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ABILITY DIFFERENCES AND COGNITIVE MAPPING SKILL

Perry W. Thorndyke, Sarah E. Goldin

March 1981

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Compares good and poor cognitive mappers on a number of individual difference variables potentially related to cognitive mapping skill: spatial abilities, visual/verbal processing style, motivation, and experience. Good and poor mapper groups were given several assessment tests for each of these categories. Comparisons of good and poor mappers' performance on these tests indicated that only spatial abilites reliably distinguished good mappers from poor mappers. Good cognitive mappers showed greater visualization ability, spatial orientation ability, visual memory, and field independence. Other measures showed no between-group differences. It is concluded that spatial ability is a major determinant of cognitive mapping skill and that spatial ability tests can be used to select personnel for tasks requiring navigation, orientation, and spatial judgment skills.

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## PREFACE

This Note describes a portion of a study undertaken at Rand for the Army Research Institute under Contract No. MDA903-79-C-0549, to investigate individual differences in spatial knowledge acquisition and spatial judgments. The Note extends and elaborates on results reported in companion Note N-1664-ARMY, An Analysis of Cognitive Mapping Skill. The findings should interest both researchers studying human spatial cognition and practitioners concerned with improving individual orientation and navigation skills.

## SUMMARY

This Note examines a number of individual difference variables that are potentially related to cognitive mapping skill and compares good and poor cognitive mappers in terms of those variables. Good and poor cognitive mappers were identified on the basis of the accuracy of their spatial knowledge about their own community. On the basis of previous research, which showed that good mappers surpass poor mappers in learning a novel environment from navigational experience, in learning a map, and in producing accurate spatial judgments, we identified four categories of individual difference variables that could plausibly be related to cognitive mapping skill: spatial abilities, visual/verbal processing style, motivation, and experience. In the present study, several assessment tests for each of these categories were administered to groups of good mappers and poor mappers. Paper-and-pencil aptitude tests from the French Kit of Factor-Referenced Cognitive Tests were administered to assess verbal comprehension, visualization ability, spatial orientation, visual memory, and field dependence. Self-report questionnaire items were used to assess visual/verbal processing style, exploratory motivation, motivation to consciously control learning, disorientation anxiety, and map-using motivation. Questionnaires were also used to gather data on each subject's overall range of geographic experience and his or her experience in using maps. Comparisons of good and poor mapper groups on each of these variables indicated that only spatial abilities reliably distinguished good from poor mappers. Good cognitive mappers showed greater visualization ability, spatial

orientation ability, visual memory, and field independence. Other measures revealed no between-group differences. We conclude that spatial ability is a major correlate of cognitive mapping skill and that spatial ability tests can be used to select personnel for tasks requiring navigation, orientation, and spatial judgment skills.

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Several individuals contributed to preparation of this Note. Jackie Berman and Doris McClure gathered and analyzed the data. Kay McKenzie and Nancy Lees prepared the manuscript. Barbara Rose provided useful comments on an earlier draft.

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# TABLES

# I. INTRODUCTION

Effective navigation in an environment requires a broad repertoire of spatial skills, including place learning, route finding, map interpretation, and self-orientation. These spatial skills are important in everyday activities, and in military contexts they may be critical. One of the earliest researchers on human orientation skills wrote, "It is [probable] that the loss of more than one battle has been due to the utter confusion of officers or of small bodies of troops with respect to points of the compass" (Trowbridge, 1913, p.893). The success or failure of a military operation may depend on the orientation and navigation skills of a few key personnel. Hence, commanding officers must insure that these individuals possess the requisite skills.

A considerable body of research has documented individual differences in a variety of spatial skills (Kail, Carter, & Pellegrino, 1979; Lohman, 1979; Carroll, 1980; Kozlowski & Bryant, 1977; McGee, 1979; Thorndyke & Stasz, 1980). In a recent Rand Note, we observed a variety of performance differences between "good" and "poor" cognitive mappers on a series of complex spatial knowledge acquisition and reasoning tasks (Goldin & Thorndyke, 1981). In that study, we defined subjects to be "good" or "poor" mappers according to the accuracy of their spatial knowledge of the area of the city in which they resided. In the present Note, we examine some individual difference variables that could underlie the performance variation between good and poor mappers. In particular, we contrast subjects in the two skill level groups on a variety of measures of spatial ability, visual memory, processing style and strategies, motivation, and environmental experience.

The remainder of the Note is organized as follows: First, we describe in some detail the tasks that define and distinguish good and poor cognitive mappers. We then discuss the individual difference variables examined in this study and our methods for measuring these variables. Next, we report data relating these variables to cognitive mapping skill. Finally, we attempt to synthesize a coherent description of individual differences in spatial skills.

## II. A PROFILE OF COGNITIVE MAPPING SKILL

Our sample of good and poor cognitive mappers comprised adults who had resided in west Los Angeles for at least five years. Each of these individuals had acquired his or her spatial knowledge of the west Los Angeles area primarily from navigation in the environment. To assess the accuracy of subjects' derived spatial knowledge, we administered four tests that required subjects to make spatial judgments about pairs of familiar landmarks in the environment. These tests included judgments of orientation (i.e., pointing to one landmark from an imagined position at the other landmark), location (i.e., marking on a piece of paper the location of a landmark relative to the indicated position of two other landmarks), euclidean (straight-line) distance between landmarks, and route distance along city streets between landmarks.

Goldin and Thorndyke (1981) identified good and poor mappers on the basis of accuracy on the four judgment tasks. Good mappers were consistently more accurate on these judgments than poor mappers. On subsequent experimental tasks, good mappers acquired new spatial information more rapidly and accurately than poor mappers, both when navigating in an unfamiliar environment and when studying an unfamiliar map. Good mappers also excelled at computing spatial judgments using a memorized map of an unfamiliar environment. On the other hand, good and poor mappers did not differ in their skill at reading and using road maps, interpreting and using topographic maps, or navigating in an environment using a memorized map.

These data suggest that the primary differences between good and poor mappers may be in their ability to (1) encode and/or retain knowledge of spatial relationships, and (2) manipulate their internal representation in order to compute spatial judgments. On the other hand, there seem to be no differences in ability to extract and use information from a continuously available, external visual display. Our conclusions regarding these data guided the selection of ability tests for use in the present study, as described below.

## III. INDIVIDUAL DIFFERENCE VARIABLES

Previous studies of spatial knowledge acquisition have suggested that both spatial ability and cognitive style might distinguish good from poor cognitive mappers (Goldin & Thorndyke, 1981; Stasz & Thorndyke, 1980; Thorndyke & Stasz, 1980). Therefore, we included several tests of these abilities in our individual difference test battery. In addition, research in environmental psychology has indicated that the accuracy and detail of an individual's spatial knowledge is related to the type and number of navigation experiences he or she has had in the environment. Thus, individuals with the motivation and opportunity to explore their neighborhoods have more extensive and accurate cognitive maps than those with less motivation or fewer experiences (Beck & Wood, 1976; Walsh, Krauss, & Regnier, 1979). We also attempted to measure the exploratory motivation and experience differences of our good and poor mappers. Our assessment measures are discussed in more detail below.

### BASIC COGNITIVE ABILITIES

The traditional, widely accepted structural approach to intelligence (Carroll, 1976; 1978; 1980; Guilford, 1967; Royce, 1973; Thurstone, 1946) views intellect as a complex structure composed of many basic aptitudes or abilities. These abilities have been identified through factor analytic techniques in studies by groups of independent researchers. For example, French and his colleagues (French, 1957; French, Ekstrom, & Price, 1963; Ekstrom, French, & Harman, 1976), through successive refinement, have developed a set of marker tests to measure basic cognitive abilities or "aptitude factors." According to this traditional psychometric view, an individual's ability profile determines his or her skill at executing complex cognitive tasks that tap these ability components.

