Contextual Influences of Maps and Diagrams on Learning[1]

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Abstract:
In this study, we examined the influence of graphic patterns and their interpretive context on learning accompanying prose. Subjects examined a graphic figure identified as either a map or a diagram and were instructed either to label its vertices with 12 keywords provided or to simply list them below the figure. Groups practiced performing their specific task from memory and given corrective feedback whereupon the entire procedure was repeated. Subjects then heard a narrated story with a different keyword named every third sentence. Order of appearance by the keywords was either similar to or different than that suggested by the display studied. Memory for both story information and the keywords themselves was tested using constructed response questions and a serial recall task, respectively. Subjects were also asked to rate the usefulness of experimental materials and procedures for learning keywords and story content. Results suggest maps, unlike diagrams, are sequentially encoded and that abstract graphic displays can adopt map-like characteristics as a result of the context in which they are presented. Experimental outcomes are discussed in terms of interpretive frameworks and prior knowledge.

Article:
Since the advent of the idea that verbal and visual information are mentally processed through separate channels (Paivio, 1971, 1986), there has been a renaissance in research on how graphic displays can be used to increase learning of related prose material that is either listened to (Abel & Kulhavy, 1986; Mastropieri & Peters, 1987) or read (Amlund, Gaffney, & Kulhavy, 1985; Dean & Enemoh, 1983; Royer & Cable, 1976). Maps and diagrams are two types of displays that have received particular attention by researchers eager to identify ways for heightening this effect by altering their graphic characteristics. Indeed, though there is a considerable body of research on the effect of color, shape, size, and other coding mechanisms on different tasks involving graphic displays, until recently surprisingly little has dealt specifically with maps (Robinson & Petchenik, 1976) or diagrams.

Much of this research typically has examined maps and diagrams from the standpoint of differences in their surface features; that is, how the depiction and arrangement of their particular graphic elements such as labels, symbols, and icons affects how the displays are encoded as a whole. Further, some investigators have attempted to consolidate such findings by subsuming them under a symbol systems approach to understanding how people learn from graphic displays (Kozma, 1991; Salomon, 1994; Winn, 1991). For example, there may be little difference between how maps and diagrams are mentally processed when analyzed in terms of their symbolic elements and the rules for arranging them (Winn, 1991).

In contrast to this research effort, there has been far less interest shown on how the prior knowledge surrounding the use of a given type of display influences the context for interpreting the information it contains

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and guides how such information is processed. This is the focus of the research reported herein. Physical similarities between maps and diagrams notwithstanding, there are commonsense distinctions between the two arising from the capabilities and conventions of each that have been learned through a lifetime of use. Hence, for Robinson and Petchenik (1976), a "map" is "a graphic representation of things in space" whereas a diagram is defined as "a graphic design that explains rather than represents" (Webster's New Collegiate Dictionary, 1972).

It is in this sense that, in the current study, we use the terms "diagram" and "map" (as opposed to, for instance, a "mental map"). Additionally, we have adopted the symbol systems concept employed by other researchers to examine how maps and diagrams differ in their contextual domains or "fields of reference" (Salomon, 1994) and how this influences the way each is encoded. In this paper we present a brief overview of symbol systems relative to graphic displays followed by discussion on the processing differences between maps and diagrams arising from differences in their respective domains. After a description of this study and its findings, we discuss implications for future research on maps, diagrams, and other visual displays as well.

MAPS AND DIAGRAMS AS SYMBOL SYSTEMS

In a symbol systems approach to analyzing of a communications medium such as a map, music score, or page of text, the symbolic elements and the rules for combining them (e.g., how, in the case of a map, features are spatially arranged) constitute a symbolic scheme. The overall symbol system, in turn, is the product of the interaction between this scheme and a corresponding field of reference, what Salomon (1994) respectively calls the "syntactic" and "semantic" aspects of the system. With the medium of text, for instance, letters and words (symbolic elements) and the spelling and grammatical conventions (symbolic rules) for arranging them, contribute to a scheme in which information is sequentially processed. Meanwhile, as associated field of reference (in the present example, literature) provides a context within which the scheme operates. It also provides meaningfulness to the symbol system (Salomon, 1994), a point we shall return to momentarily.

