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ABSTRACT

This report presents two experiments that compared the performance of map experts to that of novices. Subjects (from the areas of geography, educational psychology, and sociology) were 13 university faculty members in experiment one and 12 undergraduate students in experiment two. Following a practice trial, the learning of a logical map and a non-logical map was compared. Cognitive processes used in learning the maps were also examined. Procedure was identical for both experiments with the exception that experiment two subjects were asked to recall the two maps after a 24-hour period. Subjects' maps were scored by two raters for correct labels and for correct spatial placement of features. A content analysis of the sessions determined the cognitive strategies used to learn the maps. A three-way analysis of variance for map recall was conducted, with discipline as a between-subjects variable, and map and trial as within-subjects variables. In both experiments, the logic or non-logic of the maps affected only the experts. It is concluded that knowledge of principles of spatial organization must be considered as an integral factor in the map learning process. (PN)

Cognitive Strategies in Learning Maps

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Map learning has gained increasingly more attention in learning research in recent years. Some studies have focused on how cognitive maps are formed from one's direct experience with a spatial environment; others have examined the cognitive processes that are used in learning the content of an existing map.

A number of studies (for example, Kulhavy, Lee, & Caterino, 1985; Kulhavy, Schwartz, & Shaha, 1983; Thorndyke & Stasz, 1980) have involved the presentation of a map to subjects, who are then asked to recall the map after it is removed. One problem with these studies is that the maps which have been used have depicted buildings and other features placed randomly on the map. In reality, the arrangement of most features found on the earth's surface is not random, but rather exhibits some degree of spatial order and predictability. The spatial dynamics of both natural and human processes often shape distinctive and recurring locational patterns. The distributions of climatic regions, landforms, water features, and mineral resources, for example, are explainable in terms of on-going natural processes. Similarly, transportation economics, land use compatibility or non-compatibility, competition for valued locations, and spatial agglomeration advantages and disadvantages, among other things, can be seen in the patterning of human activities. For example, in cities, one is likely to find distinctive districts and neighborhoods sharing commonalities of function, economics, transportation, or social class, such as downtown business districts, industrial and warehousing districts, and lower, middle, and upper income residential areas. In fact, many spatial processes and their consequent spatial patterns have been incorporated into formal theoretical systems and models, or stated as empirical principles of spatial dynamics or organization.

If a map is viewed as the random placement of features in two-dimensional space, learning a map is likely to consist primarily of rote learning processes. However, we believe that a knowledge of principles and theoretical models of spatial organization can lead to more meaningful learning of the same map. In order to test this hypothesis, we conducted two studies in which the performance of map experts was compared to that of novices.

One expert-novice study has been previously conducted by Thorndyke and Stasz in 1980; their experts were three individuals who frequently used maps in their jobs, and their novices were five undergraduate students. No differences in map recall or cognitive processing strategies could be found that were attributable to group membership. We do not believe that map use alone, no matter how extensive, necessarily leads to an understanding of the principles and theories of spatial arrangement. In other words, frequent map users are not necessarily map "experts."

Instead, we chose as our experts individuals with training in geography. The discipline of geography has the study of spatial organization at its core. Examples of geographic principles and theories that can be applied to understanding the particular arrangement of features on a map include such ideas as central place theory, land use compatibility, network evolution models, and economic location theory. We predicted that geographers' knowledge of their field would facilitate their learning of a map, because such knowledge would allow them to organize the map features in a meaningful way. However, geographers' learning would be facilitated only when map features were arranged in accordance with recognized principles and theories of spatial arrangement, not when features were arranged randomly. In essence, we predicted a situation similar to that observed by deGroot (1965) and by Chase and Simon (1973) with master chess players and beginners: masters were far superior to beginners in recalling positions of chess pieces on a chessboard when the board's layout represented an actual game in progress; there were no differences between masters and beginners when pieces were arranged randomly on the board.

In addition to the geographers, we identified a second group of experts, educational psychologists. While educational psychologists have no expertise in principles of spatial arrangement, they do have expertise in general principles of learning and memory. These principles, if in fact they would facilitate map learning, would not discriminate between maps arranged logically and those arranged randomly.

