the simplified maps resulted in more destination errors than the veridical maps.

The chi-square test performed on the translation data yielded no significant map effects. However, the number of translation errors for each map was not the number of times out of 80 maps that the error occurred, as was the case with the destination errors, since no maps with destination errors could be used to measure translation errors. Each map had a different number of trials from which to count the number of translation errors. Therefore, it is possible that fewer errors were counted for some maps because there were fewer trials to choose from, and not because of the nature of the map itself. This may have masked true differ-

Table 4

Distribution of destination errors and translation errors (both actual numbers and percentage) for each map at both familiarity ares

Road Structure:		Veridical		Simplified		
Detail:		Low	High	Low	High	
	Area					Total
Destination	Familiar	3	7	9	5	24
Error:	Unfamiliar	5	10	22	20	57
	Total	8	17	31	25	81
Translation	Familiar	6	7	7	5	25
Error:	Unfamiliar	7	13	10	9	39
(Number)	Total	13	20	17	14	64
Translation	Familiar	7.79	9.59	9.86	6.66	39.06
Error	Unfamiliar	9.33	18.57	17.24	15.00	60.94
(Percentage)	Total	19.05	31.75	34.69	25.45	100.00

ences between maps. To account for this, a chi-square analysis was also performed on adjusted data in which the number of errors was converted to a percentage, using the following equation:

$$\frac{\text{number of errors}}{\text{number of opportunities}} \times 100$$

Using this set of data (also shown in Table 4), there was a significant main effect of familiarity ($\underline{X}^2(1)=9.57$, $\underline{p}<.01$)---there were more translation errors for the unfamiliar maps than the familiar maps.

ANALYSIS OF VARIANCE

The means and standard deviations for the five dependent variables, determined for each map, are displayed in Table 5. The means exclude the erroneous trials. Because there was missing data for all but three subjects, the computer program could not perform an analysis of variance (ANOVA) on the dependent measures. Therefore, the ANOVA was run two ways, both of which involved the substitution of missing scores to allow the analysis to be performed. Each map was presented twice to each subject. Therefore it was possible for one ANOVA to use the score for one trial to estimate the score for the other trial. Forty-nine times the trial 1 score was used as the trial 2 score and 32 times the trial 2 score was used to estimate the trial 1 score. In nine instances where both trials were unusable, the cell mean was used to fill in the blanks. In this way an estimate of the trial order effect could still be obtained.

The second ANOVA sacrificed the study of trial effects for the possible greater accuracy of the interpretation of the three other independent variables of familiarity, detail, and road structure. In this case, the mean of trial 1 and trial 2 was used as the score if neither trials were excluded. If one of the two trials was excluded, then the score for the trial with no blank was used. Again, nine cell means were used when both trials were excluded.

Using the first alternative, only the location times and the bus route times showed any effect of trial, either as a main effect or as an interaction with any of the factors. When the other three dependent variables were analyzed, the two sets of data yielded the same pattern of results. Therefore, for the two time measures, both analyses are discussed, while for the other three measures, only the ANOVA with the trial order excluded as a factor was considered. The data including trial as a factor is referred to as between trials data, and the data using the mean of both trials is referred to as across trials data. The summary tables of the seven ANOVAS are presented in Appendix H.

Table 5

Mean and standard deviation for dependent measures, for each map and total

Familiarity:		Familiar				Unfamiliar					
Road Structure:		Veridical		Simplified		Veridical		Simplified			
Detail:		Low	High	Low	High	Low	High	Low	High	Number	Total
Location Time:	Mean	17.98	24.98	21.14	30.13	26.27	41.69	34.31	40.89	559	29.16
	St. Dev.	6.67	12.83	8.30	17.95	13.91	28.98	17.54	22.56		18.96
Number of Intersections:[a]	Mean	1.96	1.97	1.90	1.99	1.95	1.92	1.71	1.72	559	1.89
	St. Dev.	.19	.16	.34	.11	.22	.27	.53	.53		.34
Bus Route Time:	Mean	21.25	28.69	26.95	27.78	27.03	34.75	30.77	34.40	640	28.69
	St. Dev.	9.84	16.35	21.44	18.69	13.69	23.87	19.69	16.88		18.27
Number of Bus Stops:	Mean	8.08	8.42	8.47	7.99	8.39	8.41	8.19	8.57	559	8.31
	St. Dev.	.61	1.28	1.20	.93	1.04	1.07	.66	.83		1.00
Number of Buses:	Mean	2.91	3.07	3.08	3.05	3.12	3.31	3.33	3.13	559	3.12
	St. Dev.	.41	.56	.71	.56	1.00	1.02	.76	.95		.77
	Number[b]	76	72	72	76	75	70	58	60		

a The number could be either 0, 1, or 2.

b The intersection score, being based on the number of intersections correctly identified on each map, includes 80 observations per map

Location of Intersections

Location Time---Between Trials Data There was a trial order main effect ($F=13.85$, $p<.01$), trial 2 yielding shorter latencies than trial 1. The ANOVA for location time indicated that the two factors of familiarity and road structure both had significant main effects: subjects read familiar maps more quickly than unfamiliar maps ($F(1, 39)=111.34$, $p<.01$), and veridical maps were more readable than simplified maps ($F1, 39)=7.71$, $p<.01$). There was also a significant Trial X Detail interaction ($F(1, 39)=5.53$, $p<.05$). Analysis of the effect of detail at both levels of the trial factor (a separate ANOVA at both trial 1 and trial 2) determined that at both trials, the maps with low detail resulted in shorter locating times than the maps high in detail ($F(1, 39)=44.19$, $F(1, 39)=21.88$, respectively, $ps<.01$). This indicates that at trial 1, the difference between high-detailed and low-detailed maps was greater than at trial 2, but there was still a main-effect of detail, regardless of the trial order. Figure 1 illustrates the shorter location times for trial 2 than trial 1, for the unfamiliar area than the familiar area, and for the veridical and low-detailed maps than for the simplified and high-detailed maps.

Location Time---Across Trials Data Again, there were main effects for familiarity, detail, and road structure ($F(1,$

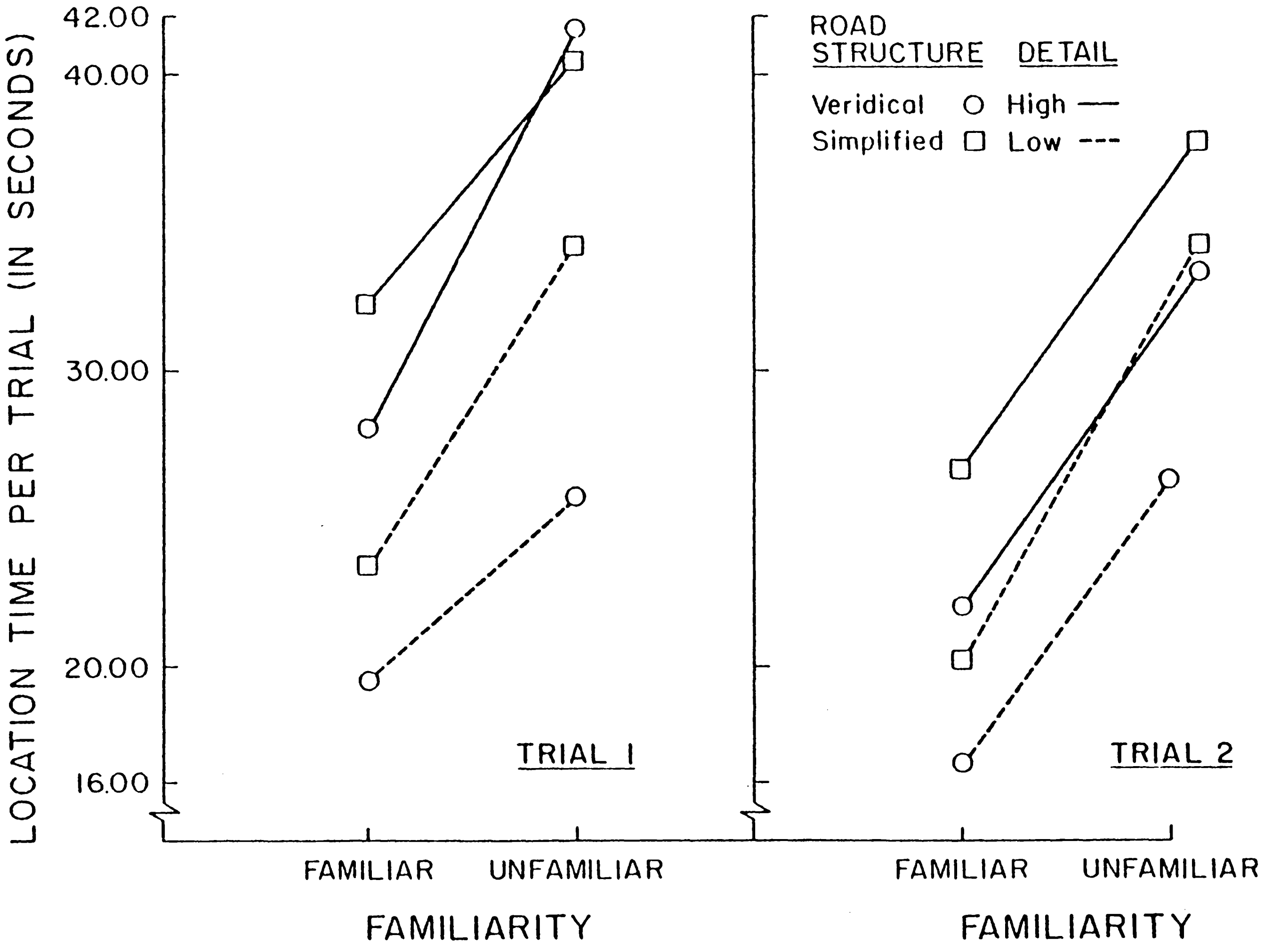

Figure 1. Latencies to circle intersections, as a function of Trial Order, Familiarity, Detail, and Road Structure (Between Trials Data).

39)=102.09, *F*(1, 39)=53.56, *F*(1, 39)=5.35, respectively, all *p*s<.01. There was a significant three-way interaction using the across trials data ($F(1, 39)=4.73$, $p<.05$). Analysis of the means determined the source of the significant three-way interaction. ANOVAS for the familiar area indicated that a simplified road structure yielded longer times than a veridical layout of roads for both low-detail and high-detail maps ($F(1, 39)=9.89$, $p<.01$, $F(1, 39)=4.52$, $p<.05$, respectively). However, for the unfamiliar area, while a simplified road structure was again slower than a veridical road structure at low-detail ($F(1, 39)=10.22$, $p<.01$), there was no difference at high-detailed maps. This relationship can be seen in figure 2.

Number of Correct Intersections Figure 3 shows all scores for the number of correct intersections located, the performance variable obtained for the first task of the experiment. There was an overall main effect of familiarity ($F(1, 39)=23.09$, $p<.01$), as well as road structure ($F(1, 39)=19.78$, $p<.01$). The significant interaction between familiarity and road structure ($F(1, 39)=18.65$, $p<.01$), indicated that the main effect of road structure was due to the data for the unfamiliar area; veridical maps resulted in more intersections correctly identified than simplified maps for the unfamiliar area ($F(1, 39)=20.68$, $p<.01$), but not for the familiar area ($p>.05$).

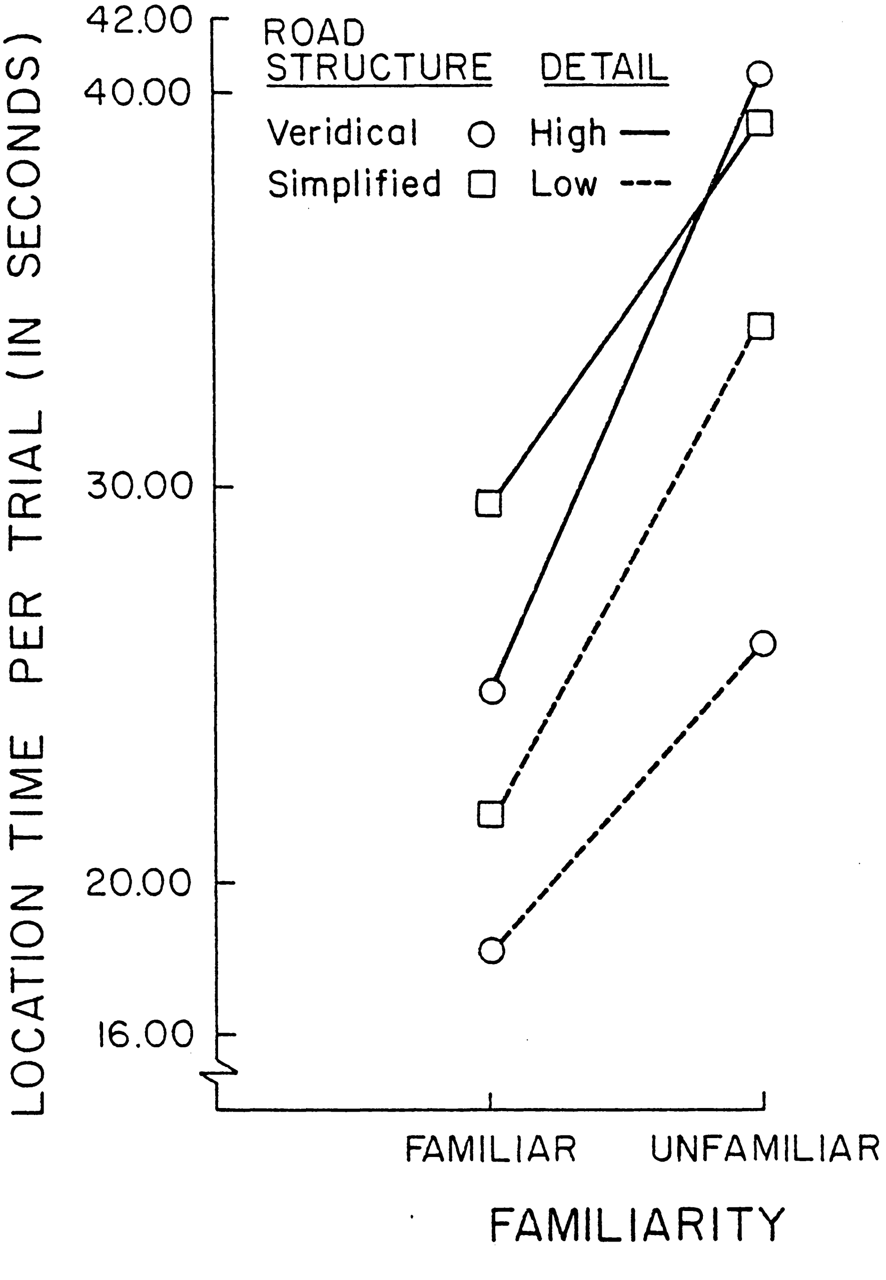

Figure 2. Latencies to circle intersections, as a function of Familiarity, Detail, and Road Structure (Acorss Trials Data).

