DOCUMENT RESUME

ED 228 271 TM 830 120

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TITLE Cognitive Processes Functional in Spatial Recall.
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SPONS AGENCY National Inst. of Education (ED), Washington, DC.
REPORT NO CSE-R-193
PUB DATE 82
NOTE 25p.
PUB TYPE Reports - Research/Technical (143)

EDRS PRICE MF01/PC01 Plus Postage.
DESCRIPTORS *Cognitive Processes; *Concept Formation; Higher Education; Map Skills; Pictorial Stimuli; *Recall (Psychology); Secondary Education; *Spatial Ability; Verbal Ability
IDENTIFIERS *Field Dependence Independence; *Figural Creativity; Learning Strategies

ABSTRACT

Little is known about the precise nature of the processing, storage, and recall strategies functional in spatial recall. High school and college samples completed tasks in field-dependence-independence, figural creativity, and verbal abilities. Spatial recall ability was assessed through a map reconstruction task in which subjects were required to accurately reproduce the spatial location of features they recalled from a learned map stimulus. Results showed that field-dependence-independence and figural creativity were significant determinants of spatial recall for both samples. Verbal ability was a significant factor only for the less verbal, more heterogeneous high school sample. The data support a model of cognitive processing in which effective recall of spatial attributes is dictated by subjects' abilities to treat spatial arrays as part-whole relations: Individual entities must be considered as separable from the whole map context. The results are discussed in conjunction with accepted theories of human memory and spatial cognition. (Author)

COGNITIVE PROCESSES FUNCTIONAL IN SPATIAL RECALL

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CSE Report No. 193
1982

CENTER FOR THE STUDY OF EVALUATION
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The project presented or reported herein was performed pursuant to a grant from the National Institute of Education Department of Education. However, the opinions expressed herein do not necessarily reflect the position or policy of the National Institute of Education, and no official endorsement by the National Institute of Education should be inferred.

TABLE OF CONTENTS

Cognitive Processes Funtional in Spatial Recall

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Abstract

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Cognitive Processes Functional in Spatial Recall

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INTRODUCTION

Research since the early 1970's has successfully established and defended the existence of imagery as a construct in long-term memory. Work by Kosslyn (1973, 1976; Kosslyn & Pomerantz, 1977) and Kulhavy (Kulhavy & Schwartz, 1980; Kulhavy, Schwartz, & Shaha, Note 1), which was based on the fundamental theories of Paivio (1971, 1975), has led to detailed descriptions of mental imagery as it applies to spatial recall abilities. Internal images have been shown to be highly isomorphic with or nearly identical to the external stimuli they represent, especially for the purpose of storing spatial information.

Although the nature of the storage format for spatial information has been well investigated, little experimentation has been aimed at describing the cognitive processes which are functional in the encoding and recall of spatial knowledge (Shaha, Note 2). The major purpose of this research is to provide evidence which will aid in developing a broader theoretical description of human spatial abilities by providing evidence of correlated cognitive processes. The studies included herein cover only three of the many possible cognitive variables which might be related to spatial recall capabilities (See Shaha & Wittrock, Note 3).

Field-Dependence-Independence

Witkin, Moore, Goodenough, and Cox (1977) explained that individuals differ in their ability to separate items or patterns from the context in which they are presented. This ability, called "field-dependence-independence," may be related to the capacity to recall map feature locations. Common tools for assessing the field-dependent-independent construct include the Imbedded Figures Test (Witkin, Moore, Goodenough, & Cox, 1977), or the Hidden Patterns Test (French, Ekstrom, & Price, 1963). These tasks require subjects to recognize patterns or figures which are hidden within an array of distracting lines. Subjects scoring high on such tasks are considered to be more able to treat arrays of objects as collections of individual entities (field-independent), while low scorers are <u>un</u>able to perceive parts or objects as being separable from the whole or field in which they are imbedded (field-dependent).

Mandler and Parker (1976) used complex pictures to test memory for spatial information. They found that when subjects encode pictorial arrays of objects which are conceptually disorganized, or not representative of a normal or natural order, the arrays are learned as part-whole relationships. Mental images are constructed by treating items from the arrays as individual entities or as members of small groups (cf., Mandler & Stein, 1977). Other studies have suggested that maps are also processed in a part-whole manner. Kulhavy, Schwartz, and Shaha found in separate studies that subjects can easily recall inter-item relations among neighboring features, but not among features spatially distant from each other either (Kulhavy, Schwartz, & Shaha, Note 1) or in terms of conceptual categorizability (Kulhavy, Schwartz, & Shaha, in press). Apparently, even though subjects store an intact image of map referents, the process by which the map information is learned and recalled is possibly based on some idiosyncratic partitioning of the features into logical spatial or conceptual sub-elements (Kulhavy, Schwartz, & Shaha, Note 1).