Our control group consisted of sociologists. While trained in a social science similar to geography or psychology, sociologists typically do not receive training either in learning theory or in principles of spatial organization.

Experiment 1

The first experiment involved university faculty in the three discipline areas of geography, educational psychology, and sociology. We compared their learning of two maps, a logical one and a non-logical one, and also examined the cognitive processes used in learning the maps.

Method

Materials. Three maps were constructed for the study. A map of a campground was constructed to be used in a practice trial. The second map, depicting a small city, is presented in Figure 1. This map is arranged in conformity with established principles of spatial arrangement. For example, the downtown commercial area, which typically emerges at the point of highest internal accessibility, is located where the major roads converge and cross the river. Industry, such as the mills and the lumberyard, is located near the railroad tracks and attracts low income residential developments to house those who cannot afford to live in the more desirable parts of town. Redevelopment is occurring near the downtown area (as evidenced by the luxury apartments and the condominiums), offering convenient access to downtown services, yet isolation from undesirable land uses found on the opposite side of the commercial core. On the outskirts are a middle class neighborhood in the upper center and an upper class neighborhood in the upper right corner, reflecting suburban lifestyle goals and successful competition for the more desirable residential locations.

The third map, presented in Figure 2, depicts an undetermined region of a larger scale than the city map, and is arranged pseudo-randomly, and in some cases illogically. For example, a river runs from the plains into the mountains rather than originating in the mountains. Transportation networks do not interconnect and, in fact, do not appear to be very efficiently planned. Cities are not located at transportation junctions, and two towns, Betsy and Adobe, cannot be reached by any noticeable means of transportation. No urban hierarchy is evident: all settlements are apparently the same size.

Subjects. Thirteen full-time faculty members at the University of Northern Colorado served as subjects. Five were members of the Geography Department, four were members of the Educational Psychology faculty, and four were members of the Sociology Department.

Procedure. The experimenter met individually with each subject. After one trial with the practice map, subjects studied each of the other two maps for a series of three 2-minute study sessions. During each study session they were asked to "think aloud," and their comments were tape-recorded. Following each study session, they were given a blank sheet of paper and asked to draw as much of the map as they could remember. Therefore, each subject drew three versions of the city map and three of the country map.

Subjects' maps were scored by two raters for correct labels and for correct spatial placement of features. Inter-rater reliability was .98.

A content analysis of the recorded study sessions was conducted to determine the types of cognitive strategies individuals used to learn the map. Each meaningful phrase was categorized based on the type of activity it reflected. In order to reflect the amount of time devoted to each study activity, the number of words was used as the unit of measurement. The four most commonly occurring activities, accounting for 95% of all study activity, are presented in Figure 3. As can be seen in this figure, three study activities (Description, Concrete Analysis, and Abstract Analysis) involved strategies directed toward learning the map content; the fourth (Procedure) was, in a sense, a non-strategy, in that map content was not being processed.

Two raters rated the content of each study session. Their initial agreement rate was approximately 70%. Inconsistent ratings were resolved by the two raters in discussion with a third rater.

Results

The analyses we employed yielded a rich body of data. For purposes of this paper, we will focus only on those results most central to our hypotheses regarding discipline-based strategy differences on logical and illogical maps.

A three-way analysis of variance (ANOVA) of map recall was conducted, with discipline (Geography, Educational Psychology, and Sociology) as a betwcen-subjects variable and map (city vs. country) and trial as within-subjects variables. The analysis yieldcd a significant interaction between discipline area and type of map ($F[2,12] = 7.22$, p .01). Means related to this interaction are depicted in Figure 4. Post hoc analyses revealed that geographers showed a significant decrease from the city map to the country map; the other two groups showed no significant differences in performance on the two maps. This finding is consistent with the hypothesis that geographers will use principles of spatial arrangement in learning a map, and will be adversely affected when a map is not arranged in congruence with such principles. The performance of the educational psychologists was better than that of the sociologists, althought not significantly so; this difference is consistent with our prediction that educational psychologists may bring their knowledge of learning principles to a learning task, but will be unaffected by congruence or non-congruence of a map's layout with geographic principles.