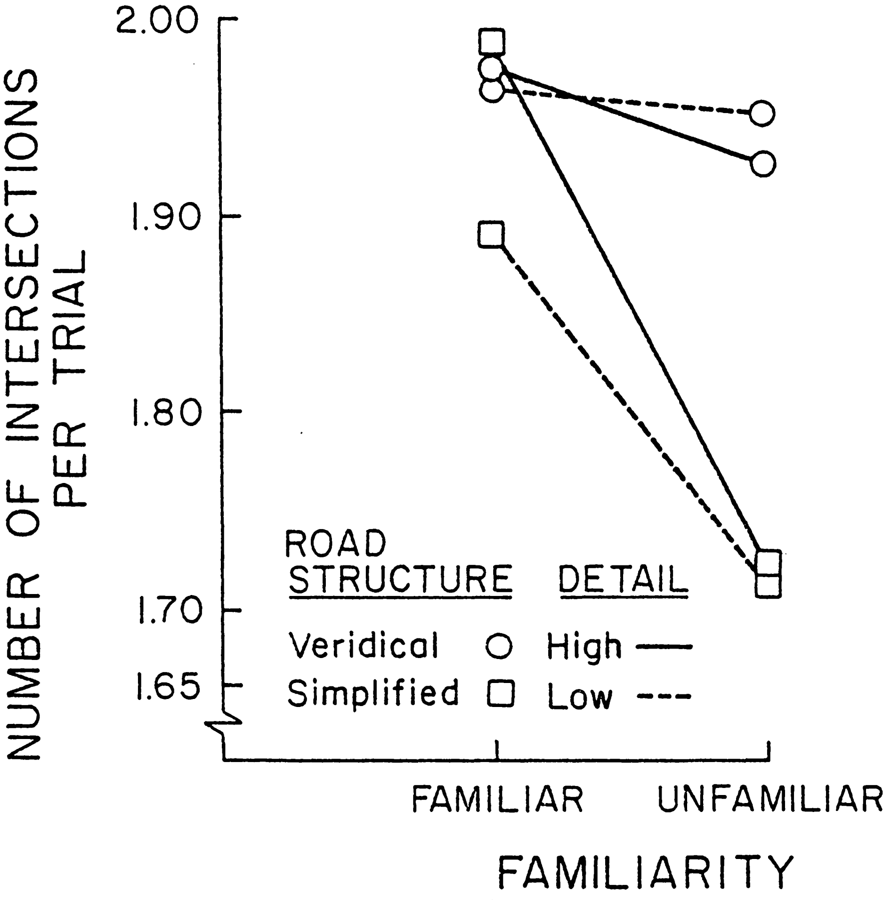

Figure 3. Number of intersections correctly circled, as a function of Familiarity, Detail, and Road Structure.

Determination of Bus Route

Bus Route Time---Between Trials Data The times for the factors of familiarity, detail, and road structure, for both trial 1 and 2, are shown in Figure 4. The ANOVA on this data resulted in main effects for trial (trial 1 greater time than trial 2, $F(1, 39)=40.37$, $p<.01$), familarity (unfamiliar greater than familiar, $F(1, 39)=27.32$, $p<.01$) and detail (high-detail greater than low-detail, $F(1, 39)=10.99$, $p<.01$). Road structure was marginally significant (veridical greater than simplified, $F(1, 39)=4.07$, $p=.051$). None of the interactions were significant.

Bus Route Time---Within Trials Data The ANOVA using the mean data also yielded significant main effects of familiarity ($F(1, 39)=26.53$, $p<.01$), detail $F(1, 39)=10.11$, $p<.01$), and road structure ($F(1, 39)=4.33$, $p<.01$), with no significant interactions ($p>.05$). The times are displayed in Figure 5, and show that familiar areas yielded shorter times than unfamiliar areas, low-detail maps yielded shorter times than high-detail maps, and veridical maps yielded shorter times than simplified maps.

Number of Bus Stops The number of bus stops for each level of each factor is depicted in Figure 6, which illustrates the significant Familiarity X Detail X Road Structure interaction ($F(1, 39)=7.71$, $p<.01$). An ANOVA of the simple

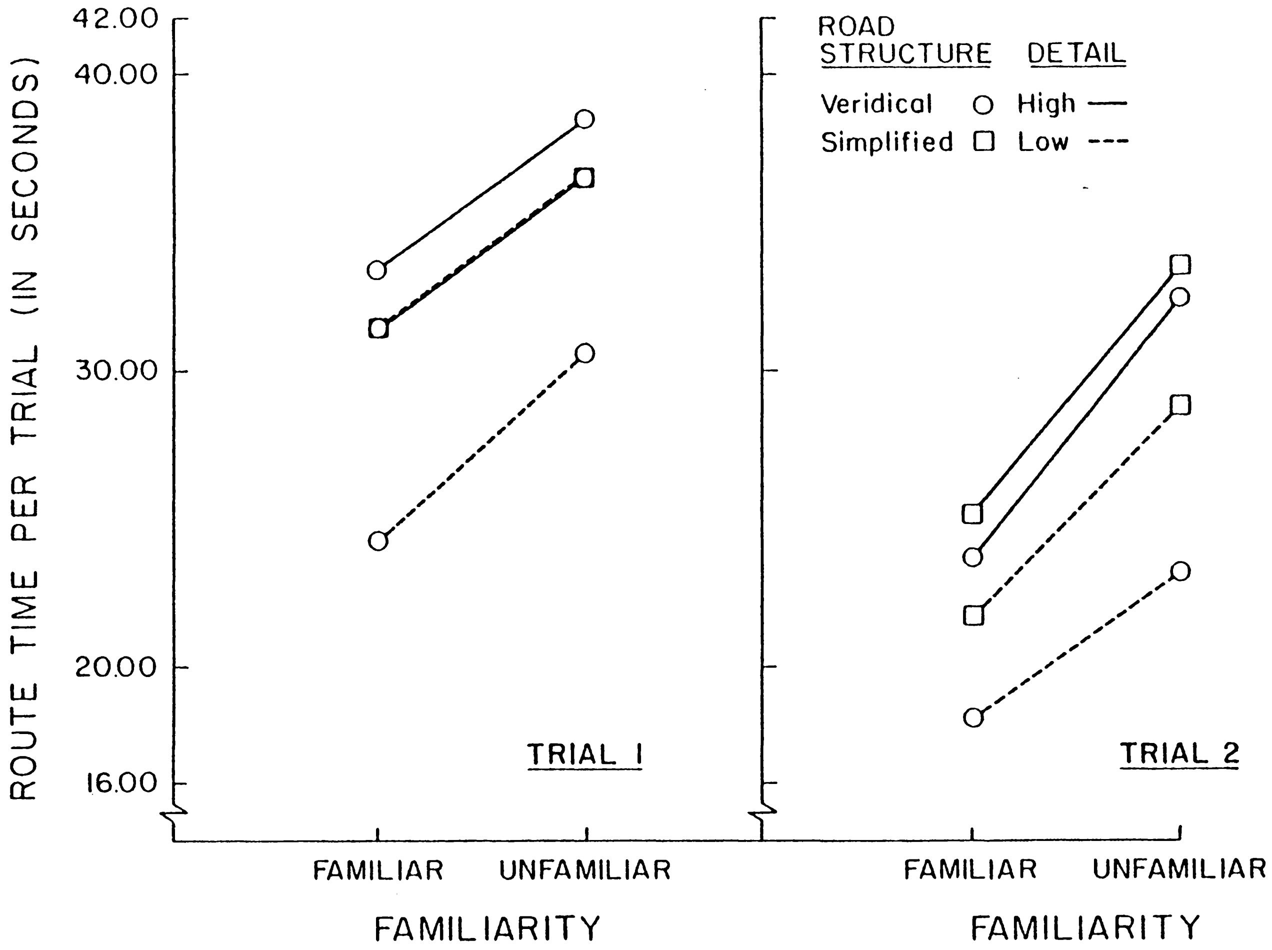

Figure 4. Latencies to determine bus route between intersections, as a function of Trial Order, Familiarity, Detail, and Road Structure (Between Trials Data).

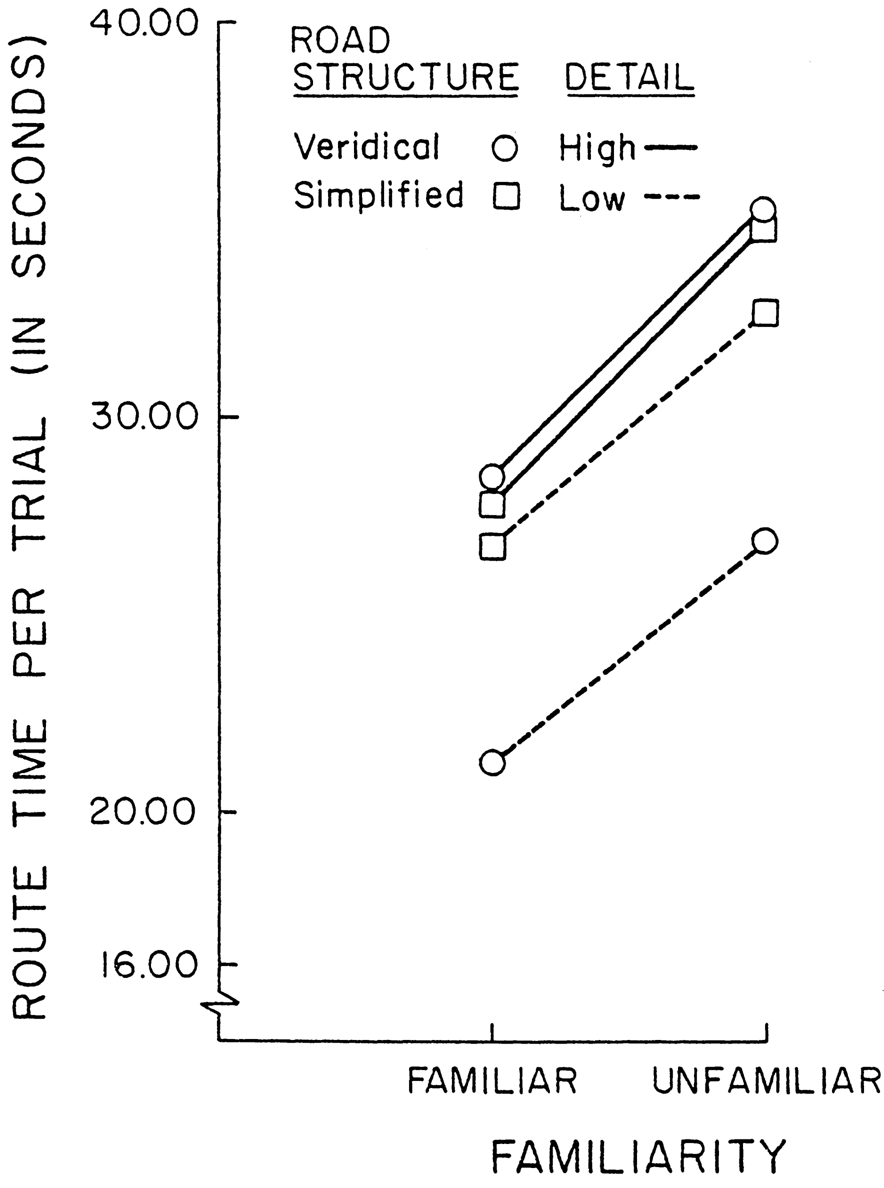

Figure 5. Latencies to determine bus route between intersections, as a function of Familiarity, Detail, and Road Structure (Across Trials Data).

interaction of detail and road structure, one each for the familiar and unfamiliar areas, yielded a significant Detail X Road Structure interaction for the familiar area ($F(1, 39)=7.73$, $p<.01$), but not for the unfamiliar area. An analysis of the simple main effects (i.e. an ANOVA, at each level of detail for Blacksburg) indicated that veridical maps resulted in a route using less bus stops than simplified maps for low-detailed maps, and an opposite pattern of results for high-detailed maps $F(1, 39)=5.14$, $F(1, 39)=4.22$, respectively, $ps<.05$). There were no other significant effects.

