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Encoding and complex figure recall

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Abstract

This study investigated the effects of type of encoding strategy (organized and disorganized) and of active *versus* passive encoding on memory for interrelated spatial material. Delayed recall performance for a complex, nonrepresentational two dimensional figure was measured in 120 normal young adults assigned to one of three groups that varied as to the approach used during the initial construction of the figure. Those applying self-generated strategies performed best. In addition, recall performances were significantly better for those applying a prescribed, organized strategy as compared with performances of those applying a prescribed, disorganized strategy. These effects were not attributable to differences on measures of IQ or spatial information processing. The findings indicated that, independent of memory ability, both the degree of organization and of active strategizing at encoding are determinants of recall ability for complex spatial information and suggest that these factors have implications for memory processes more generally. (*JINS*, 2001, *7*, 728–733.)

Keywords: Spatial memory, Organization, Encoding, Recall

INTRODUCTION

Reproduction and delayed recall of two-dimensional abstract designs are tasks commonly used to assess visual-spatial information processing, in particular constructional ability and spatial memory. Such tasks typically employ designs such as the Rey-Osterrieth Figure (Osterrieth, 1944; Rey, 1942), the Taylor Figure (Taylor, 1969), and the Visual Design (Mack et al., 1993; Seltzer & Mack, 1981) as stimulus materials. These designs consist of nonrepresentational configurations containing numerous elements. They are novel and resistant to verbal encoding to the extent that they contain complex, interrelated spatial components with few common geometric forms.

Rey (1942) initially observed that individuals used different approaches in design reproduction in terms of the order in which the elements were drawn. Subsequently, in the application of various scoring systems, investigators have referred to the level of organization evident in the approach to design copying (Eslinger & Grattan, 1990; Hamby et al., 1993; Janowsky & Thomas-Thrapp, 1993; Sullivan et al., 1992) or have used terms such as contextual (framework-focused) and featural (detail-focused) to indicate, respectively, organized and disorganized approaches (Heinrichs & Bury, 1991). The common factor in the scoring systems exemplifying these constructs can be characterized as the application of the gestalt principles of symmetry and good continuation. The reproduction of symmetrical components are scored more highly when completed successively as opposed to when drawn discontinuously or as discrete subcomponents. Likewise, application of the good continuation principle implies that better performance involves reproducing a straight line from beginning to end as opposed to reproduction of a number of discontinuous line segments.

In clinical studies using scoring systems based on these principles, it has been observed that those patients whose cognitive deficits are associated with disorganized strategies (as defined by poor symmetry and discontinuity) during initial construction of a complex design have difficulty producing accurate reproductions at delay (Bennett-Levy, 1984; Binder, 1982; Hamby et al., 1993; Heinrichs & Bury, 1991; Shorr et al., 1992; Sullivan et al., 1992). However, because the participants in these studies were cognitively impaired, the relationship between strategy and recall performance is not clear. A single lesion may affect several functions including spatial memory (Benton, 1984; Butters et al., 1970; Farah et al., 1989), and lesions in the parietal lobe have been associated with deficits of visual–spatial

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perception, construction, and memory. Deficits producing poor copy strategy also may affect spatial memory independently of the poor strategy, and executive planning deficits have been shown to affect spatial constructional performance in the absence of spatial perceptual or orientation impairments (Krikorian, 1995; Krzton et al., 1998).

Presumably, complexity in the structure of such designs creates demands on planning and organization abilities during the execution of the figure copy and in the encoding and retrieval processes involved in learning and subsequent recall. The principles of symmetry and good continuation are operationalized in terms of the sequence in which the elements and subcomponents of elements of the design are drawn. From this point of view, the use of an organized strategy at copy may produce a less demanding task at recall because information has been encoded in a more efficient and more accessible manner. To that extent, the level of gestalt organization expressed in the copying strategy reflects the degree of encoding efficiency, and this may be one factor pertinent to recall performance.