Analyses of study session content and its relation to map recall were less clear-cut. Three-way ANOVAs, parallel to that conducted for map recall, were conducted for the various categories of study session content. Probably the most interesting of the significant effects was an interaction between discipline and trial for Abstract Analysis ($F[4,50] = 3.07$, p .05). Post hoc analyses of means indicated that significant differences among the three disciplines existed only on the first trial, the trial in which the most Abstract Analysis was observed. Geographers showed the most Abstract Analysis on the first trial, with a mean of 49.3 words, the sociologists showed slightly less, with a mean of 46.3 words, and educational psychologists showed a mean of only 8.1 words. The relatively high mean of the sociologists was due almost entirely to one individual, who showed extremely high levels of abstraction on both maps. A conversation with this sociologist after the experimental session revealed that this individual had in fact received training in geographic principles of spatial arrangement. The mean for the other three sociologists was only 11.0 words.

Correlations between map recall and the content of previous study sessions were calculated. The strongest predictor of map recall was the amount of study activity classified as Description, with five of the six correlations ranging between .59 and .72. Concrete Analysis correlated with map recall in the low to moderate range, with correlations ranging from .19 to .40. Correlations of Abstract Analysis with recall were even lower, ranging from .11 to .23. These findings were puzzling, as they are contrary to many theories of learning which propose that processing information in a meaningful way will lead to better learning (e.g., Ausubel, Novak, & Hanesian, 1978; E. Gagne, 1985).

Study activity classified as Procedure was typically moderately but negatively correlated with recall; five of the six correlations were in the range of -.29 to -.65. Most of the Procedure statements involved comments and/or complaints about the task, statements which precluded learning the map and therefore interfered with performance.

Experiment 2

In Experiment 2, we set out to extend our investigation to a less experienced population, in particular to undergraduates in the same three discipline areas. In addition, we wanted to look at retention over a 24-hour period, to examine the longer-term effects of discipline and specific study activities on map retention.

Method

Materials. The three maps were the same as those used in Experiment 1.

Subjects. Subjects were 12 undergraduate volunteers at the University of Northern Colorado. Four were geography majors, four were sociology majors, and four were teacher education majors who had just completed an educational psychology course entitled "Learning Processes in Education."

Procedure. The procedure was identical to that used in Experiment 1, with the exception that subjects were asked to recall the two maps for a fourth time after a 24-hour period.

Results

Maps and study session content were scored just as they had been in Experiment 1.

A three-way ANOVA for map recall was computed, with discipline as a between-subjects variable, and map and trial as within-subjects variables.

As in Experiment 1, this analysis yielded a significant interaction between discipline and map ($F[2,63] = 5.26$, p .01). This interaction is depicted in Figure 5. As can be seen, the teacher education group and the sociology group performed very similarly on both the city map and the country map, and very similarly to each another. The geographers showed superior performance to the other two groups on the logical city map, but not on the non-logical country map.

Of the analyses of study session content, the finding most relevant to this paper is a significant main effect due to discipline found for Abstract Analysis, with Geography students showing significantly more Abstract Analysis than the other two groups.

Based on correlations of study session content with map recall, once again Descriptive activity showed the highest positive correlations with map recall, although the correlations were not as consistent or as strong as in Experiment 1. And again, Procedure activity was consistently negatively correlated with recall.

General Discussion

In both experiments, the logic or non-logic of the maps affected only our experts, the geographers. Our findings are parallel to the findings of deGroot (1965) and Chase and Simon (1973) regarding the recall of master and beginning chess players for meaningful and random arrangements of pieces on a chessboard. Furthermore, our results for map recall are consistent with our hypothesis that true map experts are likely to apply principles and theories of spatial arrangement to the learning of a map. Also supportive of our hypothesis is the greater amount of abstraction that we observed for the geography faculty and students than for their counterparts in the other two groups. The principles that the geographers apply to maps will presumably allow them to organize map features in ways that other groups cannot.