<u>Number of Buses</u> For the measure of number of buses in the bus route, there was only a main effect of familiarity ($F=9.80$, $p<.01$)...there were more buses for the unfamiliar maps than the familiar maps. The scores for this variable are displayed in Figure 7.

<u>CORRELATIONS AMONG DEPENDENT VARIABLES</u>

Correlations were determined between the dependent variables to see how a subject's score for one variable was related to his score on another variable (see Table 6). To do this, a subject's mean score (across all maps and trials) was obtained, for all five variables. Therefore, each correlation included 40 scores (40 subjects), and an estimate

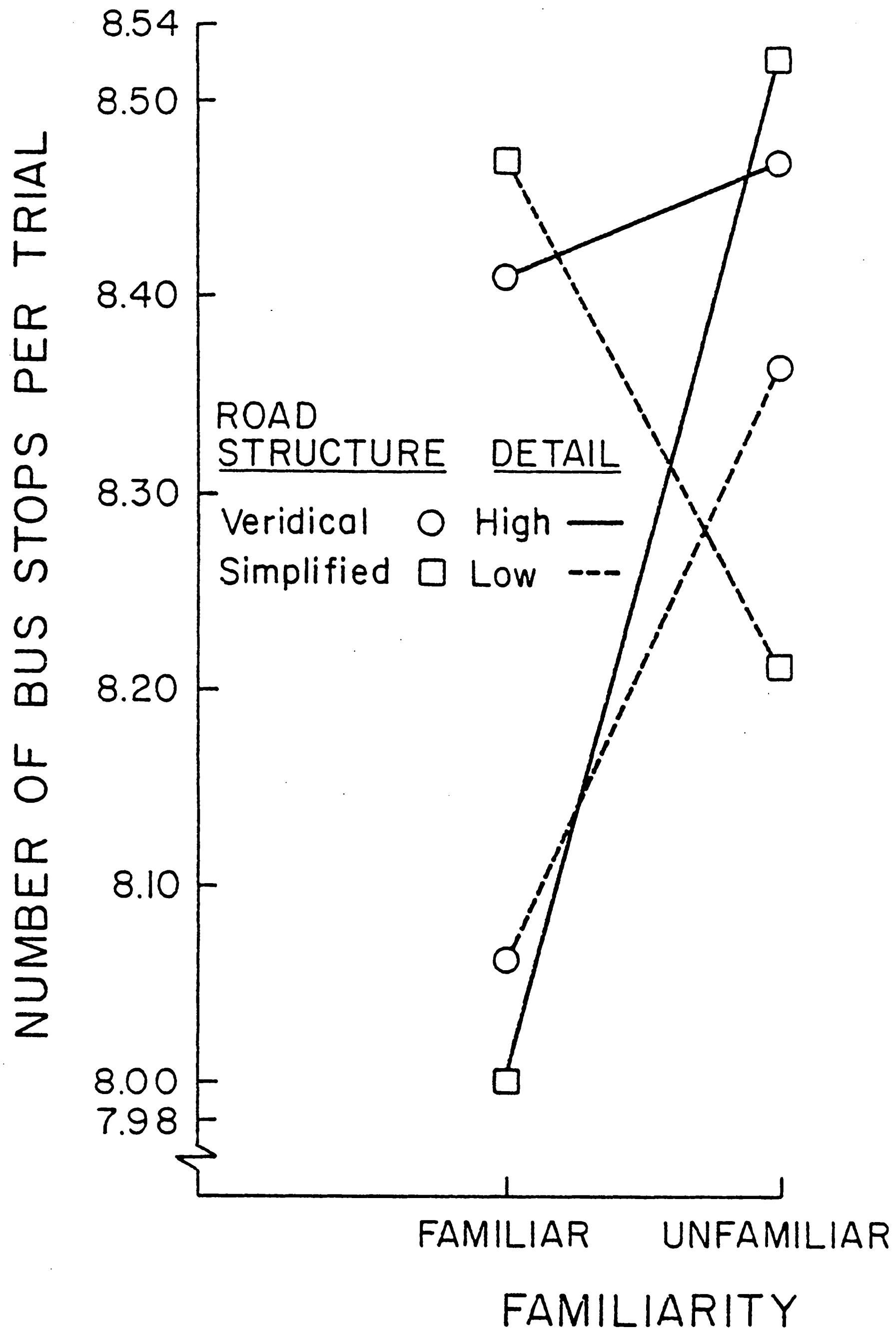

Figure 6. Number of bus stops in bus route, as a function of Familiarity, Detail, and Road Structure.

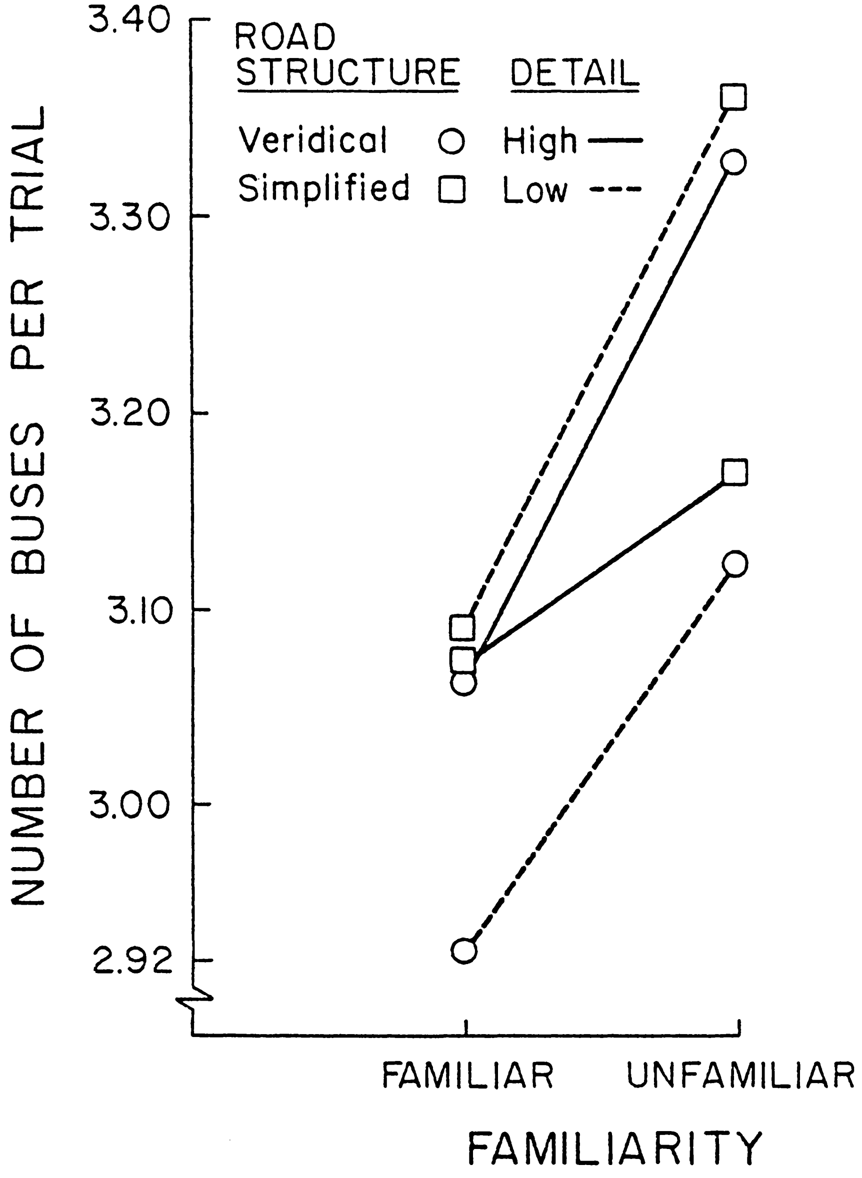

Figure 7. Number of buses in bus route,
as a function of Familiarity, Detail, and Road Structure.

of the relationship between a subject's ranking on one variable and his/her ranking on a second variable was obtained.

The measures for locating the intersections were location time and number of intersections located correctly. The location times were only for trials in which no destination error was made, whereas all trials were used for the number of intersections correctly located, either zero, one, or two. The two measures, location time and number of correct intersections located correlated significantly ($r=-.34$, $p<.05$).

The measures for determination of a bus route were bus route time and the two efficiency measures of number of bus stops and number of buses in the bus route chosen by the subject. While bus route time was not correlated with either efficiency measure, the two efficiency measures were themselves correlated ($r=.43$, $p<.01$), indicating that the chosen bus route tended to be either efficient or inefficient in terms of both number of bus stops and number of buses in the route.

The two time measures were significantly correlated ($r=.48$, $p<.01$). That is, skill at locating intersections was related to skill at determining a bus route between these two intersections. The location time correlated with

Table 6

Correlations, and their probabilites, between dependent variables

		Location Time	Number of Correct Intersections	Bus Route Time	Number of Bus Stops	Number of Buses
Location Time	r	---	-.44	.48	.34	.07
	p	---	.00	.00	.03	.65
Number of Correct Intersections	r		---	-.35	-.15	-.03
	p		---	.03	.35	.87
Bus Route Time	r			---	.21	.18
	p			---	.18	.27
Number of Bus Stops	r				---	.43
	p				---	.00
Number of Buses	r					---
	p					---

r = correlation
p = probability>|r|

the number of bus stops measure ($r=.34$, $p<.05$), but not number of buses ($r=.07$, $p>.05$). The other location measure, number of intersections correctly located was not significantly correlated with either of the efficiency measures.

Finally, bus route time correlated with the number of intersections correctly circled ($r=-.35$, $p<.05$). Thus, both speed at locating places on the map and speed at determining a bus route were related to the accuracy of locating places on the map.

FAMILIARITY WITH BLACKSBURG, LONDON, AND BUS SCHEDULES

Included on the questionnaire were two questions designed to measure the subject's knowledge of Blacksburg: length of residence in Blacksburg, and the subject's self assessment of his/her familiarity with Blacksburg. Table 7 displays statistics for all five questions. Also, the number of correct places located in Blacksburg was used as a familiarity measure.

Table 7 shows that more than three-fourths of the subjects either walked or drove around Blacksburg for the majority of their travel, and travel was equally divided between these two modes (16 subjects each). All but three of the subjects had lived in Blacksburg between one year and ten months, and four years, a range of 26 months. The res-

Table 7

Statistics for questionnaire responses

Usual method of travel around Blacksburg?

Method of Travel	Number of Responses
automobile:	16
walking:	16
bicycle:	5
could not decide:	2
motorcycle:	1

	Mean	Standard Deviation	Range
Bus schedule use?	2.12	1.20	1-6
Familiarity with Blacksburg?	4.50	1.19	1-7
Familiarity with London?	2.20	1.30	1-7
Months in Blacksburg?	34.20	14.72	22-108

Distribution of subjects in length of residence categories:

22-24 Mo.	25-36 Mo.	37-48 Mo.	Greater Than 48 Mo.
14	16	7	3

Note: Bus schedule use and familiarity were rated on a scale of 1 to 7, with 1 equal to least use or familiarity and 7 equal to most use or familiarity.

ponses to the other three questions were all of similar variability, but the average response was noticeably different between the two familiarity questions, the subjects being more familiar with Blacksburg than London, as expected ($\underline{t}(39)=7.47$, $\underline{p}<.01$). The subjects indicated very little past bus schedule use, their rating of past use being slightly lower than even the rating for familiarity with London.

The subjects' rating of their own familiarity with Blacksburg was significantly correlated with both of the objective measures, time in Blacksburg ($r=.36$, $\underline{p}<.05$) and number of places correctly located ($r=.49$, $\underline{p}<.01$).

All three measures were obtained to determine any effects, if any, these factors may have had on the dependent variables. Since these are measures of familiarity with Blacksburg, only the scores for the Blacksburg maps contributed to the dependent variables. The mean dependent variable score of the eight Blacksburg trials, for each subject, was used so that the relationship between a subject's ranking on each dependent variable, and his ranking on each familiarity measure could be obtained. There were a total of 15 correlations (see Table 8): five dependent variables X three familiarity ratings. Despite the positive correlations among the three familiarity measures, only two of the

15 correlations were statistically significant, and only marginally so. These were correlation of the number of bus stops with the number of places located in Blacksburg ($r=.33$, $p=.036$) and the correlation between the number of buses and length of residence in Blacksburg ($r=.31$, $p=.053$).