Figural Creativity

A second factor investigated in this study is "figural creativity." In recent research on locational recall of map features, Shaha (Note 4) found that there is a significant positive correlation between location recall accuracy and the amount of artistic embellishment subjects perform on features drawn during map recall exercises (cf., Kulhavy, Schwartz, & Shaha, in press; Shaha, Note 2; Shaha, Note 5). In these studies, the more details a subject added to features in a map reconstruction task the greater was the probability that the feature was correctly placed, despite any presence or lack of true "artistic" ability.

Torrance (1975) designed an instrument for measuring and quantifying the degree to which subjects add unnecessary details to drawings they create from simple line patterns. Entitled "figural creativity," this tendency to enhance drawings may be associated with processes which determine spatial recall abilities.

Verbal Ability

Verbal ability or aptitude is considered to be a latent cognitive trait which is closely associated with most other intellectual functions

(Shaha & Wittrock, Note 3). Standardized tests which include both verbal and spatial/figural tasks consistently reveal significant correlations between the two domains (i.e., Wechsler, 1974; French, Ekstrom, & Price, 1963). Almost counter-intuitively, however, research in spatial recall with maps has failed to uncover a significant correlation between spatial and verbal abilities (e.g., Kulhavy & Schwartz, 1980; Thorndyke & Statz, 1980).

The two studies reported here represent analogous experiments applied to different samples. Based on a review of previous research in map learning and spatial recall (Shaha, Note 4), it was concluded that over-reliance on college undergraduate samples in past studies may have yielded misleading results. This suspicion was especially strong due to the absence of significant correlations between verbal and spatial skills. Therefore, one study employed college students, while a second study utilized a contrasting high school sample.

METHOD

Subjects and Design

Sixty-four juniors and seniors from West Los Angeles area high schools, and 68 college undergraduates taking introductory courses in Sociology at UCLA, participated as volunteer subjects in their regular classroom groups.

Materials and Instruments

All subjects completed tests of verbal ability, figural creativity and field-dependence-independence. Verbal ability was measured with 30 multiple-choice items randomly selected from the 1980 ACT (American College Testing) preparatory manual. This fabricated test was entitled the Verbal Ability Test.

Field-dependence-independence was assessed with an abbreviated form of the Hidden Patterns Test (French, Ekstrom, & Price, 1963). Test-retest reliability for the complete test was .83 for high school samples and .82 for the college samples. The Hidden Patterns Test consisted of 190 small designs which subjects identified as either containing or not containing a given imbedded figure.

Figural creativity was measured with the Figural portion of the Torrance Test of Creative Thinking (Torrance, 1975). Test-retest reliability estimates for the Figural test were .93 and .91 for the high school and college samples, respectively. The Figural Creativity task required subjects to entitle and add details to drawings they created from simple line figures provided.

Experimental Task

The experimental task required subjects to study a map and to reconstruct the map learned from memory by correctly placing all features they could recall. The map used consisted of 20 features common to maps which were randomly spread on a 14½ inch (36 cm) square sheet of paper avoiding any obvious placement patterns. Features consisted of a drawing, which measured approximately ½ to 1 inch (1.2 to 2.4 cm) square, accompanied by a block lettered label placed beneath.

All experimental materials were presented to subjects in separate booklets, one for each task. Each booklet was covered with a green sheet of paper to avoid previewing, followed by an instruction sheet. All materials were reproduced by photocopying.

Procedures

Data for the high school and college samples were collected on two separate days, with the Verbal, Hidden Patterns, and Figural Creativity tests on the first day, and the experimental task on the second. Prior to each test or task the experimenter read the instructions aloud while subjects read along silently. After answering all procedural questions, subjects were told to begin work on the appropriate task. Subjects were always reminded that they had limited time available for task completion. The time limits enforced were as follows: Verbal Ability=five minutes; Hidden Patterns=10 minutes; Figural Creativity=15 minutes. Verbal Ability protocols were scored for number of correct responses. Hidden Pattern protocols were scored for number of correct pattern recognitions minus the number of incorrect choices. Figural Creativity protocols were scored according to the guidelines in the Torrance Test of Creative Thinking manual (1975), which involved awarding points for each detail added to a drawing, with no upper limit.