However, our measure of Abstract Analysis, as a reflection of meaningful learning, was not as closely related to map learning as was the more rote-level Descriptive strategy. There are at least two possible explanations for this finding. First, Abstract Analysis was probably insufficient if it was the only strategy applied in learning the maps. While application of abstract rules will provide an organizational structure for learning a map, eventually one must learn specific names and locations, possibly at a rote level. A second explanation lies in our observation of a possible problem with the "think aloud" study session methodology. It is our belief that, at least in some cases, a statement classified as Description may have had a more meaningful component that was not evident in what was verbalized. For example, a subject who said, "Lumberyard along the railroad," may very well have been thinking of the functional relationship between those two features without expressing that thought. Such a statement would have been classified as Description when it in fact represented more abstract thought. It is our observation that many statements classified as Description may have actually had more sophisticated strategies underlying them.

In Experiment 1, although our "learning experts," the educational psychologists, did not show map recall significantly greater than that of the sociologists, the results are in the predicted direction, providing some support for the notion that a knowledge of principles of learning may facilitate the learning process. However, this difference was not replicated with the students in Experiment 2. Perhaps one course in learning is insufficient to promote the transfer of knowledge of learning principles to an actual learning situation.

Despite the limitations of our studies, we believe we have added a new dimension to the study of map learning. Map learning cannot be conceptualized merely as a process of learning a set of features randomly arranged in two-dimensional space. Knowledge of princples of spatial organization must be considered as an egral factor in the map learning process.

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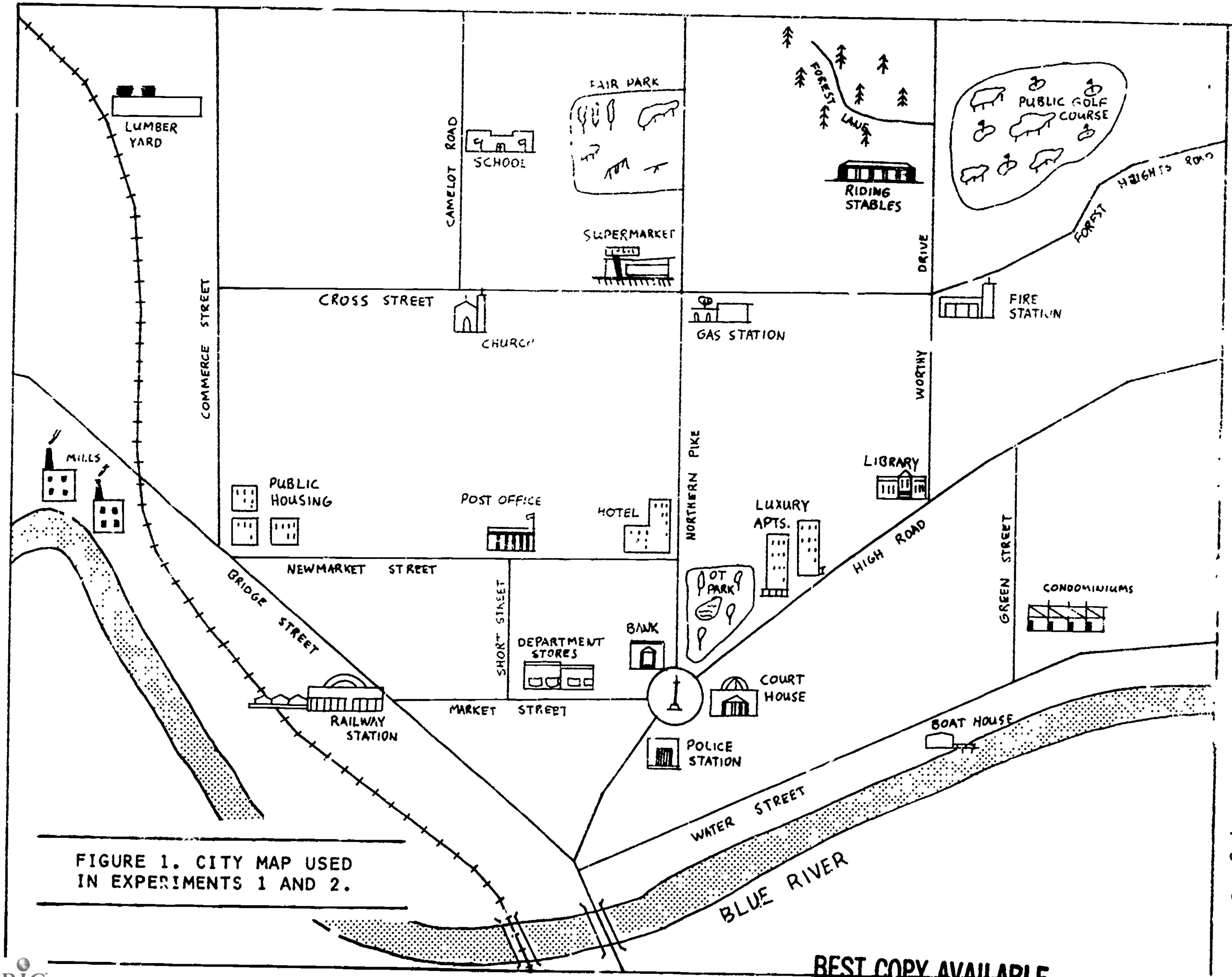