On the basis of previous research (Goldin & Thorndyke, 1981; Thorndyke & Stasz, 1980), we hypothesized that spatial ability would relate strongly to cognitive mapping skill, as indexed by the tasks examined in Goldin and Thorndyke (1981). Within the psychometric framework, spatial ability comprises a variety of distinct factors or components. Of these, three entail processing operations required on the cognitive mapping tasks that distinguished good from poor subjects in our experiments: visualization, spatial orientation, and visual memory.

Visualization ability is the ability to manipulate or transform the image of a two- or three-dimensional spatial pattern (Ekstrom, French, & Harman, 1976; McGee, 1979). Visualization ability tests require the individual to perform mental operations altering, moving, or otherwise transforming internal parts of a spatial configuration held in short-term memory. Such operations characterize the task of assuming an imagined location at a familiar landmark. Such operations are also necessary to mentally simulate traversal of a route. Mental simulation can help in estimating route distance between two landmarks or in making other spatial judgments (Thorndyke & Hayes-Roth, 1980).

Spatial orientation ability is the ability to maintain orientation with respect to objects in space and to remain unconfused by the varying orientations in a which a pattern must be perceived. Two situations arise in our cognitive mapping tasks where it is important to maintain spatial orientation. First, in performing the orientation task based on navigation experience, an individual must assume various imagined positions in the environment. To point toward unseen locations, the subject must maintain knowledge of the direction of those locations when his or her body position or orientation changes. Second, in some situations, the perspective on the world from which a location is determined differs from the perspective required for the appropriate response. This occurs, for example, when a subject must perform orientation (pointing) judgments based on a memorized map or location (map configuration) judgments based on navigation experience (Thorndyke & Hayes-Roth, 1980). On both tasks, good mappers perform more accurately than poor mappers (Goldin & Thorndyke, 1981).

Visual memory ability is the ability to encode and remember a configuration of purely spatial or pictorial information. This ability strongly predicts individuals' speed at learning a map of a novel environment (Stasz & Thorndyke, 1980; Thorndyke & Stasz, 1980). Since Goldin and Thorndyke's good mappers acquired spatial knowledge from both maps and navigation faster and more accurately than poor mappers, it is reasonable to presume that they possessed superior visual memory ability.

We also included in our ability test battery an assessment of subjects' field dependence/independence (FD/I), or cognitive restructuring ability. This ability is measured by tests in which subjects must perceive objects as distinct from their context, reorganize or segment a perceptual field, or generate organization for a field with little inherent structure of its own. "Field independent" individuals can readily perform such restructuring, while "field dependent" individuals are more constrained by the prevailing organization of the stimulus array. Traditionally, researchers have treated FD/I as a cognitive style construct measuring subjects' cognitive restructuring strategies. However, recent research suggests that FD/I actually represents a component of spatial ability (McGee, 1979; Widiger, Knudson, & Rorer, 1980).

Field independence may be related to cognitive mapping skill in at least two ways. First, to induce survey relations from navigation experience, subjects must reorganize their spatial representation by integrating a variety of perceptual experiences from different contexts. Second, to successfully learn a map, subjects must impose a coherent organization on the complex display of spatial information confronting them. Indeed, subjects' positions on the FD/I dimension accurately predict their map learning skill (Stasz & Thorndyke, 1980).

We also considered the possibility that performance differences between subject groups might be related to general intelligence and/or general memory ability. We therefore administered a test of verbal comprehension to evaluate intelligence and a test of verbal associative memory to evaluate verbal memory ability along with our tests of spatial ability.

The term "basic abilities" implies that the factors measured by these aptitude tests comprise the most elementary components of all complex intellectual tasks. While the tasks used in ability testing are simpler than naturalistic navigation or route learning tasks, they are nevertheless "complex from an information processing view" (Carroll, 1976). We do not presume to measure the most fundamental operations involved in spatial processing with these ability tests. Rather, we have used them to isolate certain aspects of complex cognitive mapping tasks in which there may be prominent individual differences. Thus, "basic" is a relative term. Nevertheless, this does not negate the potential utility of ability tests for prediction of performance in other tasks.

COGNITIVE STYLE

"Cognitive style" refers to characteristic modes of thought or preferences for particular types of processing strategies. At least four features distinguish cognitive style constructs from ability constructs: (1) Ability measures assess the content and level of performance, whereas style measures assess the manner of performance; (2) abilities are unipolar dimensions, whereas style variables are bipolar; (3) abilities are "value directional"--more is always better--whereas both contrasting poles of a style variable have some processing advantages; (4) abilities are domain- or content-specific, whereas styles influence a wide range of activities with varied content (Witkin & Goodenough, 1977).

In this Note, we focus on one particular cognitive style dimension: visual versus verbal thinking. Visualizers tend to be "concrete" thinkers and "literal" perceivers, while verbalizers are more "abstract" or "schematic" (Richardson, 1969). Differences between visualizers and verbalizers have been demonstrated in a number of domains (Richardson, 1969; Snyder, 1972), and some researchers have reported that the distinction has physiological correlates as well (Brown, 1966; Slatter, 1960). We have previously noted this processing style difference in people's strategies for learning the spatial relations in a complex natural environment (Thorndyke, 1980). In our earlier experiments, we found that visualizer strategies focused on perceptual information and visual detail and led to sketch maps filled with terrain descriptors but with few street or region labels. In contrast, verbalizer strategies focused on street names and compass directions in order to build up a network of paths and path intersections; this led to poor knowledge of the visual properties of the environment, but more detailed and metrically accurate sketch maps.

In the present research, we measured visual/verbal cognitive style through subjects' self-report ratings on a spatial styles questionnaire. This questionnaire asked them to rate the truth of 22 statements such as "I tend to think visually, with lots of images," and "I tend to think of the environment in terms of compass directions." The questionnaire items were selected on the basis of a factor analysis conducted on a larger group of subjects ($n = 72$). Visual and verbal styles were identified by averaging ratings on several items that made substantial contributions to factors that we interpreted as visualization/visual thinking and verbal/analytic thinking. In addition, subjects received two tests of self-reported imagery tendencies, the Betts Vividness of Mental Imagery Test and the Gordon Controllability of Imagery Test (Richardson, 1969). These tests measure somewhat different aspects of imagery. The Betts test assesses the detail or intensity of the sensory images formed by an individual, and the Gordon test measures the individual's capacity for manipulating those images in "the mind's eye." While the former quality seems closer to the intuitive meaning of a visual cognitive style, we included both tests to investigate the relationships between the two tests and between the tests and the spatial-ability measures.

MOTIVATION AND EXPERIENCE

Previous research has identified a variety of motivational and experiential variables that can be related to the effectiveness of individuals' spatial information processing (Beck & Wood, 1976; Canter, 1977; Carr & Schissler, 1969; Craik & McKechnie, 1977; Devlin, 1976; Downs & Stea, 1973; Lynch, 1960; Milgram & Jodelet, 1975; Rand, 1969; Stea, 1976). First, good mappers may plausibly differ from poor mappers in their intrinsic interest in or appreciation for acquiring new spatial knowledge. For instance, "rangers," individuals who explore alone or in small groups, demonstrate greater cognitive mapping skill than "fixers," who stay close to home, or "mixers," who travel in large, socially oriented groups (Beck & Wood, 1976). This finding, although correlational, is intuitively reasonable. Individuals who like to explore new places may develop more complete and accurate cognitive maps because (1) they receive more extensive environmental experience and (2) they are more likely to attend to spatial information.