The experimental task involved an encoding and a recall phase. Subjects were instructed to study the map that they would be given, and were told that they would be tested for their memory of the map. No mention was made of the actual nature of the recall task, and every effort was made to conceal the recall task sheets in order to avoid prompting the subjects. Subjects were given five minutes to study the map, and map stimulus booklets were collected at the end of the study period.

Prior to the recall task, subjects spent one minute calculating complex multiplication problems. The mathematics exercise served as an interpolated task in order to preclude recall of map information from short-term memory.

For the recall task, subjects were told to draw and label all of the features that they could recall from the map they had studied on a blank sheet of paper identical in dimension to the stimulus map. Special emphasis was placed on the need to accurately place every feature recalled. Unlimited time was allowed for completion of the map reconstruction task. Reconstructions were scored for number of features correctly placed by using transparent templates of the stimulus superimposed on the protocols. Any feature placed within one inch of the center of the corresponding feature on the template was scored as correctly located.

RESULTS

Preliminary analyses revealed a substantial advantage in favor of the college subjects for recalling numbers of features from the map. Any analyses of spatial recall ability based on comparing <u>numbers</u> of features properly located would, therefore, be biased in the direction of a college sample -- subjects recalling more features simply have a higher probability of locating more (Kulhavy, Schwartz, & Shaha, in press). In order to compensate for the effects of differential verbal recall, spatial recall accuracy was calculated as the <u>proportion</u> of features correctly located of those recalled.

Table 1 shows the means and standard deviations for both high school and college samples for all tasks. Although college means were higher for all variables measured, *t*-tests revealed significant differences only for Verbal Ability ($t=2.11$, $p<.05$).

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Insert Tables 1 & 2 here

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Table 2 presents the intercorrelation matrices for all variables for each sample. Inspection of the high school matrix shows that only Verbal Ability and Hidden Patterns ($p<.05$) failed to correlate significantly at the $p<.01$ level. The college sample matrix, on the other hand, showed lower correlations for Verbal Ability with all other factors, with only Hidden Patterns producing a significant correlation with the Verbal variable.

To determine which of the measured variables constituted the best predictors of spatial recall, a forward stepwise multiple regression analysis was performed for the high school and college samples. The results of the regressions are presented in Table 3.

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Insert Table 3 here

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Results of the regression analyses revealed that all three variables significantly predicted spatial recall for the high school students. The order of entry for the variables was as follows: (1) Figural Creativity, (2) Hidden Patterns Test, (3) Verbal Ability. The three variables together accounted for 31% of the total variation in spatial recall accuracy.

For the college sample, however, Verbal Ability was not a significant contributor to the regression solution (R^2 change <.01), and so it never entered. The order for the stepwise regression entries was as follows: (1) Hidden Patterns Test, (2) Figural Creativity. The two significant factors together accounted for 24% of the variation in spatial recall accuracy.

DISCUSSION

This study revealed two major findings. First, Verbal Ability scores were a significant predictor of spatial recall for the high school sample. Inspection of the means and standard deviations in Table 1 reveals that the college sample was a more homogeneous group and scored higher on the average than the high school sample. Suspicions that over-reliance on college undergraduates may have been responsible for past failures to uncover significant verbal/spatial relationships appear to have been well founded. The significant positive correlation between verbal and spatial scores in the more heterogeneous high school sample indicates that less verbal students have lower spatial recall.

A second important finding was the relationships between spatial recall and both field-dependence-independence and Figural Creativity scores. Field-independent subjects were better able than field-dependent students to remember spatial information and accurately place map features that they recalled during the reconstruction task. Based on the fundamental theories of field-dependence-independence (Witkin, Moore, Goodenough, & Cox, 1977), results in the present studies indicate that subjects recall map features as discrete entities or small groups from within the total map context or field. Reconstruction of a spatial array is achieved by successive recall of map microstructures from within the macrostructure of the stored map image. Field-dependent subjects who cannot separate out the discrete features from within the map context in which they are presented are less capable of reconstructing the spatial array accurately. Field-independent subjects, on the other hand, find the task easier to complete. This conclusion supports Mandler and Parker's (1976) findings concerning part-whole processing strategies.