One other approach to evaluating the effect of familiarity with Blacksburg on the dependent variables was to categorize the subjects according to familiarity as operationally defined by the three familiarity measures. The subjects were divided into high, medium, and low familiarity groups. The breakdown for each level of the three measures was as follows:

Length of Residence in Blacksburg	High	16 subjects
	Medium	12 subjects
	Low	12 subjects
Familiarity with Blacksburg	High	17 subjects
	Medium	17 subjects
	Low	6 subjects
Locating Places in Blacksburg	High	14 subjects
	Medium	16 subjects
	Low	10 subjects

This was the optimal breakdown of the subjects, given the limitation of many identical scores. There were no differences between the high, medium, and low groups for any of the three familiarity measures ($p>.05$)

The subject's own rating of his/her possible familiarity with the section of London displayed was also obtained to

Table 8

Correlations, and their probabilities, between dependent variables and familiarity measures

		Residence in Blacksburg	Familiarity With Blacksburg	Number of Places Located on Map	Familiarity With London
Location Time	r	-.07	-.28	-.17	.57
	p	.67	.08	.29	.73
Number of Correct Intersections	r	-.16	.13	.27	-.10
	p	.33	.42	.09	.56
Bus Route Time	r	.25	.01	.04	.35
	p	.12	.97	.82	.03
Number of Bus Stops	r	.09	.30	.33	.17
	p	.59	.06	.04	.29
Number of Buses	r	-.31	.04	.02	.35
	p	.05	.82	.89	.03

r = correlation
p = probability r

see if there was any perceived familiarity with the London area, or the road layout of the area. Interestingly, this estimate of familiarity with London was significantly correlated with bus route time ($r=.35$, $p<.05$) and with the number of buses in the bus route ($r=.35$, $p<.05$).

The subjects' professed familiarity with bus schedules was not correlated with any of the five dependent variables ($p>.05$).

METHOD OF TRAVEL

A fifth question included on the questionnaire asked the subject to indicate his/her most often used method of transportation around Blacksburg (see Table 7 for a distribution of the responses). Of the 40 replies, 16 indicated walking and 16 indicated the automobile. Since none of the other transportation alternatives included more than five subjects, walking and driving subjects were compared to see if there were any differences. A t-test was performed comparing these two groups of subjects on the five dependent variables. Only Blacksburg data was used, since the method of travel relates only to Blacksburg.

Only the time to determine the bus route was significantly different between the two groups of subjects ($t=2.80$, $p<.01$). The mean time for those who travel by car was greater than the mean time for those who walk (28.23 vs. 22.14).

These two modes of travel were also compared along the three dimensions of familiarity with Blacksburg: number of places located, self-reported familiarity with Blacksburg, and length of residence in Blacksburg. The former two tests involving measures of familiarity were significant ($t(15)=2.18$, $p<.05$, $t(15)=3.06$, $p<.01$, respectively). That is, the mean number of places located was greater by drivers than by walkers (7.31 vs. 6.12), and drivers reported a greater familiarity with Blacksburg than did walkers (5.00 vs. 3.94).

MAP PREFERENCE

The subjects were requested to indicate their preference of maps, for both familiarity levels, Blacksburg and London, by rank ordering the four maps for each location (See Table 9 for the means and standard deviations of their choices). There were significant differences between their choices, as determined by an ANOVA on the dependent variable of rank, for both the four Blacksburg (familiar) maps ($F(3, 36)=12.08$, $p<.01$) and the four London (unfamiliar) maps ($F(3, 39)=7.29$, $p<.01$). The specific differences responsible for the main effects were studied by using the Duncan post hoc test (.05 significant level). For the familiar area, both the veridical maps (high-detailed and low-detailed were significantly more preferred than both simplified maps (again both high-detailed and low-detailed). For the unfamiliar area of London, the veridical low-detailed map was more preferred than both veridical maps (high-detailed and low-detailed), while the veridical high-detailed map was more preferred than only the simplified high-detailed map.

FIELD DEPENDENCE

The last set of data obtained from the subjects was a measure of their field dependence, their score on the Group Embedded Figures Test (GEFT), which was the number of figures outlined correctly. Field dependence was considered a continuous variable, where the higher the number, the higher the subject's field independence.

The GEFT score was correlated with the five dependent variables to see if field dependence was related to ability to use the map. It was correlated with both location measures, location time ($r=-.34$, $p<.05$) and number of intersections correctly circled ($r=.37$, $p<.05$). The GEFT score was not correlated with any of the measures for bus route determination.

Table 9

Mean and standard deviation of subjects' preference among the four maps representing a familiar and an unfamiliar area

	Road Structure	Veridical		Simplified	
	Detail	Low	High	Low	High
Area					
Familiar	Mean	1.92	2.13	2.88	3.07
	Standard Deviation	.92	1.16	1.09	.89
Unfamiliar	Mean	1.95	2.35	2.70	3.00
	Standard Deviation	.90	1.19	1.16	.96

As with the three familiarity measures, the subjects were divided into three levels according to their GEFT scores. Fifteen subjects were placed in a high GEFT category, 12 in a medium category, and 13 in a low category. An ANOVA was then performed on the dependent measures, comparing scores for the high, medium, and low GEFT groups. Only the location time resulted in a significant main effect ($\underline{F}(2, 37)=3.44$, $\underline{p}<.05$). A Duncan post hoc test (at .05 probability) revealed that the time for the subjects rated field dependent was significantly greater than the time for subjects rated as having a moderate amount of field dependence (32.56 vs. 25.57), but was not significantly different from the scores for subjects rated as field independent.

The subjects' GEFT score was also correlated with the number of errors that were made, both destination and translation, in order to determine whether subjects low in field dependence committed more errors than subjects high in field dependence. The field dependence score was significantly correlated with the number of destination errors ($r=.50$, $\underline{p}<.01$), although not with the number of translation errors.

DISCUSSION

PRACTICAL IMPLICATIONS OF MAP FACTORS

The time to locate the intersections, and the time to determine a bus route both decreased from trial 1 to trial 2. This means that increased familiarity with the maps resulted in shorter map reading times. However, practice did not increase the accuracy of locating the intersections. Therefore, some other means, other than practice, must be chosen to increase the accuracy of locating points on a map, such as changing the road structure or detail included on the map.

The two types of errors, destination and translation, must be considered before an overall conclusion concerning which maps were optimal can be made. In deciding which maps should be presented to readers of bus schedules, the importance of the dependent variables, and the kinds of errors made, must also be considered. The variables which were most critical to a person trying to read a bus schedule and ride a bus were weighed more heavily than those not as important.

Destination errors, as well as translation errors, may prevent the traveler from ever reaching his destination. If a traveler cannot look at a bus schedule and determine a bus route that will get him/her to the destination, s/he will not travel by bus. Additionally, Everett et al (1977) pointed out that the consequences of making an error in riding a bus can be quite aversive. One can lose valuable time in reaching a destination, become completely lost, or worst of all, become stranded in a dangerous section of town. For these reasons, the errors for each map were stressed highly, as was the dependent variable of number of intersections circled correctly.

Also of importance when deciding which maps should be presented to bus riders, though less so, were the efficiency measures of number of bus stops and buses. Even if the traveler chooses a route that will get him/her to the destination, the route may include so many buses and involve so many bus changes that it would be impractical with regard to time and convenience to travel using that route. The map must allow the reader to determine a bus route that can be used easily and efficiently to reach one's destination. Of these two efficiency measures, the more critical one is the number of buses, since a greater number of buses increases the number of bus transfers, and probably would increase bus transit time significantly. The number of bus stops would probably increase transit time only marginally. It is noteworthy that the subjects were not specifically asked to produce the most efficient route. However, a map which produces the most efficient route, without much mental effort by the reader, is still the more efficient map than a map in which a less efficient route is determined.

There is a difference between statistical significance and scientific significance, the practical application of the results. The two time measures yielded many statistically significant results of the independent variables which are quite relevant to the hypotheses proposed in this thesis concerning which maps conform best with an internal representation. As for practical considerations, however, the statistically significant differences in the times are not quite as relevant. At most, there was a difference of several seconds between two maps. That is, a map reader may spend ten more seconds reading one map than another. When considered next to the possible hour or more which might be spent in transit using one map rather than another, because of errors, the importance of the time factor diminishes.

The fact that fewer errors, both destination and translation, were committed reading familiar maps than unfamiliar maps has relevance to the theory proposed as to what the internal representation of an area is. However, a map reader must read a Blacksburg map for Blacksburg and a London map for London. What this means is that if the map is of an unfamiliar area, more destination errors will be made. Destination errors can be decreased by presenting an area, not in a simplified manner, which is apparently confusing, but veridically.

There was a significant effect of road structure for destination errors, suggesting that veridical maps be used when presenting bus schedules in a pictorial form. This holds true when considering all dependent variables with one exception: when the veridical map is low-detailed and the area is familiar, the number of the number of bus stops in the chosen bus route will increase. Since this measure is of less importance in deciding which maps are best presented to bus riders, the overall conclusion, with regard to road structure, is to present the map with a true-to-life representation of the roads.

There were no main effects of detail revealed for either the number of errors, both destination and translation, the number of correct intersections, or even the two efficiency measures, although there was a main effect for both time measures; i.e., low-detailed maps were read more quickly than high-detailed maps. However, it is recommended that maps include extra detail for the following reasons. First, the decrease in map perusal time for location was 9.5 seconds, and for bus route it was almost five seconds, a statistically significant difference, but really not very much time is lost using high-detailed maps. Secondly, there were no differences between low-detailed and high-detailed maps with the more critical measures. And third, not including extra detail on a map has one possible drawback. If the bus rider wants to travel to a place that is not mentioned on the map, and he does not know where it is, then a map with no extra detail would not be optimal in that respect. Therefore, the suggestion is to present maps including extra detail, not because high-detailed maps are more readable, which apparently they are not, but because the bus rider would be able to plan a route with the knowledge of where the destination is.

To conclude this section, the consideration of the importance of the dependent measures, and of the effect of the three independent variables of familiarity, detail, and road structure, lead to the conclusion that, to increase bus ridership through improved map readability, the make-up of pictorial bus schedules should be a veridical non-simplified one, but should include extra detail. This suggestion holds true for both maps of a familiar area and an unfamiliar area.

THEORETICAL IMPLICATIONS OF MAP FACTORS

It was argued that, with regard to choosing an optimal map to present to bus riders, the accuracy and error measures would be considered highly important, the two efficiency measures would have moderate importance, and the two time measures would have minimal input into the final decision. With regard to the theoretical implications of the results, different measures were emphasized most. A map in which extra detail is included would be read more quickly by subjects familiar with that area, if indeed the subjects used the information to aid them in reading that map. Therefore, the results of the time measures are stressed with regard to conclusions reached concerning the effects of map detail. Regarding road structure, the assumption of this experiment was that the road structure which represents the environment in a way most similar to the map reader's representation would be the map that is read most quickly, because fewer transformations of the external map to conform with the internal map would be needed. In other words, the map which most conforms to the reader's cognitive map would involve less recoding to read it, and so a shorter time would result. Therefore, the time measures again were the most critical measures when considering the theoretical implications of the results. In addition, a map most closely resembling its internal representation should yield less errors than a map conforming less closely, and so the two error measures, and the accuracy measures (number of intersections correctly circled) were also considered. The two efficiency measures have more practical than theoretical relevance.

In general, three main effects were obtained: familiar maps were easier to read than unfamiliar maps, veridical maps were more readable than simplified maps, and, for the two time variables, low-detailed maps yielded shorter latencies than high-detailed maps.

The reason that familiar maps were more readable than unfamiliar maps was that the subjects, being from Blacksburg, already had knowledge of Blacksburg roads represented internally, whereas for London they did not. This stored information could be used to aid their performance.

It was proposed that an internal representation of a familiar area containing knowledge of places and roads would be reflected by performance on maps with and without extra detail, (such an idea being supported by past research). Detailed maps were read more slowly than low-detailed maps for both familiarity levels. One possibility was that the extra irrelevant information "gets in the way" ---making it more difficult to focus in on the relevant information.

This would be reflected in the longer times for high-detailed than low-detailed maps. It was also possible, however, that the longer times reflected the fact that the subjects paid attention to the extra detail (adding several seconds to their time) but that the extra time spent did not detract from performance. This idea is supported by the fact that there were no more errors for the high-detailed than the low-detailed maps.

It was predicted that for familiar areas veridical maps would be easier to read than simplified maps, because the knowledge of the twists and of the roads would be contained in the internal maps. The same logic was responsible for the prediction that for the London area, a simplified layout of the area would be easiest to read, because people simplifiy their cognitive maps of unfamiliar areas by systematically distorting the road network, eliminating the twists and turns thought to be helpful for a familiar area. The finding was that veridical maps were predominantly the easier maps to read, regardless of the familiarity of the area, indicating that the internal representation of an area is best approximated externally by a veridical (non-simplified) representation of the area.

Bartram found that, what he called "schematic" maps were read faster than road maps. However, his schematic maps not only exaggerated angles between roads and eliminated all curves (road structure factor), but all roads unrelated to the bus schedules, and all unecessary detail, was also removed (detail factor) thereby confounding road structure and detail. In addition, his schematic map included a different color for each route, but one color represented all routes on the road map, thereby confounding color as well. Bartram was therefore not testing road structure alone. As a result, he could not conclude that it was the simplified road structure which accounted for faster times for the "schematic" maps.

In the case of Blacksburg, one possible reason for veridical maps being more readable than simplified maps, was due to Blacksburg's familiarity to the subjects. The subjects knew the idiosyncracies of the roads, and where their position on a map should be in relation to the other roads. A map in which the road structure was not displayed veridically did not correspond to the subjects' cognitive map. Slower times were the result, as well as an increase in errors for the simplified, though distorted, maps.