FIGURE 1. CITY MAP USED IN EXPERIMENTS 1 AND 2.

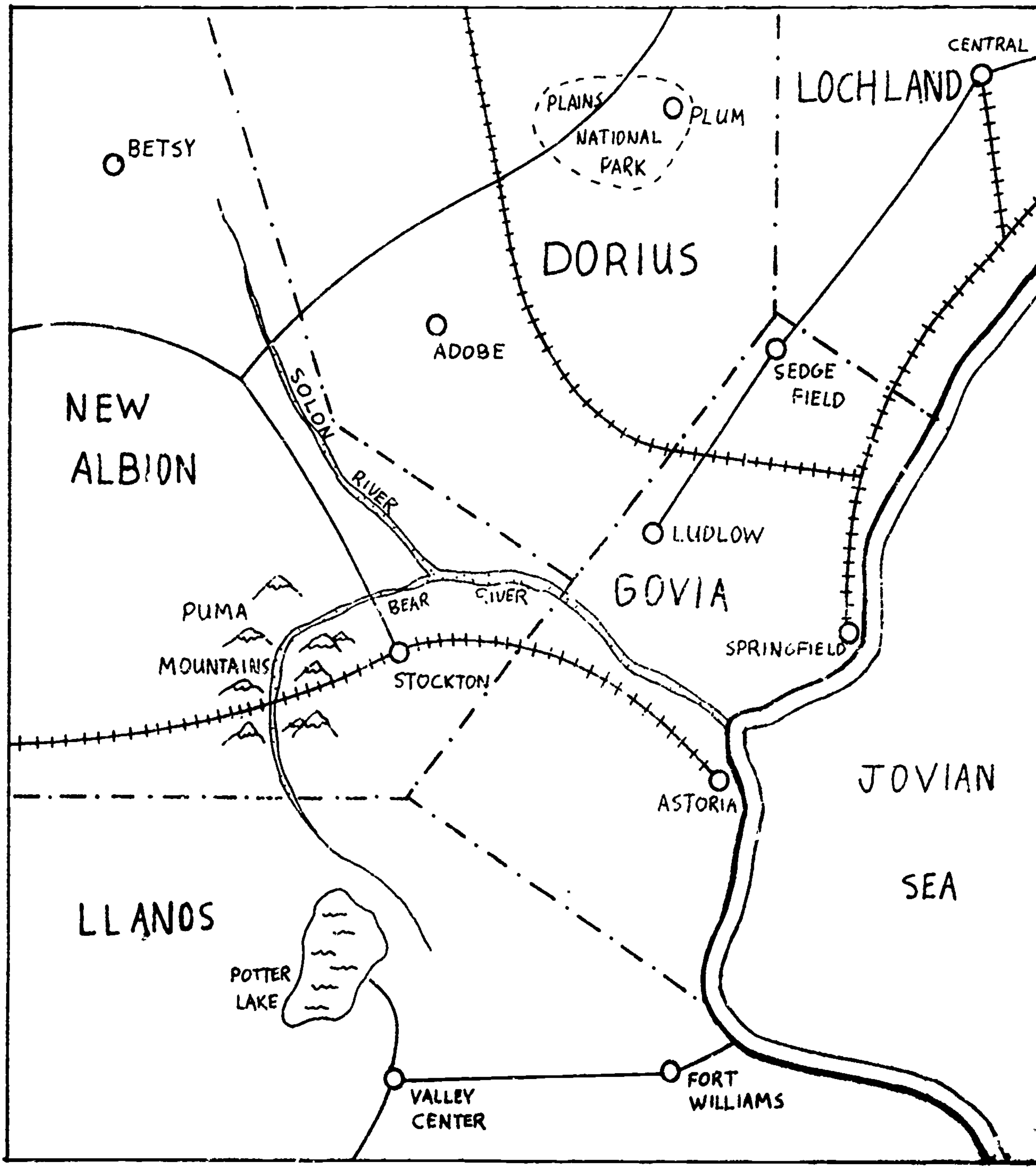

FIGURE 2. COUNTRY MAP USED IN EXPERIMENTS 1 AND 2.

FIGURE 3

FOUR MOST COMMON STUDY ACTIVITIES

DESCRIPTION: DESCRIPTION OF MAP FEATURES WITHOUT ORGANIZATION, INTERPRETATION OR MODIFICATION. ROTE LEARNING IS PROBABLY INVOLVED IN THIS ACTIVITY.

EXAMPLES:
NAMING ITEMS - "RAILWAY STATION."
LISTING ITEMS - "LOCHLAND, DORIUS, GOVIA."
IDENTIFYING LOCATIONS - "MILLS ALONG RIVER."

CONCRETE ANALYSIS: ORGANIZATION OF MAP FEATURES IN A CONCRETE MANNER. HIGHER-LEVEL INFORMATION PROCESSING IS INVOLVED IN THIS ACTIVITY.

EXAMPLES:
COUNTING ITEMS - "TWO PARKS."
GROUPING ITEMS BY CATEGORY - "EAST-WEST STREETS ARE CROSS STREET, NEWMARKET STREET."
FORMING PERSONAL ASSOCIATIONS - " I USED TO LIVE IN A TOWN CALLED NEWMARKET."
USING MNEMONICS - "TWO IS A SHOE, DORIUS IS THE NAME OF THE BRAND."