Another potentially independent factor might involve the degree of active engagement of executive processes at time of encoding. For example, in verbal paired associate learning experiments, participants who generated their own paired responses to given cue words during learning trials performed better at recall than those provided with both cue and response words (Scheft & Biederman, 1990; Schefft et al., 1997). Furthermore, it has been shown that nonimpaired middle-aged participants are as capable of producing effective strategies as young adults on explicit working memory tasks, although they are not as effective at actively utilizing such strategies (Daigneault & Braun, 1993). Older participants exhibit poorer memory performances that are not attributable to deficiencies of encoding, retrieval, storage, or interference effects. These data suggest that self-generation, or more specifically, active application of encoding strategy, is a determining factor in memory performance independent of the nature of the strategy applied.

The current study investigated the effects of organizational strategy and of active processing at time of encoding on recall of interrelated spatial information in a nonclinical sample. The use of normal young adults provided substantial assurance that other cognitive factors that might affect executive function, visual–spatial information processing, or memory were minimized and allowed attribution of effects to the experimental manipulation. We predicted that self-generating copy strategy would result in enhanced recall relative to either of two passive conditions in which copy strategy was prescribed. We also predicted that dictating an organized copy strategy based on the principles of gestalt processing—good continuation and symmetry—would lead to greater recall accuracy than dictating a disorganized copy strategy. While the findings would provide pertinent information concerning the role of executive function in recall of complex spatial information, they also might be expected to have more general implications for memory encoding and retrieval processes and cognitive rehabilitation.

METHODS

Research Participants

One-hundred-twenty undergraduate volunteers (58 men and 62 women) were recruited from the University of Cincinnati. Each student reviewed and signed an informed consent document when enrolled and received course credit as compensation for participating in the study. Each participant was evaluated individually in offices at the university.

Procedure

The participants were assigned consecutively to one of three groups that varied as to the method used to administer the design-copying task. Aside from this manipulation, the procedure was identical for all three groups. In two of the groups, the strategy employed in design construction was controlled. An organized strategy conforming to the rules of symmetry and good continuation was prescribed in the organized dictated (Org) group, and a disorganized strategy was prescribed in the disorganized dictated (Dis) group. In the self-generation (SG) group, no such instruction was provided and participants were free to apply approaches that they devised on their own. It was presumed that the nature of the task would potentiate active executive processing for participants in the self-generation group relative to those in the two groups that were prescribed strategies. For participants in the prescribed strategy groups, the task demands would tend to diminish active, self-generated approaches.

Copy and delayed recall performances of the Visual Design (Seltzer & Mack, 1981) were obtained from each participant. The Visual Design (Figure 1) is similar to the Rey and Taylor figures, although it is symmetrical with respect to the number of elements to the right and left of midline and contains fewer elements amenable to verbal encoding. The participants were not informed at the time of the initial construction that delayed recall of the design would be obtained. This conformed to the standard clinical administration for this task. In addition, the absence of this information would tend to mitigate the inclination to generate idiosyn-

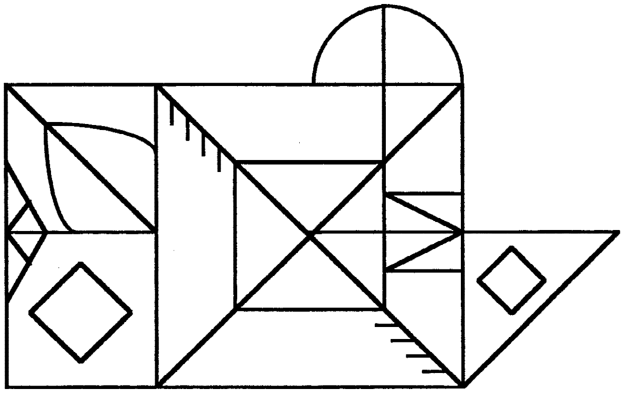

Fig. 1. The Visual Design.

cratic strategic approaches to the copy task that might confound the prescribed strategies and, thereby, subvert the experimental manipulation.