This explanation, however, cannot account for the road structure results involving unfamiliar maps, in which veridical maps were again more readable than simplified maps. One hypothesis which can concerns the subjects' previous map experience. It is probable that the majority of the maps people read are road maps, which of necessity present roads in a veridical, not simplified, manner. It is also probable that all the subjects, being above the driving age, have used road maps, if not extensively, then at least occasionally. Presenting a map of roads in which there are no curves and all intersections are either 90 degrees or 45 degrees may have confused the subjects. In other words, the subjects may simply have been used to reading a veridical road map, and may have had little experience with a simplified road map.

Another reason that the simplified maps may have been easier to read than the non-simplified maps is that perhaps a road network of straight roads and angular intersections was disorienting or disquieting to people viewing a map because of its unreality. According to this explanation, people have built up an internal plan, or "schematic", of how roads truly make up a town or a city. The map reader's knowledge of the world is of a world with curved, not perfectly straight, roads. Seeing a map in which roads are presented in a manner contrary to their cognitive schemas takes longer to read and more errors are committed.

These two explanations are related in that it is experience with a non-simplified, veridical world, whether that be a road map, (former explanation), or the actual roads themselves (latter explanation). These explanations receive support from the subjects' ratings of the maps, which revealed that they preferred the veridical maps to the simplified maps. These ratings were made after their performance using the maps, and so are probably due, in part, to a reflection of the actual performance. Still, the veridical maps received the least preferred rating, 2.15, and the simplified maps received the most preferred rating, 2.85. The ratings for the low-detailed maps (2.32) and the high-detailed maps (2.57) were each more moderate. This suggests that the subjects felt quite strongly that the veridical maps, for both the familiar and unfamiliar area, were more to their liking. If it is true that people do prefer external representations (maps) in a form similiar to their internal representation (cognitive maps), then their cognitive maps are of a veridical nature. The world really is full of curved roads intersecting in an unsystematic way, and a distorted, though simplified, map may be confusing to map readers.

Map complexity is not a crucial factor responsible for a map's readability, or even map preference. In the pretest, high-detailed maps were rated as more complex than low-detailed maps. High-detailed maps were also less readable than low-detailed maps. However, there was no significant difference between the preferences for low- detailed and high-detailed maps. The complexity of the maps, with regard to the maps's road structure, had no bearing on either the subjects' scores or their map preference. The veridical maps were rated as more complex, yet these maps were both more readable and more preferred. It is not likely that it is the complexity of the maps per se which is responsible for the greater readability of the veridical maps. It is more plausible that it is the maps' correspondence with reality, its veridicality, which is the primary reason for its greater readabiltiy.

CORRELATIONS AMONG DEPENDENT VARIABLES

The location measures, location time and number of intersections correctly located, were significantly correlated. This means that if a subject's location times were fast on trials in which no destination error occurred, then on all trials they located most of the intersections presented to him/her; if a subject's times were slow, then there fewer correctly circled intersections overall. In other words, a subject's speed in finding two intersections correctly was related to his/her overall accuracy. This being a correlation, however, does not imply that greater speed causes greater accuracy. Indeed, a factor causing both is probably responsible for the significant relationship, that being a general map-reading ability. This map-reading ability is probably due in part to the subjects cognitive style, with field-independent subjects having greater ability than field-dependent subjects, since the GEFT score was significantly correlated with both location measures.

The fact that the two efficiency measures were correlated is not surprising. A long bus route in most cases involves more bus stops and bus changes, while a short bus route involves fewer bus stops and buses. The amount of time spent in determining a bus route was not correlated with either of these efficiency measures. This means that the simple act of taking a longer time to look for a route did not increase efficiency, in and of itself. This also is not surprising when it is considered that the subjects were not told to search for an efficient route. The reason that the subjects were not given those instructions was to obtain a measure of which maps automatically elicit an efficient route. Therefore, the subjects were only looking for the first route that they could find, regardless of its efficiency. If the subjects were told to search for the most efficient route they could find, it is probable that the amount of time spent searching for a route would be related to the efficiency of that route. This should be studied in a future experiment.

The subjects who located the intersections quickly also determined a bus route quickly, while those performing slowly did so for both tasks. Additionally, both time variables were significantly correlated with the number of intersections located correctly. It is probable, then, that the map-reading ability previously mentioned is responsible for both the speed and accuracy of map reading.

There was one other significant correlation, that between location time and the number of bus stops. This is unexpected, since the time to determine a bus route was not correlated with the number of bus stops, an efficiency measure of the bus route. The only logical explanation for these results is again that a general map-reading ability was responsible for subjects locating intersections quickly and selecting a route with few bus stops in it.

Because of the high correlations between several of the dependent variables, it was probable that they were measuring much of the same underlying abilities. Specifically, the two variables of number of bus stops and number of buses appear to be measuring the same ability, that of choosing an efficient bus route. Location time's high correlation with number of intersections correctly located indicates that both are measuring the ability to locate places on a map. And finally, the high correlation between the time measures, location time and bus route time, indicates a general map-reading ability.

FAMILIARITY MEASURES

The three measures of familiarity with Blacksburg were correlated with the scores for the Blacksburg maps to see what the effect of familiarity would be. It must be recalled that, to assure an effect of familiarity, a requisite for participation in the study was a length of residence in Blacksburg of at least two school years. Therefore, the limited number of significant correlations were probably due, in large part, to the effectiveness of this requisite. All subjects were at least somewhat familiar with the Blacksburg area, and so even if some subjects were more familiar with Blacksburg than others, they were all familiar enough so that differences between the subjects' scores were minimal. This would account also for the non-significant differences between dependent scores for subjects rated low, medium, and high in these three measures of familiarity. In order to see the effects familiarity with Blacksburg has on the dependent variables, a future experiment should include a group of subjects unfamiliar with an area to be compared to a group of subjects more familiar with that area.

Interestingly, the subjects' own rating of familiarity with London correlated with two of the five dependent measures---bus route time and the number of buses in the bus route. It is probable that the subjects based their ratings, either consciously or subconsciously, on their own previous performance. If the subjects remembered having difficulty with the London maps, they may have reported that they were very unfamiliar. If, on the other hand, they were not particularly troubled by the London map they may have rated their familiarity as not quite so low.

METHOD OF TRAVEL

It was determined that subjects who travel around Blacksburg most by automobile took more time to determine a bus route between two intersections. Yet it was also determined that the 16 subjects who drove located more places than walking subjects, and reported their own familiarity with Blacksburg as higher than subjects who walked. The former results suggests greater knowledge of Blacksburg for walkers than drivers, while the latter results suggest greater Blacksburg knowledge for drivers than walkers. It is possible to reconcile these apparently conflicting results by proposing that people who walk pay more attention to the streets and the street names between their destinations than do people who drive. When they had to determine a route between two intersections on the bus route map, they were better prepared, and their times reflected this. On the other hand, people who drive travel more and come into contact with more places and these subjects, with this knowledge, reported their familiarity as greater than those who walk.

MAP PREFERENCE

The subjects preferred both veridical maps to both simplified maps for the familiar area, Blacksburg. The subjects were from Blacksburg, and so had at least partial knowledge of the roads' true nature. The same pattern of preferences was obtained with London maps, except that the veridical high-detailed map was more preferred than only the simplified high-detailed map, and not the simplified low-detailed map. Similar results for both familiar and unfamiliar areas suggest that people prefer maps in which roads are presented as they really are, rather than as distorted. This conclusion was also reached when considering the ANOVA results.

These preferences corresponded with their performance, since for the three dependent variables in which there was a main effect of road structure (both time variables and the location variable), veridical maps were more readable than simplified maps, meaning that the subjects' subjective preference corresponded with their objective measure. One possible explanation for this is that the subjects remembered their own performance and, based on that, decided which map they preferred. An alternative possibility consistent with results discussed up to now is that the same factor was responsible for both performance and preferance, that being the fact that a veridical representation of an area is the form in which an area is internally represented as well.

FIELD DEPENDENCE

The GEFT was presented to the subjects to obtain an estimate of their cognitive style (specifically, field dependence). It was hypothesized that field independent subjects would be better at reading a map than subjects with field dependence, because the two map tasks required the subjects to break up the field into discrete parts, which field-independent subjects are better able to do. The subjects were required to complete two tasks involving the maps. The GEFT score was significantly correlated with both measures for task one, locating the intersections, but with none of the three measures for task two, determining a bus route. The negative correlation with location time reflects the fact that as the field dependence score increased (greater field independence) the time to locate intersections on the map decreased (greater ability). The positive correlation with the number of intersections reflects the positive relationship between the field dependent scores and the number of intersections; the greater the field independence, the greater the ability to locate intersections on the map. In addition, the GEFT scores were divided into low, medium, and high. There were differences between these groups only with the location time.

Therefore, field dependence was related to the ability to locate places on a map, but not to the ability to use the map. Since field independence implies ability to focus in on relevant information and the ability to ignore irrelevant information, evidently these two abilities were important for both the GEFT and locating places on a map. Field independence is not an importance skill for using the map, once the critical places have been found.

The subject's GEFT score was related to the number of destination errors the subject committed, (the greater the field independence, the fewer the errors). What this means is that high field independence can help one to avoid destination errors, and safely reach one's destination. However, both low and high field dependent subjects committed translation errors equally. Field independence did not help in the translation of the bus route from a pictorial to a verbal mode.

CONCLUSIONS

It was stated in the beginning of this paper that research dealing with transit informational aids is severely lacking. The research reported here used subjects' ability to read a pictorial bus schedule to investigate the two map variables of road structure and detail. The conclusion was reached that a) bus route maps are most easily read when roads are presented veridically and b) extra detail does not aid in the readability of a map, but should be included, nevertheless, to help bus riders plan their routes. These are just two of the many variables which should be investigated in order that potential bus riders receive information that they can understand and use to plan a bus trip.

The methodology employed to determine what maps are most easily read when presenting a bus schedule was also used to investigate cognitive maps. It was concluded that the subjects' internal representation of both areas represented was best approximated externally by a non-simplified, veridical road structure, since those maps were more readable. Both direct methods of assessing internal representations (e.g. map drawing) and indirect methods (e.g. map reading performance) must continue for there to be a final determination of the form and knowledge contained in cognitive maps.

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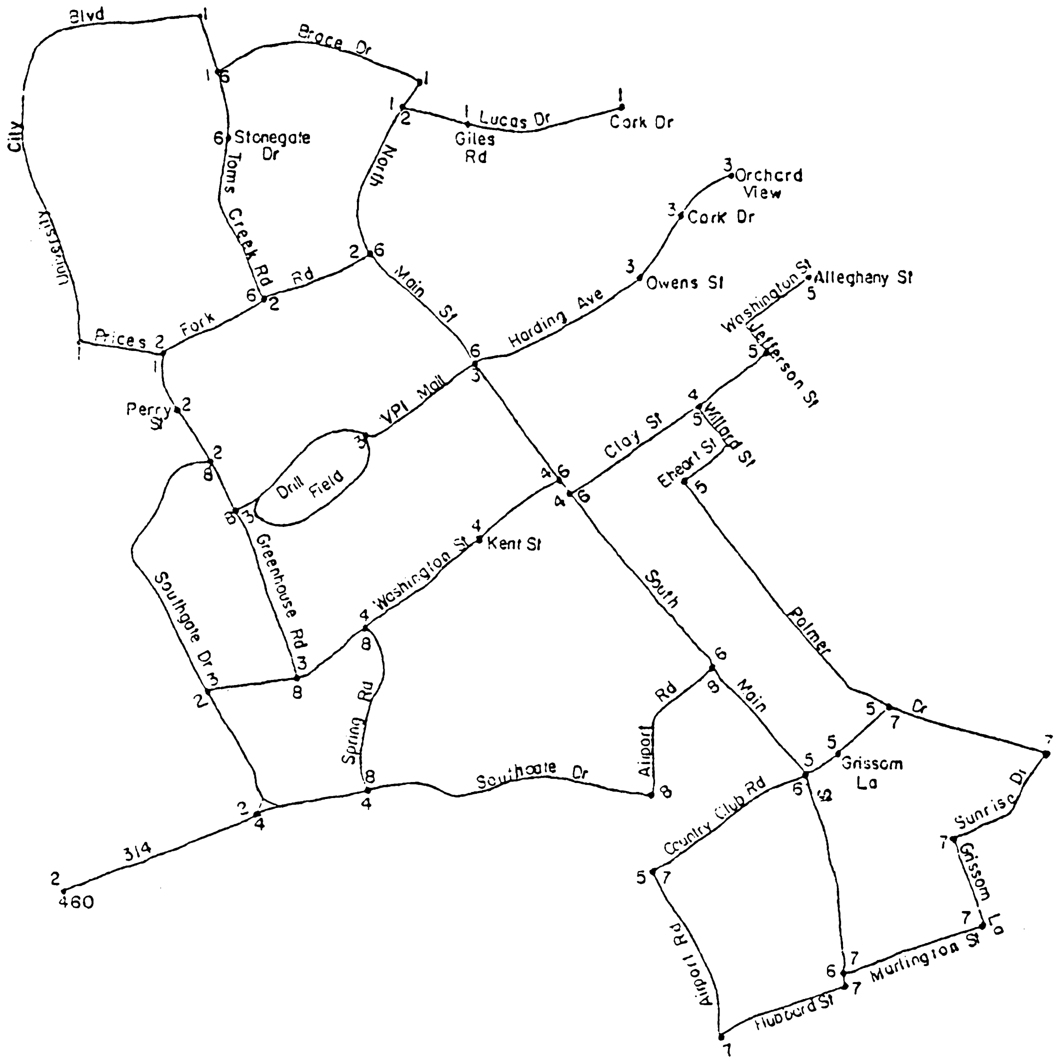
Appendix A