ABSTRACT ANALYSIS: ABSTRACT MANIPULATION AND INTERPRETATION OF MAP FEATURES IS PERFORMED AT THIS LEVEL OF ACTIVITY.

EXAMPLES:
APPLYING THEORIES OR MODELS - "THE STREET PATTERN HAS BEEN DETERMINED BY THE RIVER."
IDENTIFYING FUNCTIONAL RELATIONSHIPS - "BANKS NEED TO HAVE THE PROTECTION OF THE POLICE."
DESCRIBING EXPECTATIONS - "ALL THE TRADITIONAL THINGS ALONG THE RAILROAD, THE MILLS AND THE LUMBERYARDS AND SO ON."
DRAWING INFERENCES ABOUT TOPOGRAPHY - "THERE IS A ROAD WHICH APPARENTLY LEADS TO HIGHER ELEVATION CALLED HIGH ROAD, AND THAT'S WHERE THE LUXURY APARTMENTS ARE, WHERE THEY CAN LOOK DOWN OVER THE VIEW OF THE VALLEY."

PROCEDURE: DESCRIPTION OR CLARIFICATION OF THE LEARNING TASK. LEARNING OF THE MAP CONTENT ITSELF IS NOT INVOLVED.

EXAMPLES:
CLARIFYING THE TASK - "SO I GET THREE SHOTS AT IT?"
COMMENTING ABOUT THE MAP IN GENERAL - "NO SCALE."
COMMENTING ABOUT THE TASK DIFFICULTY - "THE DETAIL IS OVERWHELMING."