The organized and disorganized copy strategies were prescribed by presenting eleven successive line drawings containing elements of the figure (see Figure 2). The first drawing contained one component of the design, and each successive drawing incorporated an additional component, highlighted in color, along with those elements presented previously. The sequence of elements used in the disorganized strategy was derived from examination of a large number of protocols from cognitively impaired patients whose reproductions exhibited asymmetry and discontinuity in approach. The patient protocols used for this purpose were obtained from a neuropsychological consultation program that served patients with developmental cognitive disorders, severe psychiatric conditions, and acquired brain disorders such as head trauma and dementia. The participants produced, on a single sheet of paper, one completed reproduction of the design in incremental fashion as each prescribed component was successively revealed. The participants in the self-generation group were exposed to the entire design and asked to copy it without further instruction. The examiner produced a schematic rendering of the participant's production that indicated the order in which each segment of the design was drawn. This information was used for strategy scoring purposes.

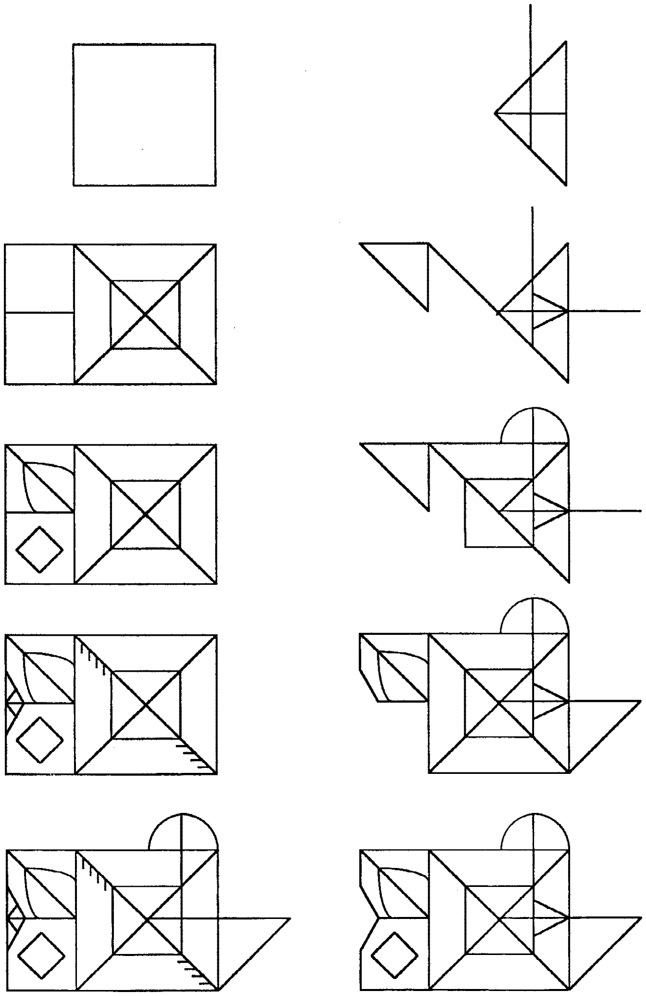

Fig. 2. Sequence of stimuli presented to the organized group (Org), left column, and the disorganized group (Dis), right column. In each column, representations of every second stimulus from sequences of 11 stimuli are shown.

Delayed recall of the Visual Design was obtained approximately 45 min after completion of the copy. Other cognitive tasks were administered during the interval, although none of the intervening tasks involved visual–spatial information processing in order to avoid the possibility of interference effects. These tasks included verbal attention and memory measures and a verbal IQ estimate.