Another motivational dimension that could plausibly relate to cognitive mapping skill is the degree to which an individual exercises conscious control over his or her encoding of spatial information. Research on map learning (Thorndyke & Stasz, 1980) and planning (Goldin & Hayes-Roth, 1980) has demonstrated that individuals who show greater awareness of their own processing strategies and who make conscious attempts to control these strategies have higher levels of task performance. The same may be true in the cognitive mapping domain. Individuals who consciously try to remember streets and landmarks or who feel that it is important to find more efficient routes may acquire more accurate and complete knowledge of the environment.

A third motivational dimension that could relate to the accuracy of individuals' cognitive maps is their comfort with and enjoyment of maps. Maps provide a shortcut to acquiring configural and distance information about the environment, as well as providing a schema for organizing spatial information acquired through navigational experience. Presumably, people who are extremely uncomfortable using maps may suffer a deficit in developing spatial representations.

A final motivational dimension that could relate to cognitive mapping skill is the fear of becoming disoriented. This fear could prevent individuals from exploring new terrain and hence could severely limit their spatial knowledge acquisition.

We assessed subjects on all four of these motivational dimensions by combining various items from our spatial style questionnaire or through a separately administered map experience questionnaire.

Experience is a fourth potential correlate of individual differences in cognitive mapping performance. A wide range of environmental experiences could facilitate learning in a novel environment, through any of several mechanisms: Extensive geographic experience may provide broad principles or heuristics for dealing with new environments. For example, individuals who have visited many cities may develop a "city schema" that includes information such as "the bus and railroad stations are usually in the seedier section of town." Extensive geographic experience may also build confidence that will allow the individual to explore without fear of becoming disoriented. Finally, such experience may provide a set of reference environments that facilitate the representation of new environmental knowledge. For example, noting that "San Francisco is sort of like Pittsburgh" may help someone familiar with Pittsburgh to navigate in and form a mental map of San Francisco.

Experience in looking at or using maps is another experiential variable that could be related to the ease with which an individual manipulates spatial information. Using a map to navigate requires visualization and perspective-shifting processes. Frequent exercising of these processes may lead to generally greater accuracy and speed in manipulating spatial information. Frequent map users may also develop specialized strategies for selecting and encoding information on a map, strategies that enable them to represent spatial information more efficiently and accurately.

In this study, we measured both overall breadth of travel experience and experience in using maps. The overall-experience variable was computed as the sum of the number of locales in which the subject had lived for a month or more, the number of states he or she had visited, and the number of foreign countries he or she had visited. Experience with maps was measured by summing responses to questionnaire items about the frequency with which subjects habitually consulted different kinds of maps for different purposes.

# IV. METHOD

Our basic approach in this study paralleled that of our earlier work (Goldin & Thorndyke, 1981). Having obtained groups of subjects who performed well or poorly on cognitive mapping tasks, we collected measures of ability, style, motivation, and experience from these subjects. We then compared the good and poor cognitive mappers on each of these individual difference dimensions.

## SUBJECTS

### Source

Thirty-seven adult subjects (30 females and 7 males) were solicited by newspaper advertisements to participate in the study, as described in Goldin and Thorndyke (1981). Since we intended to define cognitive mapping skill in terms of subjects' knowledge of a highly overlearned environment--their own community--we required that all subjects be residents of an area of west Los Angeles known as Brentwood for at least five years. Subjects were paid $5 per hour for participation throughout the study.

### Selection of Skill Groups

From this initial sample, we selected for further testing two groups of 12 subjects: a group of subjects with good cognitive mapping skill, and a group with poor mapping skill. We used the accuracy of subjects' spatial judgments about Brentwood to classify them as good or poor cognitive mappers. Since we assumed that they had acquired their knowledge about their local environment mainly through direct experience, this criterion seemed to capture the intuitive meaning of "cognitive mapping skill": the ability to abstract accurate spatial/relational information about an environment from direct experience in that environment.

All 37 subjects received a set of four spatial judgment tasks involving seven familiar landmarks in the Brentwood area. In the orientation task, subjects were given all possible pairs of the seven landmarks. They were told to imagine standing at the first landmark of each pair, facing in a specified direction, and then to estimate the bearing of the second landmark from that imagined position. Performance was measured as the mean angular error in orientation estimates. In the euclidean distance estimation task, subjects were asked to estimate the straight-line distance between each pair of landmarks. Performance was measured as the within-subjects correlation between estimated and actual distances. Similarly, the route-distance estimation task required subjects to estimate the distances between members of each landmark pair along a specified route. Once again, the actual/estimated correlation provided our performance measure. Finally, the location task required subjects to locate landmarks on a piece of paper in the correct orientation and distance relationship to two reference landmarks provided by the experimenter. Performance in this task was measured as the mean absolute angular disparity between the correct orientation angle and the angle implied by the subject's landmark location.

Detailed performance data on the assessment tasks as well as on other cognitive mapping tasks is provided in Goldin and Thorndyke (1981). Performance measures on all four tasks were converted to rank-order scores to facilitate intertask comparison, and a composite score was calculated for each subject by taking the mean of the ranks for the four tasks. Subjects who scored above the median on the composite score as well as above the task median on at least three of the individual tasks were designated as *good cognitive mappers*. Subjects who scored below the median on the composite score and on at least three of the separate tasks were designated as *poor cognitive mappers*. Twelve subjects met the criteria for each of these groups. The subsample of 24 subjects selected by these criteria form the basis for all the analyses reported in this Note.

## MATERIALS

### Ability Tests

Subjects spent one 2-hour session working on a number of standard tests of basic cognitive abilities from the French Kit of Factor Referenced Cognitive Tests (Ekstrom, French, & Harman, 1976). The tests included one test of verbal ability (Advanced Vocabulary Test II), two tests of visual memory (Shape Memory Test and Building Memory Test), two tests of spatial orientation ability (Card Rotations Test and Cube Comparisons Test), two tests of visualization ability (Form Board Test and Paper Folding Test), and the Hidden Figures Test, a measure of FD/I.[1]

[1]The French Kit labels the factor associated with this test "Flexibility of Closure." The Hidden Figures Test was modeled on and

Subjects also completed a two-trial verbal memory test, using a list of 20 concrete nouns. Tests were scored as indicated by the French Kit reference manual. Table 1 presents brief descriptions of the tasks involved in each of the tests used in this study.

Questionnaire Measures

Each subject completed two questionnaires. One, the spatial style questionnaire, included items related to the subject's spatial abilities, navigation and orientation preferences, and general "style" of processing spatial information. This questionnaire also included questions assessing the range of the subject's geographic experience. The other, the map experience questionnaire, included questions on the subject's familiarity with and liking for maps. Groups of individual items from the both questionnaires were averaged to assess various aspects of motivation and experience. The questionnaires are reproduced in Appendixes A and B. The items used to measure each variable are summarized in Table 2.

Imagery Tests

Each subject completed the Betts Vividness of Mental Imagery test and the Gordon Test of Image Controllability, as revised by Richardson (1969). These tests are reproduced in Appendixes C and D. Scores on these tests provided secondary measures of visual/verbal cognitive style. Vividness scores were calculated by taking the mean of all

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is nearly identical to the Group Embedded Figures Test, one of the marker tests for FD/I.