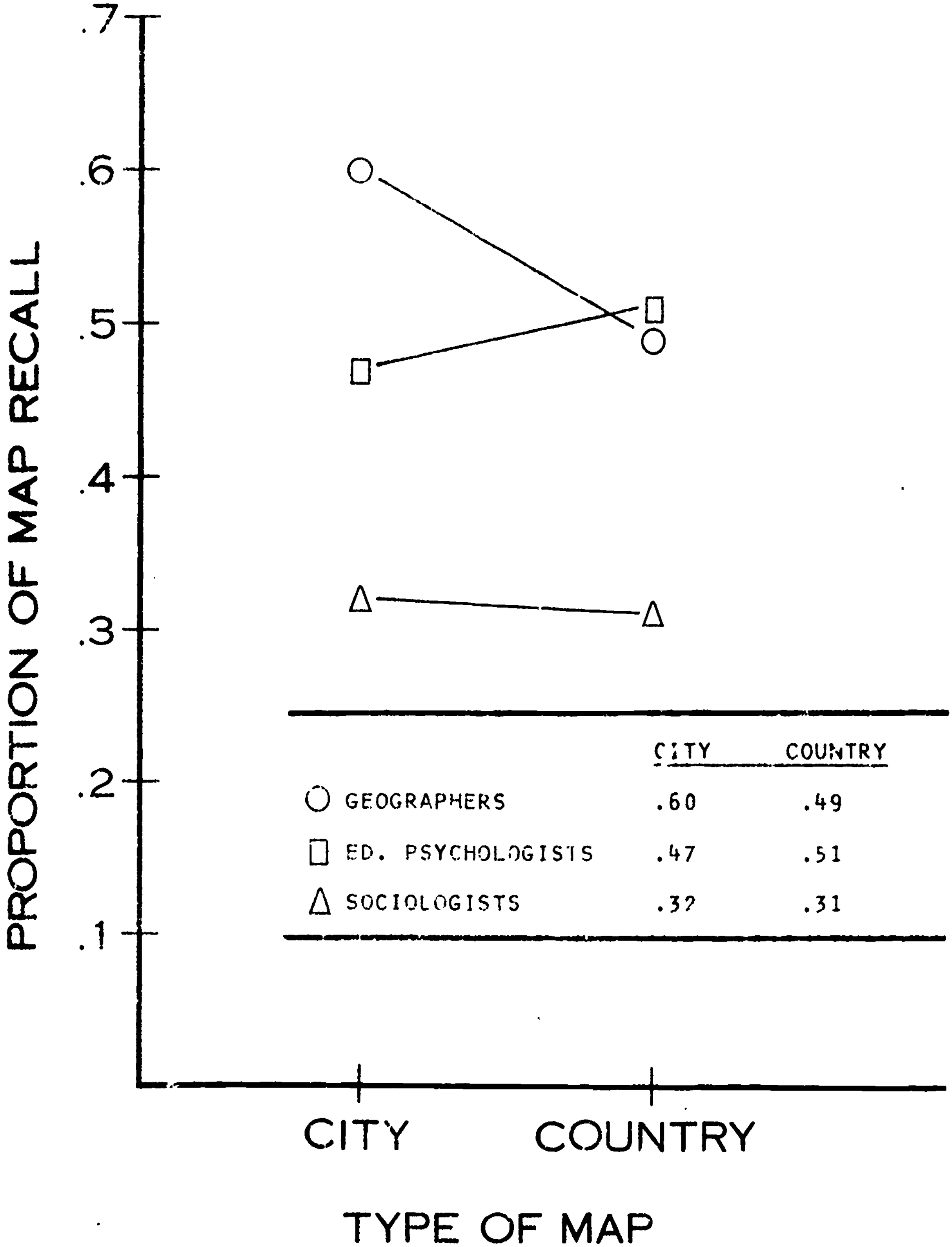

FIGURE 4. THE INTERACTION BETWEEN DISCIPLINE AND MAP RECALL AMONG FACULTY SUBJECTS IN EXPERIMENT 1.