The scoring system for reproduction accuracy for the Visual Design drawing is based on 17 scoring units. Up to two points are given for each unit depending on the degree of distortion and the placement of the unit relative to other components of the design. The maximum total score is 34 (Mack et al., 1993). Accuracy scores were derived for both the figure copy and recall. In addition, a strategy score that quantified organizational level was adapted from a perceptual cluster scoring system developed initially for use with the Rey-Osterrieth figure (Shorr et al., 1992). Under this system, one point was given for each connected element drawn either continuously or contiguously. This strategy score was computed for the figure copy and recall. Because copy strategy was controlled in the organized and disorganized groups, these scores were invariant for participants in each of those groups. The prescribed strategy for the organized group produced the maximum score (28) for all participants in that group, while the copy strategy score for members of the disorganized group was 12.

In addition to the Visual Design, a number of other cognitive measures were administered in order to evaluate aspects of spatial information processing ability and overall intellectual capacity independently. These included the Block Design subtest of the Wechsler Adult Intelligence Scale–Revised (Wechsler, 1981) to assess visual-spatial constructional ability, the Corsi Block Tapping task (Milner, 1971), a measure of spatial attention, and the Spatial Paired Associate Learning task (Krikorian, 1996), a nonverbal parallel of verbal paired associate learning tasks, as a measure of spatial memory. The Peabody Picture Vocabulary Test–Revised (Dunn & Dunn, 1981) was administered as an estimate of IQ. The spatial tasks were administered after the delayed recall of the design was obtained.

RESULTS

Table 1 contains summary demographic and cognitive performance data for each group. As expected, there was little variability in age and educational level for this undergraduate sample. The representation of males and females within each group was substantial, although the gender proportions were not equivalent except in the organized group.

Table 1. Demographic information and cognitive performance by group

	Group				
Variable	Org (*n* = 40)	Dis (*n* = 42)	SG (*n* = 38)	*F*	*p*
Age (years)	20.4 (2.8)	19.8 (1.8)	19.5 (1.5)	1.99	.14
Education (years)	12.8 (1.0)	12.8 (.94)	12.6 (.80)	.59	.55
Gender (M:F)	20:20	16:26	22:16	—	—
IQ estimate (PPVTR)	100.3 (17)	101.7 (12)	99.7 (13)	.20	.82
Spatial attention (CB)	29.2 (4.0)	28.6 (4.0)	30.2 (4.7)	2.5	.09
Spatial construction (BD)	11.6 (2.9)	11.1 (2.9)	11.8 (2.8)	.54	.58
Spatial memory (S-PAL)	13.9 (4.6)	13.7 (3.1)	13.5 (3.7)	.12	.89

Note. Data is reported as mean (*SD*). Gender is represented as male:female proportions. Org = group prescribed the organized figure copy strategy, Dis = group prescribed the disorganized figure copy strategy, SG = self generation group given no strategy for figure copy task. PPVTR = Peabody Picture Vocabulary Test-Revised, CB = Corsi Block Tapping task, BD = Block Design subtest from WAIS–R, Spatial PAL = Spatial Paired Associate Learning task. All *F* values have *df* = 2,117.

The participants were of average range overall intellectual ability, and there was no between group difference in IQ estimate as indicated by ANOVA (see Table 1). In addition, there was no group difference for any aspect of spatial information processing, as univariate analyses for measures of spatial attention, spatial construction, and spatial memory indicated equivalent performances in all groups.

The measures of Visual Design copy and recall performance are presented in Table 2. As shown, the degree of organization as quantified by the copy strategy score was much lower in the Dis group relative to the Org and SG groups. The mean strategy score for the SG group was slightly less than that of the Org group, and the range of strategy scores in the former (15–29) indicated that there was no overlap with the scores in the Dis group.