Table 1

DESCRIPTION OF TASKS IN ABILITY TESTS

| Ability | Test | Description |
|---|---|---|
| Visualization | Form Board | Select a subset of shapes that can be combined to form a standard shape. |
| | Paper Folding | Given a picture of a square of paper folded once or twice and punched with several holes, select from five alternatives the one that shows how the paper will look when unfolded. |
| Spatial orientation | Card Rotations | Given a standard irregularly shaped form, select from six alternatives the forms that are simple rotations (rather than mirror reversals) of the standard. |
| | Cube Comparisons | Given two drawings of a cube with different orientations, decide whether the two represent the same or different cubes, under the assumption that no two faces are alike. |
| Visual memory | Shape Memory | Given an array of irregular shapes to study for 4 minutes, identify which of several candidates answer shapes were previously seen, in same orientation. |
| | Building Memory | Given a map of the arrangement of various buildings to study for 4 minutes, indicate the location of each previously seen building on a skeleton map. |
| Field independence | Hidden Figures | Select which of five geometric figures is embedded in a complex pattern. |
| Verbal intelligence | Vocabulary | Select one of five alternatives as the closest synonym to a test word. |
| Verbal memory | Free Recall | Recall a list of 20 auditorily presented concrete nouns. |

## Table 2

### SUMMARY OF QUESTIONNAIRE ITEMS MEASURING COGNITIVE STYLE, MOTIVATION, AND EXPERIENCE[a]

| Category | Variable | Questionnaire[b] | Items |
|---|---|---|---|
| Cognitive style | Visual style | SS | Q8 - I can imagine mental images of places I have been without much trouble. |
| | | | Q11 - I tend to think visually, with lots of mental images. |
| | | | Q20 - I feel I have a mental map of places I know well. |
| | Verbal/ analytic style | SS | Q12 - I tend to think of my environment in terms of compass directions. |
| | | | Q21 - I am good at estimating distances. |
| | | | Q1 - (reverse scale) I frequently can find my way to a place without being able to give someone else directions. |
| Motivation | Exploratory motivation | SS | Q2 - I enjoy exploring new places. |
| | | | Q10 - I like to travel. |
| | | | Q13 - I like to drive. |
| | | | Q16 - I enjoy looking at and studying maps. |
| | Conscious control | SS | Q7 - I consciously try to remember streets and landmarks when traveling in a new environment. |
| | | | Q14 - I often do the planning and navigating for a long trip. |
| | | | Q15 - When driving or walking around, I feel it is important to find the best route. |
| | Disorientation anxiety | SS | Q6 - I hate being lost. |
| | | | Q9 - I always like to know where I am. |
| | Map-using motivation | ME | Q5 - How comfortable and competent do you feel in general when using maps? (1 to 5 rating) |
| | | | Q6 - How much do you enjoy using and looking at maps? (1 to 5 rating) |
| Experience | Overall geographic experience | SS | Sum of: |
| | | | How many places have you lived for a month or more? |
| | | | How many states have you visited? |
| | | | How many foreign countries have you visited? |
| | Map-using experience | ME | Sum of Questions 1, 2, 3 |
| | | | Assessing (1) frequency of using maps for different tasks and (2) frequency of using different types of maps. |

[a] All measures are averaged item ratings, unless otherwise noted.

[b] SS = spatial style questionnaire; ME = map experience questionnaire.

ratings, then inverting the scale to make higher average ratings indicate greater vividness. Controllability scores consisted of tha number of imagery subtasks the subject said she or he could perform, i.e., the number of "yes" responses.

PROCEDURE

Subjects completed the various measures described above in several different sessions spread out over a 9-month period. Other spatial tasks (described in Goldin and Thorndyke (1981)) were also included in these sessions. The spatial style questionnaire was completed first, in the same session in which the assessment task battery used to select subject groups was administered. The ability tests were administered in a session about 6 months later that also included map learning tasks. Finally, the map experience questionnaire was administered during a session about 3 months later, along with the map using tasks.

# V. RESULTS

This section presents our comparisons of good and poor mappers on each of the individual difference measures described in Section IV. All comparisons contrasted the performance of good and poor mappers using *t* tests with a significance level of .05.

## COGNITIVE ABILITIES

Good and poor mappers differed in several measures of ability. As Table 3 shows, verbal intelligence and associative memory did not distinguish good from poor mappers. However, strong and consistent differences are apparent on spatial ability components.

First, good cognitive mappers possess greater spatial visualization ability than poor mappers, as indicated by the large performance differences on the Form Board and Paper Folding tests. In Goldin and Thorndyke (1981), we hypothesized that good and poor mappers might differ in visualization ability, since visualization appears to be a necessary component of many of the spatial judgment tasks in which good mappers excelled. These tasks, which included orientation judgments, route distance estimation, and euclidean distance estimation, all require visualizing transformations or permutations of an image. Such image transformations form the basis for most tests of visualization ability.

Good cognitive mappers may also possess superior spatial orientation skills. Good mappers performed significantly better than poor mappers on the Cube Comparisons test ($t(22) = 3.04$, $p < .01$). However,

Table 3

ABILITY-TEST PERFORMANCE OF GOOD AND POOR COGNITIVE MAPPERS

| Test | Good Mappers | Poor Mappers | *t*-value |
|---|---|---|---|
| Visualization | | | |
| Form Board | 15.9 | 1.2 | 3.12[a] |
| Paper Folding | 12.0 | 8.0 | 2.27[b] |
| Spatial Orientation | | | |
| Card Rotations | 98.2 | 79.9 | 1.32 |
| Cube Comparisons | 20.0 | 8.8 | 3.04[a] |
| Visual Memory | | | |
| Shape Memory | 17.3 | 17.4 | .03 |
| Building Memory | 19.8 | 14.8 | 2.47[b] |
| Field Independence | | | |
| Hidden Figures | 21.1 | 10.7 | 3.80[a] |
| Verbal Memory (percent correct) | 62.9 | 54.6 | 1.72 |
| Vocabulary | 37.1 | 31.5 | 1.47 |

[a] $p < .01$.
[b] $p < .05$.

the superiority of the good mappers on the other spatial orientation test, Card Rotation, was not reliable. The two tests do correlate significantly ($r = .51$, $p < .01$), but far from perfectly. In fact, the

Cube Comparison scores correlate more strongly with measures of visualization ability ($r = .74$ and $r = .73$ for the Paper Folding and Form Board tests, respectively). Thus, although the two tests purport to measure the same underlying ability, they may in fact require slightly different processing skills.

We also obtained some evidence that good mappers have better visual memory ability than poor mappers. Good mappers excelled on the Building Memory test. This test is also a reliable predictor of good and poor map learners (Stasz & Thorndyke, 1980; Thorndyke & Stasz, 1980). Good and poor mappers did not differ on the Shape Memory test, although the correlation between this test and the Building Memory test was significant ($r = .63$, $p < .01$). While the split-half reliability of the other tests was quite high ($r \geq .79$), the reliability of the Shape Memory test was very low ($r = .08$). Thus performance on this test may not be a valid indicator of subjects' true ability.

Finally, good cognitive mappers scored significantly higher than poor mappers on the Hidden Figures test. This result is also consistent with the findings of Stasz and Thorndyke. Their measure of field dependence, the Group Embedded Figures Test (GEFT), showed a strong correlation with map learning skill. In addition, they found that performance on this test correlated highly with the Building Memory test ($r = .63$). In the present study, we also found a strong relationship between the Hidden Figures test and the Building Memory test ($r = .63$, $p < .01$).

While good mappers outperformed poor mappers on most tests of spatial ability, the groups did not differ on tests of verbal ability or associative long term memory. This finding indicates that good mappers are not generally superior information processors; rather, cognitive mapping skill appears to be a specialization of spatial processing skills. In our sample, these skills appear to be more or less independent of verbal ability. Thus, our results lend further support to a fundamental distinction between spatial and nonspatial abilities.

To this point, we have used the term "spatial abilities" to include orientation, visualization, and visual memory. The traditional psychometric framework treats these abilities as distinct, orthogonal components of spatial ability (Ekstrom, French, & Harman, 1976; McGee, 1979). However, in this study, these components were highly related. Table 4 presents the intercorrelations among the various ability tests; 15 of the 18 correlations between tests purportedly measuring different skills are significant. Excluding correlations involving the Shape Memory Test (which had low reliability), the lowest correlation relating any two spatial tests is .51 ($p < .01$). The data suggest that ability tests tap many of the same processing skills, and that the factors comprising general spatial ability may be less independent than has previously been supposed.