The eight maps presented to subjects
(reduced 35 %)



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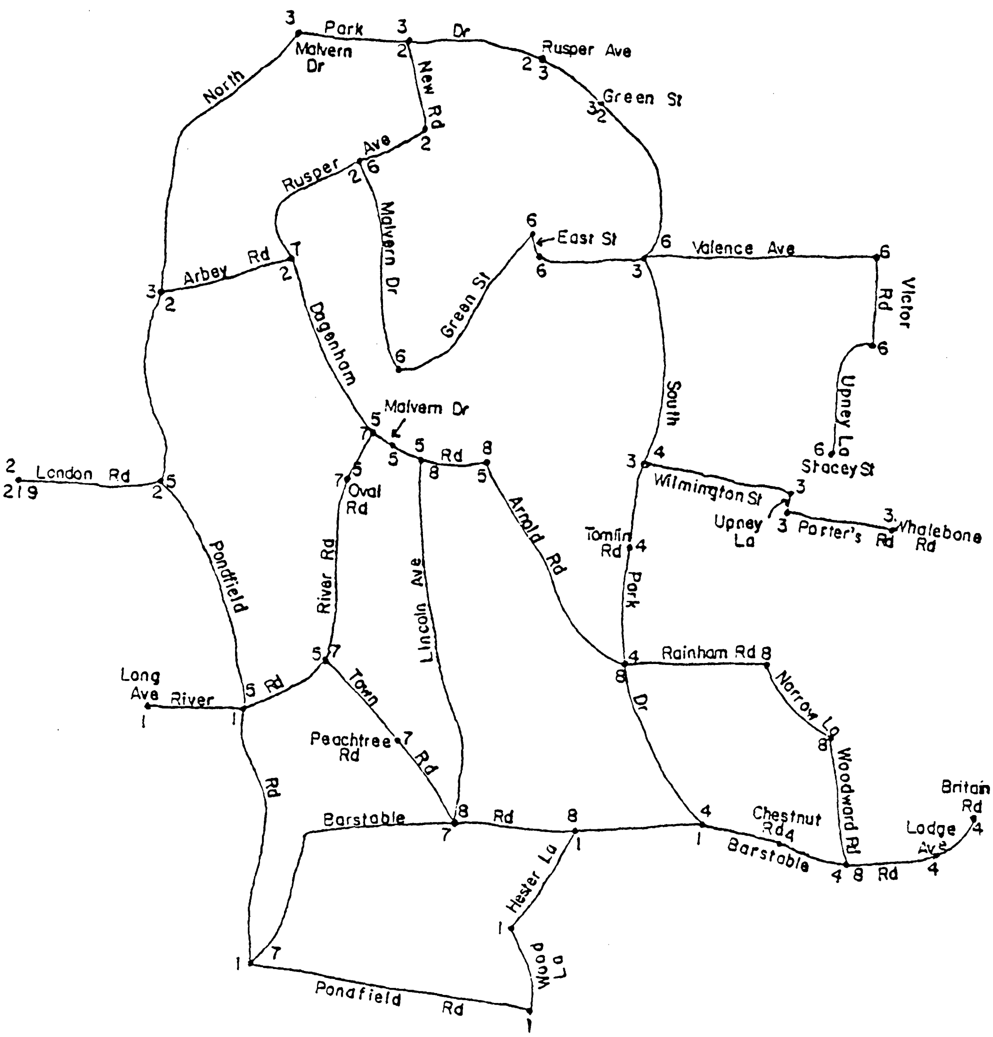