All three groups achieved mean figure copy accuracy scores of between 80% and 90% of the maximum possible score of 34 (Table 2). However, there was a significant difference between the groups for copy accuracy [$F(2,117) = 8.88$, $p < .0001$], and *post-hoc* Tukey comparisons confirmed that this difference was due to the relatively diminished reproduction accuracy of the disorganized group relative to the other two groups ($p < .05$). The effect sizes for the copy accuracy differences between the organized and disorganized and between the self-generation and disorganized groups were .71 and .77, respectively.

To control for this difference in copy accuracy on recall performance, the recall score was divided by the copy score to obtain a percent or ratio recall that was thought to be an unbiased measure of recall accuracy. The recall percentage score was used to test the primary predictions regarding differences between the disorganized and organized groups and between the organized and self-generation groups. Preplanned comparisons indicated that the organized group achieved a significantly higher ratio score than the disorganized group [$t(80) = 7.9$, $p < .05$]. The effect size was very large, $d' = 1.75$. In addition, the self-generation group achieved a significantly higher ratio score than both the organized group [$t(76) = 2.2$, $p < .05$, $d' = .49$], and the disorganized group [$t(78) = 10.14$, $p < .0001$, $d' = 2.28$].

As an ancillary analysis, we examined the possibility of gender effects on design reproduction strategy at recall. A Group × Gender ANOVA was performed and failed to show either a main effect for gender [$F(1,114) = 1.92$, $p < .18$] or a Gender × Group interaction [$F(2,114) = .31$, $p < .74$].

Table 2. Visual Design copy and recall performance

	Group		
Test performance	Org (*n* = 40)	Dis (*n* = 42)	SG (*n* = 38)
Copy accuracy	29.6 (3.1)	27.4 (3.3)	29.8 (2.4)
Copy strategy	^{a}28.0 (0.0)	^{a}12.0 (0.0)	26.2 (2.7)
Recall accuracy	18.8 (5.1)	10.5 (4.0)	21.22 (5.2)
Recall strategy	23.4 (3.5)	6.9 (2.8)	23.0 (5.7)
Recall accuracy ratio	.63 (0.2)	.39 (0.1)	.71 (0.2)

Note. Data is mean (*SD*) performance. [a]Strategy scores for these groups were invariate. Org = group prescribed the organized figure copy strategy, Dis = group prescribed the disorganized figure copy strategy, SG = self generation group given no strategy for figure copy task.

DISCUSSION

The purpose of this study was to evaluate the effects of level of organization and of active executive processing during encoding on recall for interrelated spatial information. The experimental manipulations produced several effects supporting the predictions. As expected, participants prescribed the disorganized strategy when copying the figure recalled substantially fewer elements after the delay period as compared with those prescribed the organized approach. This finding corroborated the prediction that an organized gestalt approach at time of encoding would produce greater delayed recall accuracy than a segmented (disorganized) approach.

In addition, the self-generation group demonstrated greater recall accuracy than both the organized and disorganized groups. The equivalence of the groups on measures of visual-spatial construction, spatial attention and memory, and IQ supports the notion that the findings are attributable to differences in copy strategy and level of active processing rather than to other potentially confounding cognitive factors.

The superior performance of the self-generation group relative to the organized group was particularly notable, given that the level of organization as measured by the strategy score for figure copy was not greater for the SG group (Table 2). Apparently, despite utilizing equivalently organized approaches during the copy task, the demand for greater effort in active executive processing among participants in the self-generation group enhanced recall accuracy. This suggests that both level of organization and degree of active strategizing during encoding were factors in their superior recall performance, presumably a function of improved retrieval accessibility of the structure of the figure associated with those factors.