## COGNITIVE STYLE

Table 5 compares good and poor mappers on our various measures of visual/verbal style. These include two measures derived from the spatial style questionnaire and scores on the two imagery tests. (Refer to Table 2 for item descriptions.) As Table 5 shows, good and poor mappers did not differ on any of these style measures. Thus, these data do not

Table 4

INTERCORRELATIONS AMONG ABILITY TESTS

| | Form Board | Paper Folding | Card Rotations | Cube Comparisons | Shape Memory | Bldg Memory | Hidden Figures | Verbal Recall |
|---|---|---|---|---|---|---|---|---|
| Form Board | -- | | | | | | | |
| Paper Folding | .60[a] | -- | | | | | | |
| Card Rotations | .64[a] | .72[a] | -- | | | | | |
| Cube Comparisons | .73[a] | .74[a] | .51[a] | -- | | | | |
| Shape Memory | .32 | .51[a] | .47[a] | .25 | -- | | | |
| Building Memory | .51[a] | .61[a] | .55[a] | .60[a] | .63[a] | -- | | |
| Hidden Figures | .71[a] | .54[a] | .61[a] | .65[a] | .36 | .63[a] | -- | |
| Verbal Recall | .44 | .40 | .07 | .47[a] | .30 | .42 | .30 | -- |
| Vocabulary | .55[a] | .22 | .31 | .24 | -.12 | .06 | .41 | .22 |

[a] $p < .01$.

Table 5

VISUAL/VERBAL STYLE AND IMAGERY MEASURES FOR GOOD AND POOR COGNITIVE MAPPERS

| Measure | Good Mappers | Poor Mappers | *t*-value |
|---|---|---|---|
| Visual Style Questionnaire | 1.8 | 1.9 | - .30 |
| Verbal Style Questionnaire | 3.0 | 3.8 | -1.84 |
| Gordon test of Image Control | 8.8 | 8.7 | .07 |
| Betts test of Image Vividness | 2.2 | 1.9 | 1.58 |

support our initial hypothesis that good cognitive mappers tend to be visual thinkers and/or to have more vivid or controllable images.

We categorized subjects as visual thinkers if they had a mean rating of 3.00 or less on the items indexing visual thinking (3.00 was the midpoint of the scale, which ranged from "very true" (1) to "not at all true" (5)). Using this criterion, we found that all subjects in both groups consider themselves visual thinkers. On the other hand, using the same criterion for categorizing subjects as verbal/analytic, we found that significantly more good mappers produced ratings that put them in the verbal/analytic group (8 vs. 3, $\chi^2 = 4.20$, $p < .05$). Thus, there is some evidence that the good cognitive mappers tend to approach an environmental learning task from a more analytic perspective, trying to establish a frame of reference in terms of compass directions and focusing on symbolic rather than only perceptual information. However, the generally equivalent scores of the two groups on other style measures suggests that either a visual or a verbal/analytic orientation can be compatible with effective mapping of the environment.

This conclusion is consistent with the protocols taken from subjects learning a new environment (Thorndyke, 1980). In Thorndyke's study, two subjects with equivalent spatial ability but different verbal abilities attempted to learn a new environment from a series of automobile trips through the environment. The subject with high verbal ability used a verbal/analytic strategy for acquiring spatial relations, while the subject with low verbal ability relied on visual memory and mental simulation to deduce spatial relations. While the relative rates at which they acquired different types of spatial knowledge varied with their style, they both acquired sufficient knowledge after four trips through the environment to perform equally well on tests of their spatial knowledge.

Although good mappers differed from poor mappers in visualization and visual memory abilities, they did not differ systematically on either imagery test. In fact, neither imagery test correlated significantly with any of the spatial ability test measures (highest correlation = .26, ns, for the Gordon test with the Cube Comparisons test). This result suggests that the Betts and Gordon imagery tests do measure style, rather than visualization ability, as we had expected. The Betts test purports to measure image vividness, but the vividness of an image may be unrelated to its accuracy. For example, expert chess players report imaging the chessboard and pieces as an aid to play, but in a sketchy, schematic fashion, rather than in rich detail (Binet, 1966).

The Gordon test purports to measure an individual's capacity for image manipulation. Although this seems quite close to the definition of visualization ability, the Gordon test was originally designed to distinguish individuals with "controllable" images from individuals with "autonomous" images--images that changed spontaneously without the imager's volition. The test provides no objective criterion for the accuracy of an individual's image manipulation, but measures only the subjective impression that the image can be manipulated. Thus, the Gordon test, like the Betts test, is best considered a measure of cognitive style rather than ability. The fact that it fails to distinguish between good and poor mappers does not weaken our conclusions concerning intergroup differences in visualization ability.

It is interesting to note that while neither imagery test correlated significantly with spatial ability, the two tests themselves were reliably related ($r = -.49$, $p < .05$). The direction of this correlation suggests that individuals with more vivid images find these images more difficult to control. These results agree with findings reported by Richardson (1969), who noted that individuals with vivid imagery sometimes reported that their images exhibited a kind of autonomy, changing spontaneously but resisting conscious control.

## MOTIVATION

Table 6 compares good and poor mappers on several aspects of motivation examined in this study: interest in exploring new places, motivation to consciously control and optimize spatial processing, anxiety or discomfort associated with disorientation, and interest in maps and map using. These aspects of motivation were assessed by subjects' ratings of items from the spatial-style and map-experience questionnaires. (Refer to Table 2 for specific items.) As Table 6 shows, good mappers did not differ reliably from poor mappers on any of these measures, although the conscious-control and map-motivation measures showed trends in the expected direction. Thus, we have no evidence that motivation, at least as measured in this study, is reliably related to cognitive mapping skill.

Practically any theory of environmental learning predicts that such learning should be related to motivation. However, motivational correlations may be local and task-specific, rather than reflecting enduring differences between individuals. Alternatively, stable individual differences in motivation may be related to learning, but only at the extremes of the distribution. The individual who gets terribly anxious

Table 6

MOTIVATION MEASURES FOR GOOD AND POOR COGNITIVE MAPPERS

| Measure | Good Mappers | Poor Mappers | *t*-value |
|---|---|---|---|
| Exploratory motivation | 1.9 | 2.0 | - .07 |
| Conscious control | 1.8 | 2.2 | -1.21 |
| Disorientation anxiety | 2.1 | 2.1 | 0 |
| Map-using motivation | 4.2 | 3.7 | 1.29 |

at the thought of being lost or the individual who takes personal pride in finding his or her way around in a strange city may represent a special case in which motivation measurably correlates highly with environmental learning. For the average individual, however, cognitive abilities and environmental structure may overshadow motivation as important correlates of cognitive mapping performance.

## EXPERIENCE

Contrary to expectation, neither general experience nor map using experience appears to be related to cognitive mapping skill as measured here. The good and poor mapper groups did not differ on our geographic-experience measure, which summed the number of places in which an individual had resided, the number of states he or she had visited, and the number of foreign countries he or she had seen (means of 33.3 and 29.6 for good and poor groups respectively, $t(22) = .54$, ns). Good and poor mappers also did not differ in their experience with maps, measured as the frequency of contact with various kinds of maps and map using tasks (means of 33.3 and 28.7, respectively, $t(22) = 1.72$, ns). Thus, differences in cognitive mapping skill in our sample are not related to differences in prior experience at acquiring spatial knowledge.

## VI. GENERAL DISCUSSION

We can summarize the results of this study quite succinctly: spatial ability is the major category of individual difference variables that distinguish good from poor cognitive mappers. Neither processing style, motivation, nor experience were measurably related to cognitive mapping performance in this study. Of course, these results do not categorically rule out all aspects of these factors as predictors of cognitive mapping skill. As we noted at the outset, many researchers have demonstrated the existence of situations in which these variables predict spatial knowledge. However, our data indicate that the clear-cut differences in spatial skill observed in our subject groups cannot be predicted from these factors.