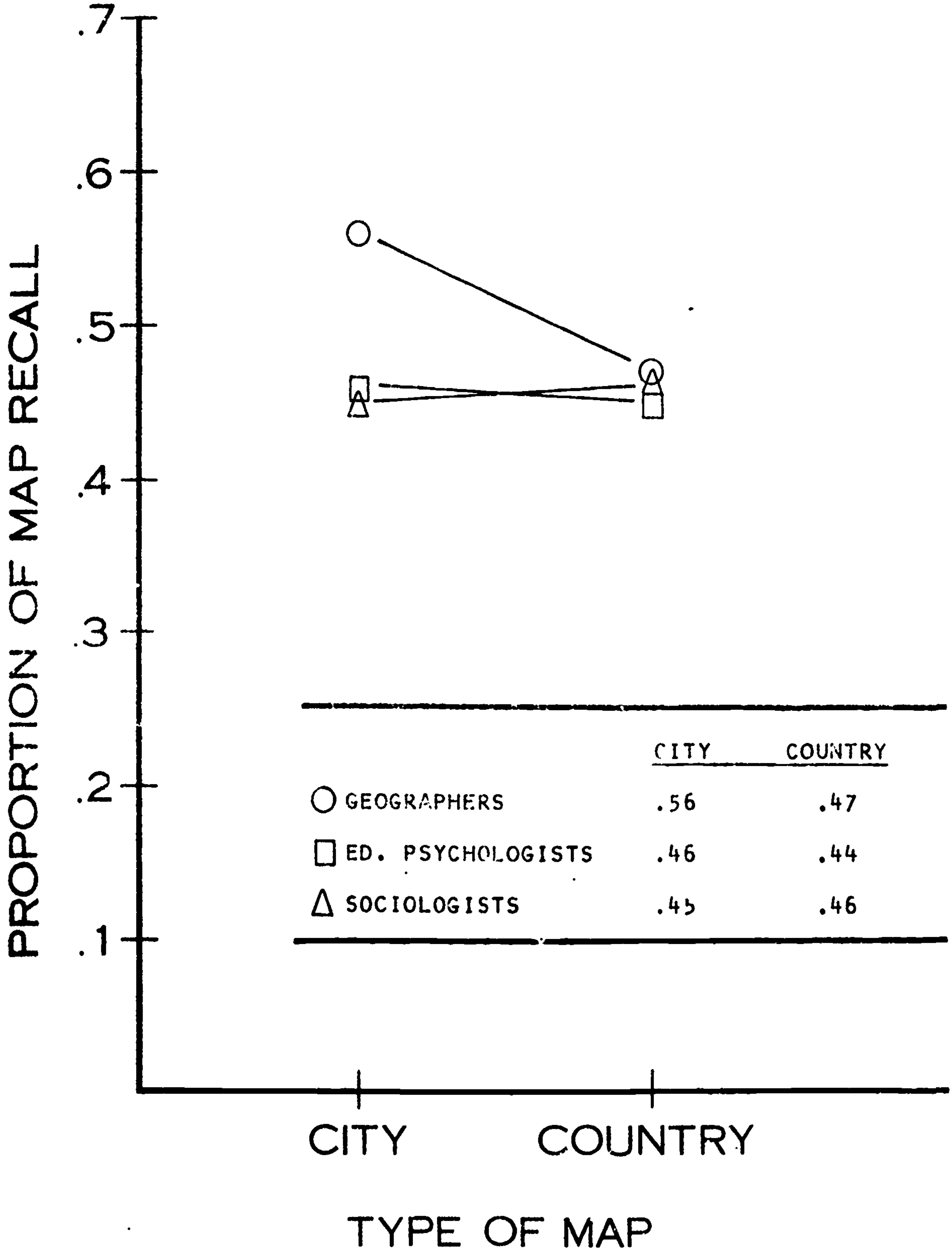

FIGURE 5. THE INTERACTION BETWEEN DISCIPLINE AND MAP RECALL AMONG UNDERGRADUATE SUBJECTS IN EXPERIMENT 2.