Figural Creativity performance results also tend to support the conclusion that spatial recall is dependent upon part-whole strategies. When subjects were careful to enhance or embellish individual feature drawings, they appeared to be reflecting a tendency to treat features as individual entities, employing a cognitive treatment of the items as being separable from the whole map. Also, visual inspection of both map recall and creativity protocols reaffirmed prior research findings that real "artistic" ability is not the relevant factor in Figural Creativity or spatial recall (Shaha, Note 3).

Taken as a whole, the Figural Creativity and Hidden Pattern tasks results support a theory of cognitive treatment of spatial information wherein spatial arrays are recalled as collections of discrete features or groups of features from within the map context. Studies verifying the relationship between field-dependence-independence and spatial recall using alternate strategies may be warranted to further support this finding. Rod-and-frame tests or other Imbedded Figure or Hidden Pattern tasks would be appropriate techniques (Witkin, Moore, Goodenough, & Cox, 1977).

It is important to note here that these results do not contradict findings by past researchers concerning spatial information processing strategies. Paivio (1971) explained that map-like spatial information, unlike prose, is processed in parallel, not sequentially. In other words, one reads prose and encodes the information sequentially as it is encountered, whereas information in a map or a picture is seen and encoded simultaneously or in parallel (cf., Navon, 1977; Paivio, 1975; Shaha, Note 4; Shepard & Chipman, 1970).

The results of this study do, however, support the proposition that field-independent people are most probably better at processing pictorially-presented information accurately due to their ability to treat each object in the array as a discrete entity. This applies not only to maps, but also to complex pictures or dot arrays. (Halpern, Fishbein, & Warm, 1979; Sekular & Abrams, 1968).

Another implication in this study applies to map-dependent institutions. Agencies which depend on efficient map learning and recall abilities in personnel, such as the military, or geographic and cartographically-oriented institutions, would be well advised to study the potential use of field-dependence-independence assessment techniques for screening or remedial decisions. Such a strategy could identify personnel with field-dependent deficits which will make spatial learning more difficult and less efficient. Based on this diagnosis, personnel could be referred for remedial training or channelled into alternate jobs where their dependence on spatial recall abilities would be reduced. Certainly the military could benefit from such an assessment strategy.

Perhaps the most important purpose and implication of these studies is to draw the attention of researchers to the need for investigating the cognitive processes which underlie spatial abilities. Investigating or treating only symptoms of deficiencies in learning or recall abilities cannot lead to sound theory or effective treatment strategies (Shaha & Wittrock, Note 2). These studies constitute only an initial, incomplete effort toward seeking out the underlying causes of spatial recall differences in humans.

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Table 1

Means and Standard Deviations for Both Samples

for All Tests and The Experimental Task

	Field-Dependence-Independence		Figural Creativity		Verbal Ability		Spatial Recall	
	Mean	SD	Mean	SD	Mean		Mean	SD
High School	83.32	32.59	74.59	19.23	16.04	8.21	.39	.18
College	118.29	24.93	87.21	23.36	24.53*	4.06	.63	.16

*p<.05

Table 2

Intercorrelation Matrices For Both Samples For All Tests and Tasks

	High School (n=64)				College (n=68)			
	Field-Dependence-Independence	Figural Creativity	Verbal Ability	Spatial Recall	Field-Dependence-Independence	Figural Creativity	Verbal Ability	Spatial Recall
Field-Dependence-Independence		.44**	.29*	.38**		.38**	.26*	.43**
Figural Creativity			.36**	.46**			.22	.37**
Verbal Ability				.42**				.13

*p<.05

**p<.01

Table 3

Forward Stepwise Regression Analyses For Both Samples For All Tests and The Experimental Task

	Individual Variables					Total Solution		
	Variables	b	SE b	t	Significance	R^2	F	Significance
High School Sample	Figural Creativity	.2805	.1076	2.608	.01	.308	11.8697	.0001
	Field-Dependence-Independence	.2355	.1049	2.245	.03			
	Verbal Ability	.2107	.1009	2.089	.04			
College Sample	Field-Dependence-Independence	.3382	.1051	3.219	.002	.235	12.4265	.0001
	Figural Creativity	.2415	.1051	2.298	.02			