On the other hand, our data indicate that spatial abilities are strongly correlated with cognitive mapping skill. Good cognitive mappers score higher than poor mappers on tests of visualization ability, spatial orientation ability, visual memory, and field independence. Every spatial ability test, with the exception of the unreliable Shape Memory test, correlated significantly with the composite performance scores used as the criterion for selecting good and poor mappers. These correlations ranged from a low of .46 ($p < .05$, for the Card Rotations test) to a high of .78 ($p < .01$, for the Hidden Figures test). Among the other variables, only conscious control motivation correlated significantly with composite performance ($r = .42$, $p < .05$).

As we argued in the Introduction, each of these abilities plays a role in the knowledge acquisition, organization, or computation required to make spatial judgments. The results presented here indicate that cognitive ability tests may serve as useful predictors of success on spatial tasks in real world settings. Thus, military personnel who have the skill to acquire and/or use terrain information may be successfully identified on the basis of their scores on these ability tests. The advantage of using such tests as assessment tools lies in their relative simplicity: They require only a short time to administer, they can be administered concurrently to large groups, and they can be scored by machine.

We should qualify this recommendation, however, by noting that good and poor mappers did not differ on all the spatial tasks tested in our earlier study (Goldin & Thorndyke, 1981). In particular, cognitive mapping skill did not predict performance on map reading, map interpretation, and navigation tasks. These tasks may not require the same kind of abilities as are used in learning a new environment from direct experience or from a map.

Since cognitive abilities are traditionally considered to be stable individual characteristics, these results may seem to indicate that people cannot be trained to be good cognitive mappers. However, abilities exert their influence through interaction with other factors, such as strategies, knowledge, and processing style (e.g., Thorndyke & Stasz, 1980). For example, individuals with high spatial ability may adopt learning or computation strategies that are more effective than those of individuals with low ability. The use of such effective strategies may or may not <u>require</u> a high degree of skill in the processes measured by spatial ability tests. Thus, to the extent that such strategies are independent of ability, they are presumably trainable. However, to the extent that their use requires high spatial ability, training is unlikely to reduce performance differences between high- and low-ability subjects and may even increase those differences (e.g., Thorndyke & Stasz, 1980).

Consideration of individual processing styles may also help to improve cognitive mapping performance. Individuals could be taught to employ processing styles that emphasize abilities in which they excel. To some extent, people seem to adopt appropriate styles spontaneously (Thorndyke, 1980). However, the "appropriate" style may also be determined by an interaction with environmental characteristics or task constraints. For example, a visually oriented person would probably not perform well in a visually homogeneous environment with few landmarks, or on a task in which he is instructed to focus on verbal information such as street names. Similarly, a verbally oriented individual would suffer in an environment devoid of verbal information or on a task that required recognition of landmarks on the basis of visual details. It is not surprising that we found few systematic differences in the processing styles of good and poor cognitive mappers, since our design was not sufficiently sensitive to detect this type of interaction. Further research on the relationship of processing style to cognitive mapping under special constraints could provide a basis for training individuals to select an optimal processing style for a given situation.

Precise understanding of the mechanisms that link components of spatial ability to cognitive mapping will require considerable further research. However, the present data, in conjunction with previous results (Goldin & Thorndyke, 1981), allow us to propose a tentative model of cognitive mapping that can account for individual differences. This model must include processes for acquiring and storing spatial information, processes for reorganizing and transforming this information in memory, and processes for accessing this information and using it to compute spatial judgments.

Visual memory would influence the first set of processes. In order to acquire spatial knowledge from direct experience, an individual must notice distinctive visual features in the environment and retain a representation of those features, along with a representation of the order in which they occurred. Good visual memory will insure accurate encoding of these features in a form that is durable and reliable. On successive exposures to the environment, an individual with good visual memory will recognize landmarks and route choice points, while an individual with poor visual memory may confuse novel with familiar landmarks. Thus, an individual with good visual memory will have an advantage in navigating. Furthermore, the procedural knowledge that he or she acquires through navigation will be more accurate and coherent. Since route distance estimates and orientation estimates are most easily derived from procedural knowledge (Thorndyke & Hayes-Roth, 1980), an individual with good visual memory should perform more accurately on these spatial judgment tasks as well. In contrast, individuals with poor visual memory should find these judgment tasks difficult. Their procedural representations are likely to be confused and inaccurate; hence, they may make errors in mental simulation that reflect underlying errors in their knowledge, or they may be forced to base their judgments on less optimal sources of knowledge.

Field dependence and visualization would influence the second set of processes. After considerable experience with a particular environment, an individual can gradually integrate local information about landmarks and routes to form representations of more global properties of the space, including straight-line distances, regional shapes, and configural relations among landmarks, i.e., survey knowledge. Although the mechanisms of this integration process are poorly understood, considerable restructuring of information must be required. Field independent individuals excel in this kind of restructuring; thus, they should develop survey knowledge more easily than field dependent individuals. Abstraction of survey knowledge may also require that different portions of the procedural representation be normalized, rotated, or compared in order to establish correspondences. These transformation processes will involve visualization; hence individuals high in visualization ability should again show faster and more accurate development of survey knowledge.

Finally, visualization and spatial orientation would play a large role in the third set of processes, computation of spatial judgments. Many spatial judgment tasks (e.g., route distance estimation and orientation judgments) require the individual to mentally simulate travel through the environment. This mental travel process requires an ability to visualize the environment as seen from ground level and to dynamically manipulate that environmental image in response to simulated changes in bearing and location. Spatial orientation ability also plays a role in mental simulation, by helping the individual to maintain a consistent frame of reference as the direction of "travel" changes.

Spatial judgment computations also frequently require shifts of perspective between a bird's-eye view (looking down at a mental map from above) and a ground-level view (looking horizontally, with the personal frame of reference embedded within the spatial representation). Tests of spatial orientation ability require very similar perspective shifts. Thus, individuals who score high on spatial orientation tests should be less confused by perspective shifts needed to compute various spatial judgments.

The present research represents only a preliminary step toward understanding cognitive mapping skill. We have characterized individual differences in cognitive mapping in terms of task profiles and basic cognitive abilities. Other research has attempted to specify detailed performance models for particular spatial judgment tasks (Thorndyke & Hayes-Roth, 1980). The next logical step would be the formulation of prescriptive models that link the cognitive requirements of the task to the cognitive resources available to the individual--not only cognitive abilities, but also consciously controlled processing strategies. Once this is accomplished, researchers can focus on methods for training poor cognitive mappers to become good ones.

## Appendix A

### SPATIAL STYLE QUESTIONNAIRE

We would greatly appreciate your taking the time to complete this simple questionnaire. Please feel free to expand on any questions for which you feel this is necessary. This is not a test of any kind; we are simply trying to gain some information on how people deal with new environments in everyday life. Please answer all questions on the basis of your own personal experience.