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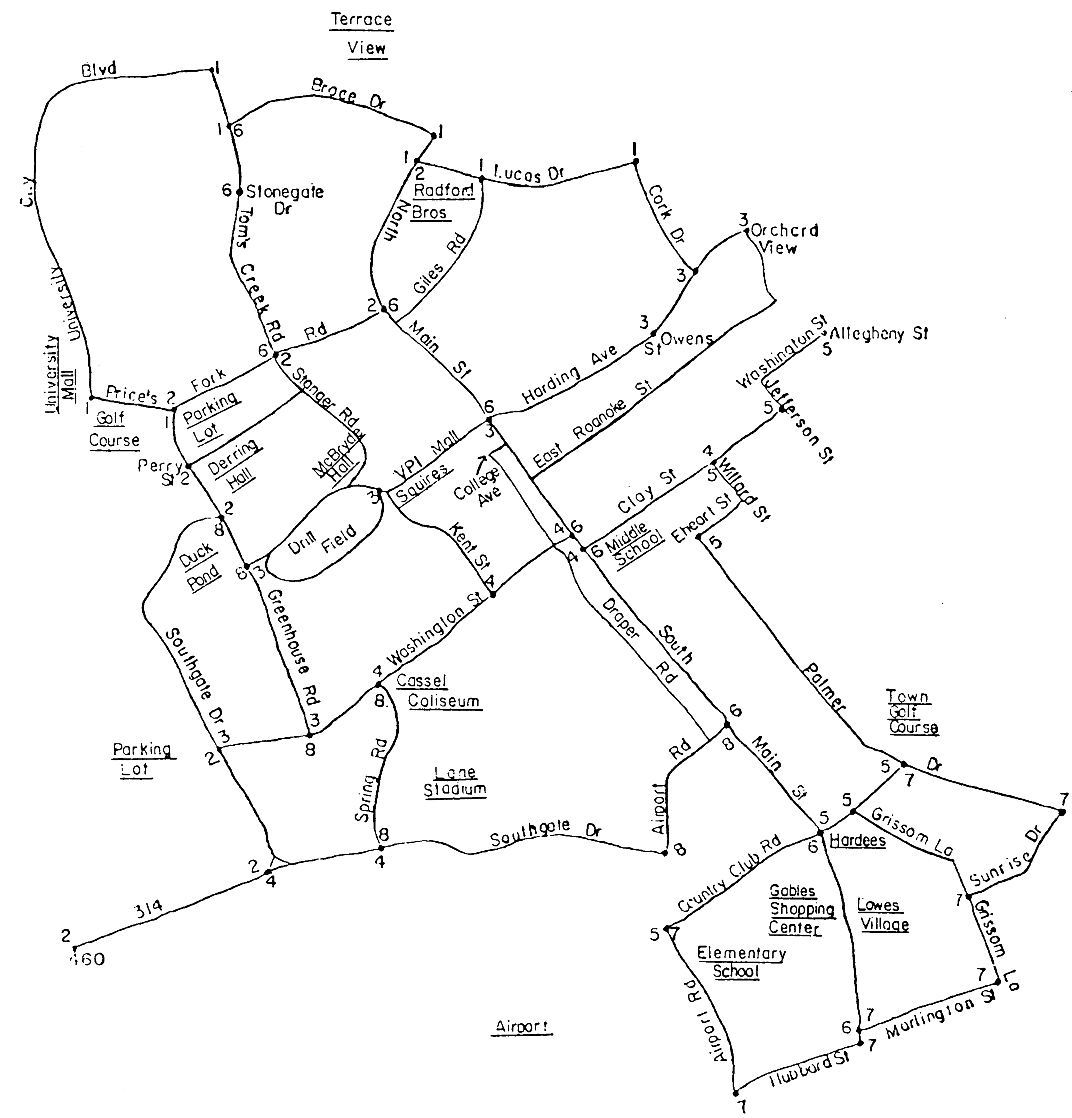
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Derring Hall
Stanger Rd
McBryde Hall
VPI Mall
Squires
College Ave
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Jefferson St
Clay St
Willard St
Ehcart St
Middle School
Perry St
Duck Pond
Drill Field
Kent St
Greenhouse Rd
Washington St
Cassel Coliseum
Southgate Dr
Draper Rd
South Main St
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Town Golf Course
Parking Lot
Spring Rd
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Airport Rd
Southgate Dr
Grissom La
Sunrise Dr
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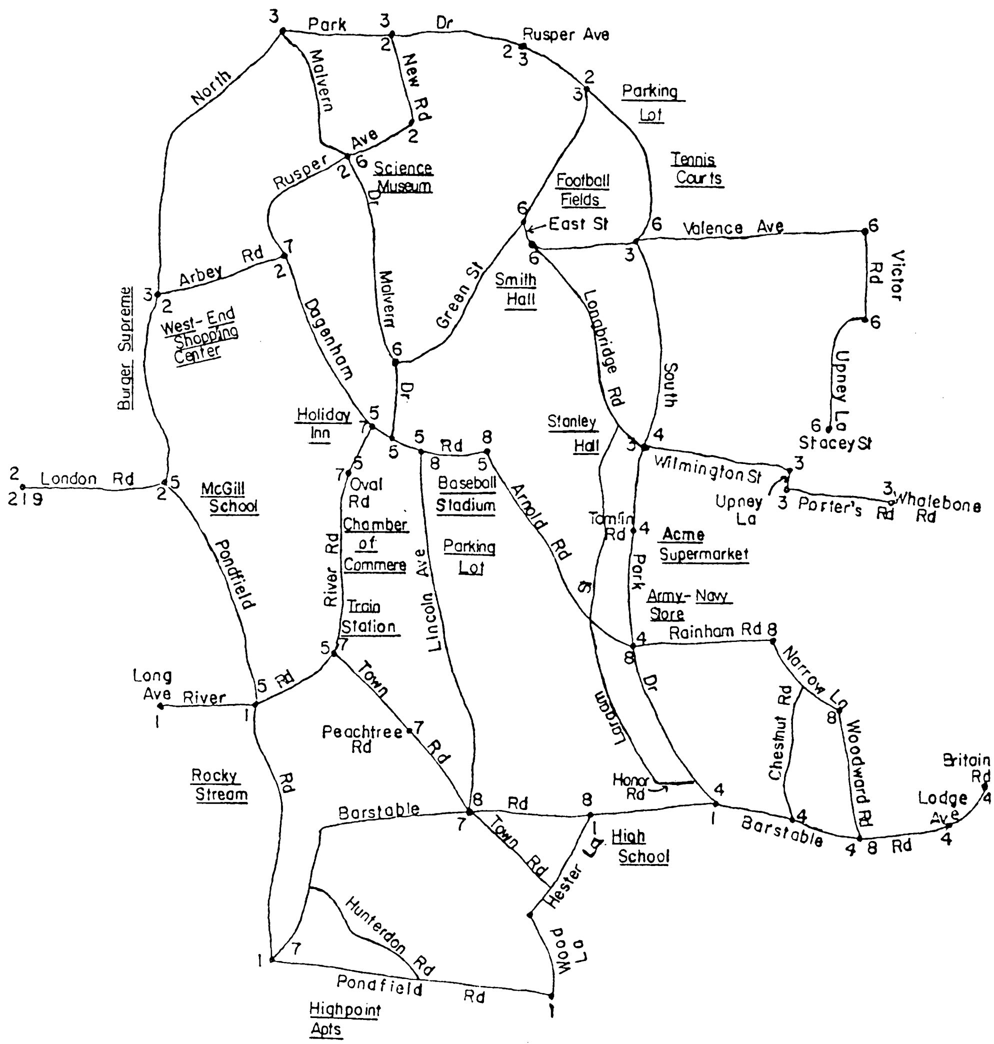
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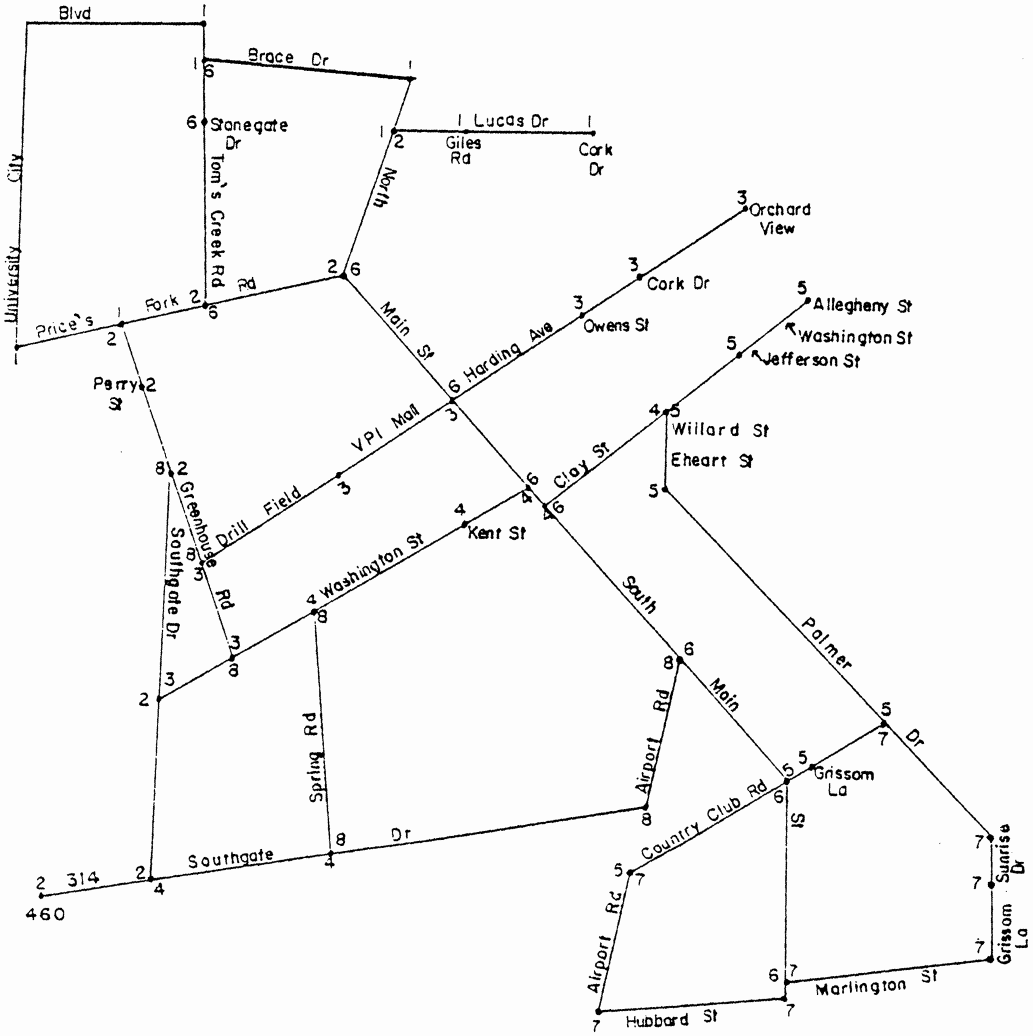
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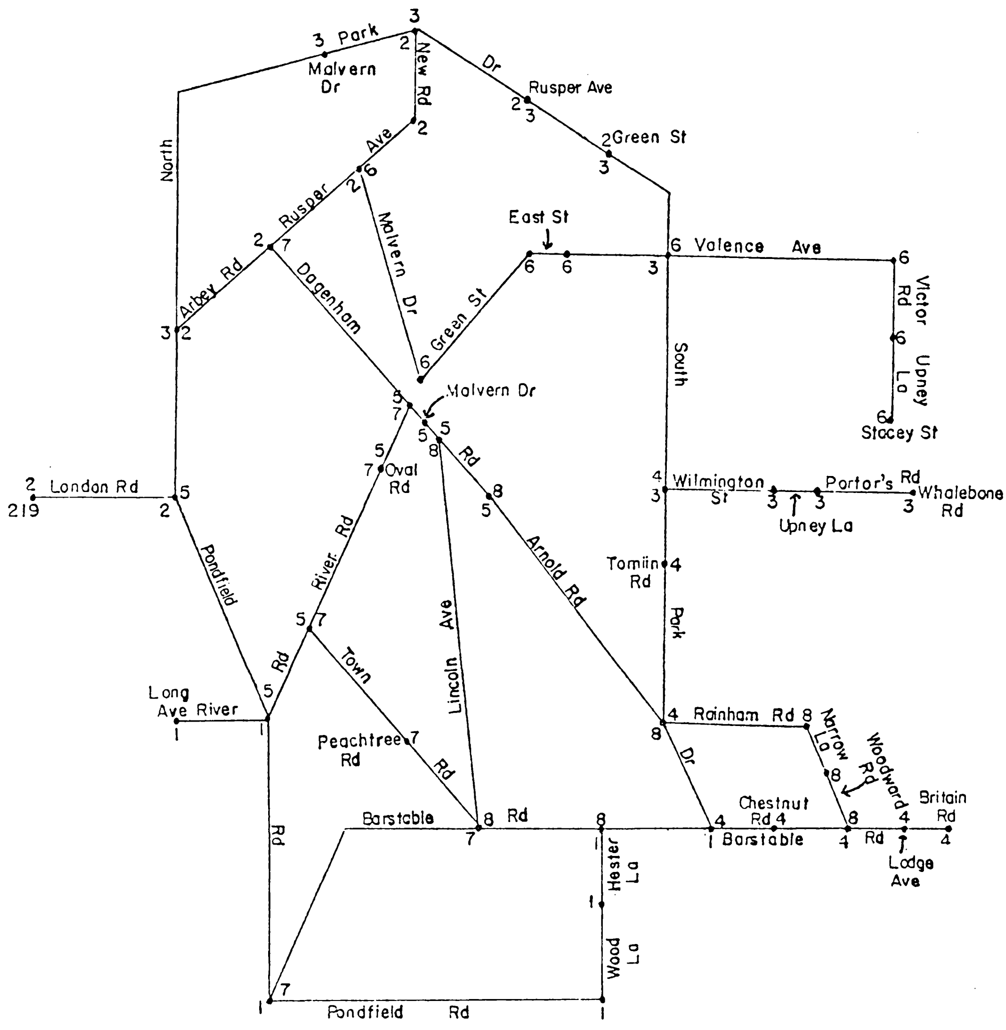
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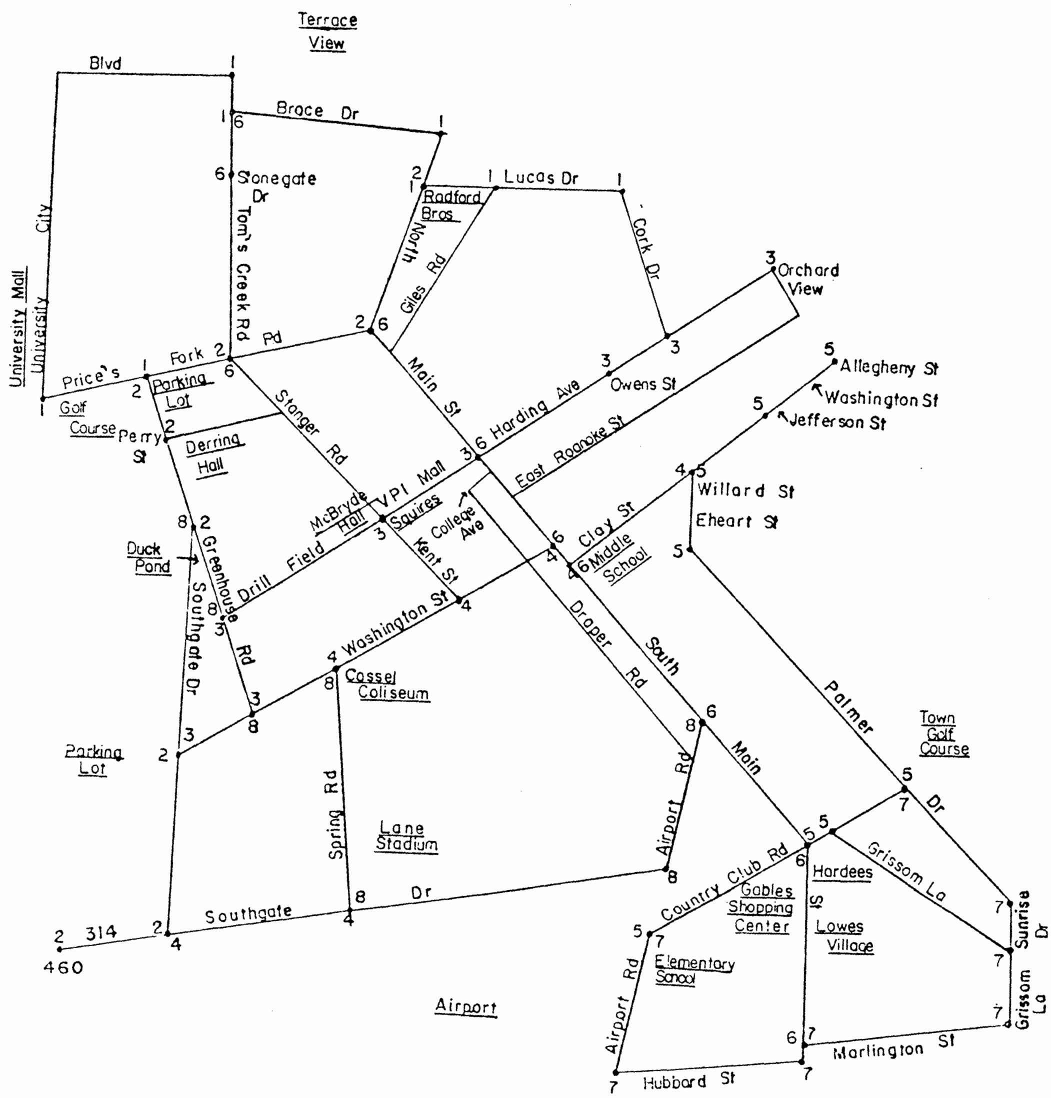
Map Six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Gables Shopping Center
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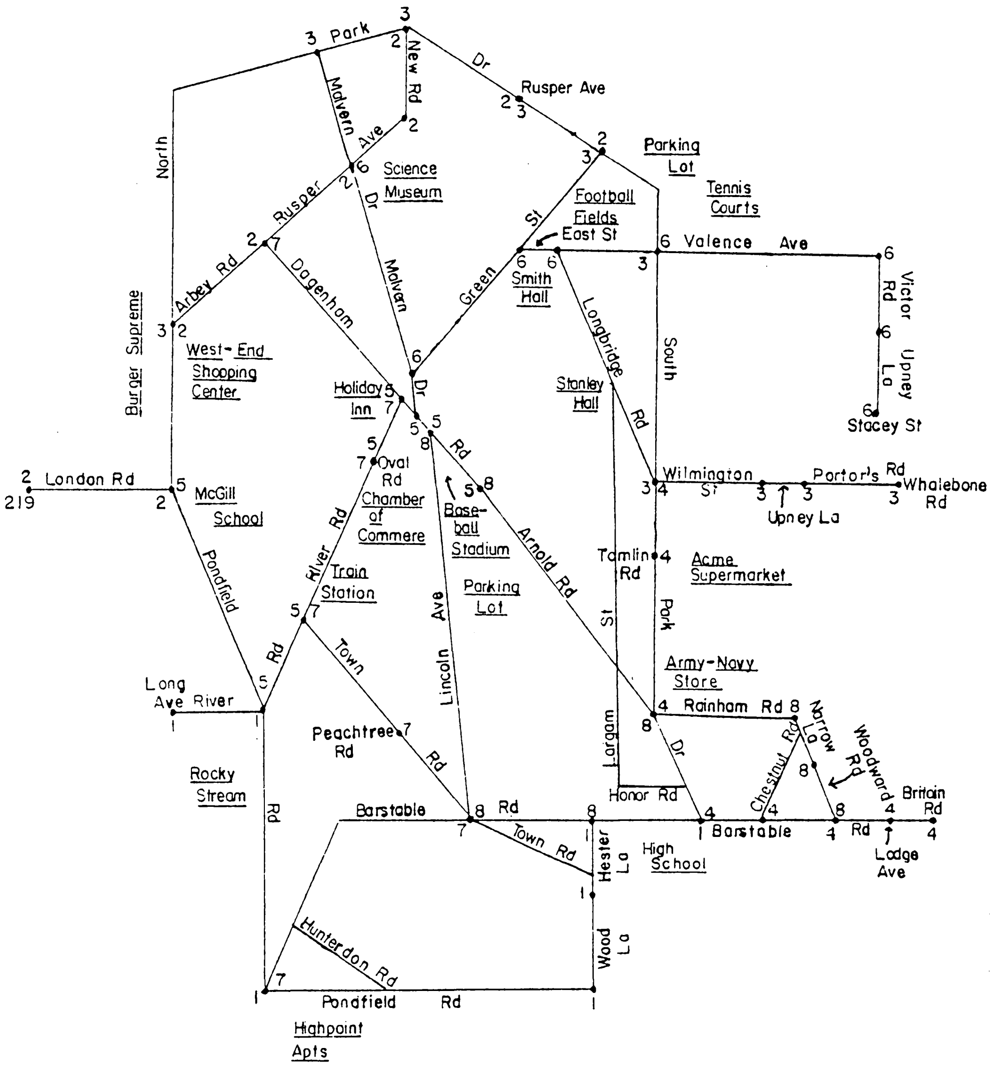
Map Seven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Park
Town
Rd
Army-Navy Store
Long Ave
River
Rainham Rd
Narrow La
Woodward Rd
Peachtree Rd
Largam
Dr
Chestnut Rd
Rocky Stream
Rd
Rd
Honor Rd
Britain Rd
Barstable
Rd
Barstable
Rd
Town Rd
Hester La
High School
Lodge Ave
Hunterdon Rd
Wood La
Pondfield Rd
Highpoint Apts

Map Eight

Appendix B

Balanced Latin Square Design

Subject:	1	2	3	4	5	6	7	8
Map:	1	2	3	4	5	6	7	8
	2	3	4	5	6	7	8	1
	8	1	2	3	4	5	6	7
	3	4	5	6	7	8	1	2
	7	8	1	2	3	4	5	6
	4	5	6	7	8	1	2	3
	6	7	8	1	2	3	4	5
	5	6	7	8	1	2	3	4

Appendix C

INSTRUCTIONS

I will place in front of you a map of eight bus routes for either the city of Blacksburg or another city unfamiliar to you. Written on top of each map will be two pairs of street intersections. The first intersection is the departure point and the second intersection is the destination for a bus trip. I would like you to first locate each point and circle it with a pencil.

After you have marked both points, I would like you to work out the buses needed to travel from the first point to the second. There are eight (8) bus routes, the stops being indicated by a number next to a dot. First, write down at the bottom of each map the buses you would take, and second, draw on the map the route to be taken.