Such a finding is consistent with the concept of self-generation as described in the Kanfer and Schefft (1988) model with respect to learning novel semantic associates. The self-generation effect observed here demonstrates the importance of this factor for learning and retention of interrelated spatial information as well. As noted, non-impaired, late middle-aged individuals show diminished ability to engage in active application of strategies as compared with young adults, even when the former are capable of producing such strategies (Daigneault & Braun, 1993). One might infer that the effect of active encoding reflects processing essential to establishing internal mental structure and that for the participants in the self-generation group this factor contributed to the creation of a subjective cognitive structure for the spatial configuration. This concept was introduced by Mandler (1967) who observed that actively organizing to-be-learned material increased recall. As observed in our sample, although participants in the organized group passively applied copy strategies equivalent to those produced in the self-generation group, their recall accuracy was relatively diminished. More generally, it might be asserted that active encoding processes are an essential determinant of learning and recall, particularly for complex, interrelated material for which generation of cognitive structure is fundamental. It is of interest to note that self-guided practice also has been shown to produce enhanced learning of complex motor skills (Wulf & Toole, 1999), suggesting that active executive processes may contribute to learning complex material and procedures, both cognitive and noncognitive. The implication of such findings for rehabilitation would appear to be that training individuals with executive function impairments to use organized approaches should enhance memory performance, although not to the same degree that self-guided production and execution might. Applying the manipulation used in this experiment with cognitively impaired, brain-injured participants should provide information regarding the degree to which prescribed strategies, as opposed to autonomously generated strategies, would enhance memory functioning.

The experimental manipulation did entail certain inequalities between the self-generation group on the one hand and the organized and disorganized groups on the other. Because the two groups that were prescribed strategic approaches were presented with sequences of several incomplete figures, it is possible that interference contributed to the diminished recall they demonstrated. However, this possibility would seem to be remote. Each of the incomplete figures was a cumulative representation that contained a new element nested in the previously presented configuration. Accordingly, an incrementally increasing gestalt was presented, and there was no inconsistency between the partial figures or distortion of elements. Another inequality between the self-generated and prescribed strategy groups was time of exposure to the design. Because of the nature of the experimental manipulation, the prescribed strategy groups had greater exposure time to the individual components of the design, while the self-generation group had greater exposure to the complete figure. It is conceivable that this factor caused greater attention to the featural elements for the prescribed groups and greater attention to the overall gestalt for the self-generation group, thereby promoting enhanced gestalt processing for members of the latter. Although this possibility is not supported by the equivalence of recall strategy scores for the organized and self-generation group, it remains a consideration and a factor that might be controlled in future investigations.

The study design did not entail a direct assessment of the degree of active processing at encoding, although the manipulation was designed to elicit and isolate this factor in the comparison of performances between the organized and self-generation groups. Both of these groups demonstrated organized approaches, although in the former this was dictated while in the latter subjects derived strategies on autonomously. Furthermore, it is conceivable that other factors such as motivation may have contributed to the superior performance of the SG group. Indeed, it has been shown that enhanced effort, positive emotional valence, and a greater sense of control are associated with self-regulated tasks (Kanfer & Schefft, 1988). These factors may have contributed to our findings. On the other hand, it might be presumed that such factors would be intrinsic to or secondary to active problem solving of the type elicited in this study. Nonetheless, this issue is amenable to evaluation in future studies in which, for example, emotional valence would be assessed in the context of differential demands for autonomous memory encoding. In addition, while this study did not examine the effects of levels of disorganization on figure recall, this issue might be investigated to determine whether the degree of organization in copy strategy is systematically related to a gradient of recall performance. Furthermore, our sample included healthy young adults. While this provided substantial assurance concerning the integrity of pertinent cognitive functions, it does represent a limitation with respect to the applicability of the results to other age groups, in particular older adults. If the current manipulation were applied to healthy adults of different ages, one might expect differential findings, and, perhaps, interaction effects, especially given the apparent age-related decline in active executive processing (Daigneault & Braun, 1993).

Complex figure tasks typically have been used to measure nonverbal memory. This study provides evidence that poor copy strategy can lead to poor recall independent of spatial information processing and memory abilities. The findings underscore the importance of examining encoding strategy in relationship to recall performance as well as other measures of executive ability. Furthermore, the results imply that specific encoding factors associated with executive processes may be fundamental to learning and memory in general.

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