---

| | | |
|---|---|---|
| 1. | I frequently can find my way to a place without being able to give someone else directions. | 1----2----3----4----5 |
| 2. | I enjoy exploring new places. | 1----2----3----4----5 |
| 3. | I find maps difficult to use. | 1----2----3----4----5 |
| 4. | I need a map to find my way around in a new place. | 1----2----3----4----5 |
| 5. | I have a good sense of direction. | 1----2----3----4----5 |
| 6. | I hate being lost. | 1----2----3----4----5 |
| 7. | I consciously try to remember landmarks and streets when traveling in a new environment. | 1----2----3----4----5 |
| 8. | I can imagine mental images of places I have been without much trouble. | 1----2----3----4----5 |
| 9. | I always like to know where I am. | 1----2----3----4----5 |
| 10. | I like to travel. | 1----2----3----4----5 |
| 11. | I tend to think visually, with lots of mental images. | 1----2----3----4----5 |
| 12. | I tend to think of my environment in terms of compass directions (e.g., N, S, E, W). | 1----2----3----4----5 |
| 13. | I like to drive. | 1----2----3----4----5 |
| 14. | I often do the planning and navigating for a long trip. | 1----2----3----4----5 |

| | | |
|---|---|---|
| 15. | When driving or walking around, I feel it is important to find the best route. | 1----2----3----4----5 |
| 16. | I enjoy looking at and studying maps. | 1----2----3----4----5 |
| 17. | I frequently find myself getting lost and disoriented in new environments. | 1----2----3----4----5 |
| 18. | I can usually remember a new route that I have traveled only once. | 1----2----3----4----5 |
| 19. | When I'm with other people, I prefer to let someone else give directions or determine our route. | 1----2----3----4----5 |
| 20. | I feel like I have a mental map of places I know well. | 1----2----3----4----5 |
| 21. | I am good at estimating distances. | 1----2----3----4----5 |
| 22. | When I use a map, I need to refer back to it frequently to refresh my memory. | 1----2----3----4----5 |

23. How often do you travel around Brentwood? (Check one)

At least once a day _____ Every other day _____

A few times a week _____ Once a week _____

24. What is your most frequent mode of travel?

Auto _____ Bicycle _____ Motorcycle or moped _____

Walking _____ Public transportation _____ Other _____

25. How often do you travel around Greater L.A.? (check one)

At least once a day _____ Every other day _____

A few times a week _____ Once a week _____

Less than once a week _____

26. Where did you grow up? ________________________________

27. How many places have you lived for a month or more? Please break down your answer into the following categories:

Cities _____ Large towns _____ Small towns _____

Suburbs _____ Rural areas _____ Other _____ (please specify)

28. How many states have you visited? 1-5 ___ 6-10 ___ 11-15 ___

16-20 ___ 21-25 ___ More than 25 ___

29. How many foreign countries have you visited? ______

Can you tell us anything else that you think might be interesting or useful about the way you deal with the spatial environment?

Please oblige us by supply the following personal information:

Name ______________________ Age _____ Occupation ___________

Thank you for your cooperation.

## Appendix B

### MAP EXPERIENCE QUESTIONNAIRE

We would appreciate your answering the following questions concerning your degree of experience using different kinds of map for different kinds of tasks.

1) How often do you perform each of the following activities? Please answer by assigning each activity a number from 1 to 6, according to the following scale:

   1 = seldom or never
   2 = less than once a month
   3 = several times a month
   4 = roughly once a week
   5 = several times a week
   6 = almost every day

   (Note that the more frequent the activity, the higher the numerical rating.)

   a) Use a map to find a route to someplace you want to go ____

   b) Use a map to locate a place ___

   c) Use a map to get some idea of the general relationships among several places ___

   d) Use a map to determine how far away a place is or how long it will take to get there ___

   e) Use a map to demonstrate to someone else the location of a place or the best route to get there ___

   f) Draw a map in order to give someone directions ___

2) How often do you use each of the following kinds of maps? (Please rate for frequency using the same scale as in 1.)

   a) City street maps ___

   b) Maps of freeway systems ___

   c) State or regional highway maps ___

   d) Country map (of US) ___

e) Country map (other than US) ___

f) Hand-drawn maps ___

g) Aviation charts ___

h) Nautical charts ___

i) Topographic map ___

j) Other? (Please specify) ______________________________ ___

4) How familiar are you with the geographic areas portrayed in the maps used earlier in this experiment? Please rate according to the following scale:

1 = totally unfamiliar, have never heard of this place
2 = have looked at maps of this place once or twice
3 = have looked at maps of this place more than once or twice but have never visited there
4 = have actually been to this place once
5 = have been to this place more than once (please indicate in parentheses how many times)
6 = have lived in this place (please indicate in parentheses how long)

a) City of Rome _____

b) Country of Sicily _____

c) Western Ohio/eastern Indiana _____

5) How comfortable and competent do you feel in general when using maps? Please circle one response:

1 = Very uncomfortable - I feel very unskilled

2 = Slightly uncomfortable - I'm willing to try

3 = I can handle map tasks - I'm neutral about how I feel about them

4 = Fairly comfortable - I can use maps reasonably well

5 = Very comfortable - I'm a real whiz on map tasks

6) How much do you enjoy using or looking at maps? Please circle one response:

1 = I hate using maps, avoid them as much as possible

2 = I dislike using or looking at maps, although I'll use them when I have to

3 = I neither like nor dislike maps; they're a fact of life

4 = I somewhat enjoy looking at maps, although I don't do it too much simply for recreation

5 = I really enjoy maps for their own sake; I could spend significant amounts of time just looking at an atlas or geography book just for the fun of it

## Appendix C

### THE GORDON TEST OF VISUAL-IMAGERY CONTROL

The questions in this test are concerned with the ease with which you can control or manipulate visual images. For some people this task is relatively easy and for others relatively hard. One subject who could not manipulate his imagery easily gave this illustration. He visualized a table, one of whose legs suddenly began to collapse. He then tried to visualize another table with four solid legs, but found it impossible. The image of the first table with its collapsing leg persisted. Another subject reported that when he visualized a table the image was rather vague and dim. He could visualize it briefly but it was difficult to retain by any voluntary effort. In both these illustrations the subjects had difficulty in controlling or manipulating their visual imagery. It is perhaps important to emphasize that these experiences are in no way abnormal and are as often reported as the controllable type of image.

Read each question, then close your eyes while you try to visualize the scene described. Record you answer by underlining "Yes," "No," or "Unsure," whichever is the most appropriate. Remember that your accurate and honest answer to these questions is most important for the validity of this study. If you have any doubts at all regarding the answer to a question, underline "Unsure." Please be certain that you answer each of the twelve questions.

| | | | |
|---|---|---|---|
| 1. Can you see a car standing in the road in front of a house? | Yes | No | Unsure |
| 2. Can you see it in color? | Yes | No | Unsure |
| 3. Can you now see it in a different color? | Yes | No | Unsure |
| 4. Can you now see the same car lying upside down? | Yes | No | Unsure |
| 5. Can you now see the same car back on its four wheels again? | Yes | No | Unsure |
| 6. Can you see the car running along the road? | Yes | No | Unsure |
| 7. Can you see it climb up a very steep hill? | Yes | No | Unsure |
| 8. Can you see it climb over the top? | Yes | No | Unsure |
| 9. Can you see it get out of control and crash through a house? | Yes | No | Unsure |
| 10. Can you now see the same car running alongside the road with a handsome couple inside? | Yes | No | Unsure |
| 11. Can you see the car cross a bridge and fall over the side into the stream below? | Yes | No | Unsure |
| 12. Can you see the car all old and dismantled in a car-cemetery? | Yes | No | Unsure |

## Appendix D

## THE BETTS VIVIDNESS OF IMAGERY SCALE

Instructions for doing test:

The aim of this test is to determine the vividness of your imagery. The items of the test will bring certain images to your mind. You are to rate the vividness of each image by reference to the accompanying rating scale, which is shown at the bottom of the page. Just write the appropriate number after each item. Before you turn to the items on the next page, familiarize yourself with the different categories on the rating scale. Throughout the test, refer to the rating scale when judging the vividness of each image. A copy of the rating scale will be printed on each page. Please do not turn to the next page until you have completed the items on the page you are doing, and do not turn back to check on other items you have done. Complete each page before moving on to the next page. Try to do each item separately independent of how you may have done other items.