For example, on this much simplified map, I have written the intersections of Ace St. and Queen St., and King St. and Lemon St. First, you should locate these two points and then circle them (please do so now). Immediately following that, determine how to get from the first point to the second, using the buses, and write down the bus numbers at the bottom of the page. In the example, in order to travel from Ace and Queen to King and Lemon, one must use bus 2, then bus 3, then bus 1. And finally, draw the route on the map. One must travel along the route depicted on this map. One cannot travel from Queen and Lime to Lemon and King using Lemon St., because there is no bus that travels between these two bus stops (buses 2 and 3 are at the first stop, and bus 1 is at the second). Therefore, one cannot travel directly from the first to the second stop, using Lemon St., but must choose a second route, the one shown on the map.

Remember these rules. In order to travel between two immediate points, the same bus route must have a stop at both points. If two points are connected by a road, but the same route number is not at both points, then another road must be chosen. The buses can travel in both directions on each route. Many of the bus stops will have 2 buses stopping at that intersection. One of the buses must be chosen on the basis of which bus travels to the next stop on the way to the final destination. And finally, it is possible for a road to be disconnected, such as Ace St. stopping above Queen St. before restarting again at Queen St.

To repeat, the three tasks are:

1. locate and circle the two locations

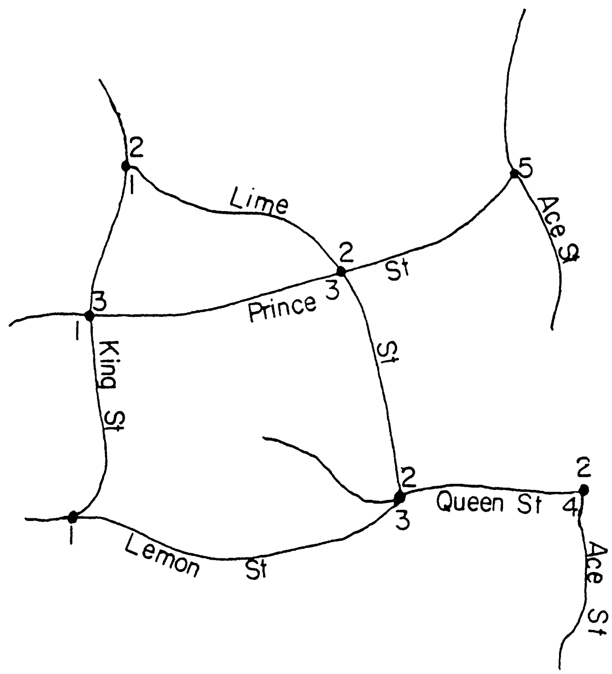
2. determine and write down the bus route numbers needed to get from the first to the second location

3. draw the route on the map

I will be timing you, so please work as quickly as possible, while still limiting errors. As soon as you have circled both points, determine the bus route you would take on the map. When you have finished drawing the bus route to be taken, turn the map over so I know you have finished. There will be a total of 16 maps. As soon as I give you the map, start your three tasks. Are there any questions?

Appendix D

Map used during practice trial



Appendix E

EIGHT PAIRS OF BLACKSBURG AND LONDON INTERSECTIONS

Blacksburg

1. Broce Dr. & Tom's Creek Rd. Willard St. & Clay St.

2. Cork Dr. & Lucas Dr. Country Club Rd. & S. Main St.

3. Orchard View & Harding Ave. Airport Rd. & Southgate Dr.

4. Stonegate Dr. & Tom's Creek Rd. Eheart St. & Palmer Dr.

5. Marlington St. & Grissom La. Spring Rd. & Washington St.

6. Sunrise Dr. & Palmer Dr. N. Main St. & Harding Ave.

7. Hubbard St. & S. Main St. VPI Mall & Drill Field.

8. University City Blvd. & Price's Fork Rd. Southgate Dr. & Spring Rd.

London

1. London Rd. & Pondfield Rd. Victor Rd. & Valence Ave.

2. Long Ave. & River Rd. Arnold Rd. & Dagenham Rd.

3. Wood La. & Hester La. Green St. & N. Park Dr.

4. Lodge Ave. & Barstable Rd. Malvern Dr. & Dagenham Rd.

5. Oval Rd. & River Rd. Wilmington St. & S. Park Dr.

6. Narrow La. & Woodward Rd. Victor Rd. & Upney La.

7. Wilmington St. & Upney La. Arbey Rd. & Rusper Ave.

8. Peachtree Rd. & Town Rd. East St. & Green St.

Appendix F

PLACES THE SUBJECTS WERE REQUIRED TO LOCATE IN BLACKSBURG

1. Burger King
2. Blacksburg High School
3. Mr. Fooz Sub Shop
4. Foxridge Apartments
5. Harbor's Landing Fish Camp
6. Capri Twin Theaters
7. Mish Mish
8. Blacksburg Public Pool
9. Maxwell's Restaurant
10. Holiday Inn

Appendix G

Questionnaire Presented to Subjects

1) What is your usual (most often used) method of travel around Blacksburg?

   a) automobile
   b) bicycle
   c) walking
   d) hitchhiking
   e) other______________

2) How long have you lived in Blacksburg (years and months)?

   ____

3) How often have you used bus schedules in your lifetime?

   +------+------+------+------+------+------+

   never used one — used moderately — used often

4) How familiar are you with the area of Blacksburg represented by the maps presented to you?

   +------+------+------+------+------+------+

   very unfamiliar — moderately familiar — very familiar

5) How familiar does the strange city represented by the maps seem to you?

   +------+------+------+------+------+------+

   very unfamiliar — moderately familiar — very familiar

Appendix H

Analysis of variance summary table for each dependent variable

Location Time (Between Trials Data)

Source	df	SS	F
Between Subjects			
Subjects (S)	39	29159.80	
Within Subjects			
Trial (T)	1	1950.04	13.85**
T x S	39	5490.27	
Familiarity (F)	1	17840.31	111.34**
F x S	39	6248.90	
Road Structure (RS)	1	3067.19	7.71**
RS x S	39	15512.83	
Detail (D)	1	9621.10	55.83**
D x S	39	6721.12	
T x F	1	50.73	0.33
T x F x S	39	6076.20	
T x RS	1	117.37	1.06
T x RS x S	39	4304.60	
T x D	1	731.02	5.53*
T x D x S	39	5159.76	
F x RS	1	34.54	0.22
F x RS x S	39	6146.18	
F x D	1	40.16	0.17
F x D x S	39	9033.54	
RS x D	1	303.54	1.39
RS x D x S	39	8546.46	

Source	df	SS	F
T x F x RS	1	71.21	0.36
T x F x RS x S	39	7638.96	
T x F x D	1	84.80	0.74
T x F x D x S	39	4459.62	
T x RS x D	1	130.14	1.10
T x RS x D x S	39	5407.52	
F x RS x D	1	508.08	2.65
F x RS x D x S	39	7484.29	
T x F x RS x D	1	78.23	0.36
T x F x RS x D x S	39	8517.53	
Total	639	170176.14	

* $p < .05$
** $p < .01$

Location Time (Across Trials Data)

Source	df	SS	F
Between Subjects			
Subjects (S)	39	16360.53	
Within Subjects			
Familiarity (F)	1	10181.34	102.09**
F x S	39	3889.34	
Road Structure (RS)	1	1133.75	5.35*
RS x S	39	3267.66	
Detail (D)	1	5810.68	53.56**
D x S	39	4231.05	
F x RS	1	12.42	0.10
F x RS x S	39	4934.04	
F x D	1	113.42	0.78
F x D x S	39	5668.31	
RS x D	1	330.18	2.47
RS x D x S	39	5221.78	
F x RS x D	1	561.13	4.73*
F x RS x D x S	39	4626.52	
Total	319	71342.15	

* $p < .05$

** $p < .01$

Number of Intersections Correctly Circled

Source	df	SS	F
Between Subjects			
Subjects (S)	39	2.52	
Within Subjects			
Familiarity (F)	1	1.31	23.09**
F x S	39	2.22	
Road Structure (RS)	1	1.19	19.78**
RS x S	39	2.34	
Detail (D)	1	0.04	0.86
D x S	39	1.74	
F x RS	1	0.66	18.65**
F x RS x S	39	1.37	
F x D	1	0.09	1.69
F x D x S	39	2.19	
RS x D	1	0.04	0.86
RS x D x S	39	1.74	
F x RS x D	1	0.01	0.08
F x RS x D x S	39	3.27	
Total	319	20.72	

** $p < .05$

Bus Route Time (Between Trials Data)

Source	df	SS	F
Between Subjects			
Subjects (S)	39	54660.20	
Within Subjects			
Trial (T)	1	7667.41	40.37**
T x S	39	7407.22	
Familiarity (F)	1	6422.45	27.32**
F x S	39	9168.82	
Road Structure (RS)	1	1003.60	4.07
RS x S	39	9621.59	
Detail (D)	1	3846.35	10.99**
D x S	39	13651.59	
T x F	1	143.98	1.01
T x F x S	39	5565.46	
T x RS	1	24.00	0.11
T x RS x S	39	8163.00	
T x D	1	75.57	0.38
T x D x S	39	7804.19	
F x RS	1	2.06	0.01
F x RS x S	39	10482.69	
F x D	1	37.15	0.15
F x D x S	39	9704.56	
RS x D	1	1437.78	3.80
RS x D x S	39	14754.87	
T x F x RS	1	26.66	0.18
T x F x RS x S	39	5635.38	
T x F x D	1	121.26	0.69
T x F x D x S	39	6855.96	

Source	df	SS	F
T x RS x D	1	244.08	1.08
T x RS x D x S	39	8795.60	
F x RS x D	1	1.24	0.00
F x RS x D x S	39	14628.94	
T x F x RS x D	1	37.88	0.17
T x F x RS x D x S	39	8922.45	
Total	639	216913.98	

** $p < .01$

Bus Route Time (Across Trials Data)

Source	df	SS	F
Between Subjects			
Subjects (S)	39	28046.70	
Within Subjects			
Familiarity (F)	1	3173.78	26.53**
F x S	39	4665.17	
Road Structure (RS)	1	530.55	4.33*
RS x S	39	4782.73	
Detail (D)	1	1764.18	10.11**
D x S	39	6803.61	
F x RS	1	2.14	0.02
F x RS x S	39	5339.93	
F x D	1	21.44	0.17
F x D x S	39	4888.31	
RS x D	1	709.89	3.71
RS x D x S	39	7454.60	
F x RS x D	1	0.06	0.00
F x RS x D x S	39	7548.13	
Total	319	75731.20	

* $p<.05$
** $p<.01$

Number of Bus Stops in Bus Route

Source	df	SS	F
Between Subjects			
Subjects (S)	39	20.50	
Within Subjects			
Familiarity (F)	1	1.80	3.03
F x S	39	23.20	
Road Structure (RS)	1	0.25	0.36
RS x S	39	27.75	
Detail (D)	1	0.45	0.81
D x S	39	21.80	
F x RS	1	0.00	0.01
F x RS x S	39	21.00	
F x D	1	1.51	2.07
F x D x S	39	28.49	
RS x D	1	1.38	1.95
RS x D x S	39	27.62	
F x RS x D	1	4.28	6.24*
F x RS x D x S	39	26.72	
Total	319	206.75	

* $p < .05$

Number of Buses in Bus Route

Source	df	SS	F
Between Subjects			
Subjects (S)	39	16.25	
Within Subjects			
Familiarity (F)	1	4.28	10.87**
F x S	39	15.35	
Road Structure (RS)	1	0.25	0.81
RS x S	39	12.25	
Detail (D)	1	0.20	0.37
D x S	39	21.05	
F x RS	1	0.00	0.01
F x RS x S	39	19.12	
F x D	1	0.05	0.10
F x D x S	39	19.57	
RS x D	1	1.01	2.59
RS x D x S	39	15.24	
F x RS x D	1	0.45	1.18
F x RS x D x S	39	14.92	
Total	319	139.99	

** $p < .01$

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RELATIONSHIPS BETWEEN MAP FORMAT AND ROUTE SELECTION: TOWARD IMPROVING TRANSIT INFORMATIONAL SYSTEMS

by

Kenneth A Spitz

(ABSTRACT)

The aims of the present study were twofold: (1) to determine the effectiveness of various map formats in presenting mass transit information; and (2) to assess subjects' internal representation of spatial features of the environment. It was hypothesized that bus route selection would be a function of both the amount of detail and the road structure presented in maps and that the effect of detail and road structure would depend upon the familiarity of the mapped area. A 2 X 2 X 2 (Familiarity x Detail x Road Structure) factorial design was employed in the experiment. The familiarity factor was manipulated by mapping a familiar area (Blacksburg, Virginia) and an unfamiliar area (an altered section of London, England). Detail was manipulated by including or not including roads and landmarks on the maps. Road Structure was manipulated by presenting roads in either a veridical or a simplified manner.

Performance on a map reading task was used to assess the effects of the independent variables. Fourty undergraduate subjects were required to first locate two intersections on

a bus route map and second, to determine a bus route between the two intersections. Five dependent measures of map reading ability were obtained. Results indicated that, for both familiar and unfamiliar areas, a veridical road structure yielded less errors and faster times for determining a bus route than did a simplified road structure, and that detail lengthened the time to perform the task.