---

The image aroused by an item of this test may be:

| | |
|---|---|
| Perfectly clear and as vivid as the actual experience | Rating 1 |
| Very clear and comparable in vividness to the actual experience | Rating 2 |
| Moderately clear and vivid | Rating 3 |
| Not clear or vivid, but recognizable | Rating 4 |
| Vague and dim | Rating 5 |
| So vague and dim as to be hardly discernible | Rating 6 |
| No image present at all, you only 'know' that you are thinking of the object | Rating 7 |

---

An example of an item on the test would be one which asked you to consider an image which comes to your mind's eye of a red apple. If your visual image was moderately clear and vivid you would check the rating scale and mark '3' in the brackets as follows:

| Item | Rating |
|---|---|
| 5. A red apple | (3) |

Now turn to the next page when you have understood these instructions and begin the test.

Think of some relative or friend whom you frequently see, considering carefully the picture that rises before your mind's eye. Classify the images suggested by each of the following questions as indicated by the degrees of clearness and vividness specified on the Rating Scale.

| Item | rating |
|---|---|
| 1. The exact contour of face, head, shoulders and body | ( ) |
| 2. Characteristic poses of head, attitudes of body, etc. | ( ) |
| 3. The precise carriage, length of step, etc. in walking | ( ) |
| 4. The different colors worn in some familiar costume | ( ) |

Think of seeing the following, considering carefully the picture which comes before your mind's eye; classify the image suggested by the following questions as indicated by the degree of clearness and vividness specified on the Rating Scale.

| | |
|---|---|
| 5. The sun as it is sinking below the horizon | ( ) |

---

Rating Scale

| | |
|---|---|
| Perfectly clear and as vivid as the actual experience | Rating 1 |
| Very clear and comparable in vividness to the actual experience | Rating 2 |
| Moderately clear and vivid | Rating 3 |
| Not clear or vivid, but recognizable | Rating 4 |
| Vague and dim | Rating 5 |
| So vague and dim as to be hardly discernible | Rating 6 |
| No image present at all, you only 'know' that you are thinking of the object | Rating 7 |

---

Think of each of the following sounds, considering carefully the image which comes to your mind's ear, and classify the images suggested by each of the following questions as indicated by the degrees of clearness and vividness specified on the Rating Scale.

| Item | Rating |
|---|---|
| 6. The whistle of a locomotive | ( ) |
| 7. The honk of an automobile | ( ) |
| 8. The mewing of a cat | ( ) |
| 9. The sound of escaping steam | ( ) |
| 10. The clapping of hands in applause | ( ) |

---

Rating Scale

The image aroused by an item of this test may be:

| | |
|---|---|
| Perfectly clear and as vivid as the actual experience | Rating 1 |
| Very clear and comparable in vividness to the actual experience | Rating 2 |
| Moderately clear and vivid | Rating 3 |
| Not clear or vivid, but recognizable | Rating 4 |
| Vague and dim | Rating 5 |
| So vague and dim as to be hardly discernible | Rating 6 |
| No image present at all, you only 'know' that you are thinking of the object | Rating 7 |

---

Think of 'feeling' or touching each of the following, considering carefully the image which comes to your mind's touch, and classify the images suggested by each of the following questions as indicated by the degrees of clearness and vividness specified on the Rating Scale.

| Item | | Rating |
|---|---|---|
| 11. | Sand | ( ) |
| 12. | Linen | ( ) |
| 13. | Fur | ( ) |
| 14. | The prick of a pin | ( ) |
| 15. | The warmth of a tepid bath | ( ) |

---

Rating Scale

The image aroused by an item of this test may be:

| | |
|---|---|
| Perfectly clear and as vivid as the actual experience | Rating 1 |
| Very clear and comparable in vividness to the actual experience | Rating 2 |
| Moderately clear and vivid | Rating 3 |
| Not clear or vivid, but recognizable | Rating 4 |
| Vague and dim | Rating 5 |
| So vague and dim as to be hardly discernible | Rating 6 |
| No image present at all, you only 'know' that you are thinking of the object | Rating 7 |

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Think of performing each of the following acts, considering carefully the image which comes to your mind's arms, legs, lips, etc., and classify the images suggested as indicated by the degree of clearness and vividness specified on the Rating Scale.

| Item | Rating |
|---|---|
| 16. Running upstairs | ( ) |
| 17. Springing across a gutter | ( ) |
| 18. Drawing a circle on paper | ( ) |
| 19. Reaching up to a high shelf | ( ) |
| 20. Kicking something out of your way | ( ) |

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Rating Scale

The image aroused by an item of this test may be:

| | |
|---|---|
| Perfectly clear and as vivid as the actual experience | Rating 1 |
| Very clear and comparable in vividness to the actual experience | Rating 2 |
| Moderately clear and vivid | Rating 3 |
| Not clear or vivid, but recognizable | Rating 4 |
| Vague and dim | Rating 5 |
| So vague and dim as to be hardly discernible | Rating 6 |
| No image present at all, you only 'know' that you are thinking of the object | Rating 7 |

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Think of tasting each of the following considering carefully the image which comes to your mind's mouth, and classify the images suggested by each of the following questions as indicated by the degrees of clearness and vividness specified on the Rating Scale.

| Item | Rating |
|---|---|
| 21. Salt | ( ) |
| 22. Granulated (white) sugar | ( ) |
| 23. Oranges | ( ) |
| 24. Jelly | ( ) |
| 25. Your favorite soup | ( ) |

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Rating Scale

The image aroused by an item of this test may be:

| | |
|---|---|
| Perfectly clear and as vivid as the actual experience | Rating 1 |
| Very clear and comparable in vividness to the actual experience | Rating 2 |
| Moderately clear and vivid | Rating 3 |
| Not clear or vivid, but recognizable | Rating 4 |
| Vague and dim | Rating 5 |
| So vague and dim as to be hardly discernible | Rating 6 |
| No image present at all, you only 'know' that you are thinking of the object | Rating 7 |

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Think of smelling each of the following, considering carefully the image which comes to your mind's nose and classify the images suggested by each of the following questions as indicated by the degrees of clearness and vividness specified on the Rating Scale.

| Item | Rating |
| --- | --- |
| 26. An ill-ventilated room | ( ) |
| 27. Cooking cabbage | ( ) |
| 28. Roast beef | ( ) |
| 29. Fresh paint | ( ) |
| 30. New leather | ( ) |

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Rating Scale

The image aroused by an item of this test may be:

| | |
| --- | --- |
| Perfectly clear and as vivid as the actual experience | Rating 1 |
| Very clear and comparable in vividness to the actual experience | Rating 2 |
| Moderately clear and vivid | Rating 3 |
| Not clear or vivid, but recognizable | Rating 4 |
| Vague and dim | Rating 5 |
| So vague and dim as to be hardly discernible | Rating 6 |
| No image present at all, you only 'know' that you are thinking of the object | Rating 7 |

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Think of each of the following sensations, considering carefully the image which comes before your mind, and classify the images suggested as indicated by the degrees of clearness and vividness specified on the Rating Scale.

| Item | Rating |
|---|---|
| 31. Fatigue | ( ) |
| 32. Hunger | ( ) |
| 33. A sore throat | ( ) |
| 34. Drowsiness | ( ) |
| 35. Repletion as from a very full meal | ( ) |

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Rating Scale

The image aroused by an item of this test may be:

| | |
|---|---|
| Perfectly clear and as vivid as the actual experience | Rating 1 |
| Very clear and comparable in vividness to the actual experience | Rating 2 |
| Moderately clear and vivid | Rating 3 |
| Not clear or vivid, but recognizable | Rating 4 |
| Vague and dim | Rating 5 |
| So vague and dim as to be hardly discernible | Rating 6 |
| No image present at all, you only 'know' that you are thinking of the object | Rating 7 |

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