As mentioned earlier, most research to date on maps and diagrams has focused on the role played by their syntactic attributes in the belief that they influence both how such displays are mentally represented and how the information they deliver is mentally processed. Such studies have often employed experimental treatments that manipulated characteristics of their particular symbol systems. Generally speaking, two subclasses of experimental variables have emerged from these efforts: one related to alterations in how display components are depicted and the other with the implicit "rules" for their arrangement. These categories roughly correspond to what Winn (1991) respectively calls "discrimination" and "configuration" processes that occur in the preattentive stage of encoding of a graphic display. Examples of map and diagram research involving discriminatory factors include studies on the visual distinctiveness (Bellezza, 1986; Winn, 1991) and form of representation (e.g., iconic, linguistic, pictorial, etc.) of display components (Kulhavy & Schwartz, 1980; Winn, 1988; Winn & Sutherland, 1989). A good example of research in this area can be seen in several map studies conducted by Kulhavy and his colleagues (Abel & Kulhavy, 1986; Kulhavy & Schwartz, 1980; Kulhavy, Schwartz, & Shaha, 1983; Schwartz & Kulhavy, 1981) that found subjects were signifIcantly better at recalling map features and related text material when the components were depicted mimetically (visually mimicking the real-world objects to which they refer) rather than through the use of labels.

Alternatively, numerous experiments have studied how the processing of a map or diagram is influenced by factors related to configuration of their components such as relative placement (Mandler & Parker, 1976; Reynolds, 1968) and inter-item distance (Kosslyn, Ball & Reiser, 1978). Winn and Holiday (1982), for instance, demonstrated subjects had greater difficulty interpreting and using a diagram of dinosaur evolution when the progression of species was arranged from right to left rather than left to right.

HOW MAPS AND DIAGRAMS SYMBOLICALLY DIFFER

Maps and diagrams are both two-dimensional arrays of seemingly discrete symbolic elements and are interpreted according to how these elements are depicted and configured. In his comparative analysis of maps and diagrams, Winn (1991) suggests that because of the syntactic similarities between maps and diagrams, they can be studied as if they were essentially the same symbol system. Even so, he points out that maps and diagrams significantly differ in their "domains of reference." Differential processing of maps and diagrams on the basis of differences in their fields of reference has not generally been a subject of study among researchers even though, as mentioned earlier, field of reference is an integral part of a symbol system. Further, the semantic components of a symbol system constitute a class of important psychological variables that influence how the information presented on a graphic display is interpreted and learned. Moreover, we contend that the mere act of presenting a subject with a display identified as either a map or a diagram invites interpretive differences that confounds comparison of the two symbol systems on the basis of their structural distinctions alone.

Examination of psychological differences between maps and diagrams from the perspective of their unique fields of reference helps to highlight, on a practical level, how the two symbol systems are set apart, particularly in how each is interpreted and used.

Robinson and Petchenik (1976) observed that, by cultural convention, there is a deeply rooted "assumption of Euclidean correspondence between the map and the referent territory" (p. 66). Further still, in a metaphorical sense maps are often interpreted as if they were the world, a phenomenon Downs (1981) describes as "naive cartographic realism." Although diagrams also spatially depict relational information, the relationships themselves are typically analogical, not spatial, in nature. It is unlikely, for example, that one would interpret the highest position on a company organizational chart to mean the person represented was located on the uppermost floor of the company's office building (Winn, 1991). In the case of a diagram, the major criterion for determining whether it is a "good representation" lies in its computational efficiency, that is, how well it facilitates search and retrieval of relevant information as well as the ability to draw inferences from that information (Larkin & Simon, 1987). A diagram of a pulley system, for example, is valuable because it indexes information in a way that supports computational processes. The worthiness of a map, on the other hand, is linked to how well it answers the fundamental question of "where" (Robinson & Petchenik, 1976).

Orientation and scale are important factors in both how a map is used and in its perceived usefulness. Yet, orientation, for example, matters little to the effectiveness of a diagram. The tendency for people to turn a map prior to using (and processing) it so that north is at the top is a deeply-rooted cultural convention: East was, at one time, placed above, hence the expression "orient" a map (Kirby & Schofield, 1991). For most people, orienting a map is done with little or no conscious thought; it is for all practical purposes, a preattentive act with no parallel among diagrams. Similarly, scale is a commonly expected feature of maps, but not diagrams. While Winn (1991) parenthetically notes bus maps are rarely to scale, one could argue that such a display is very likely to be perceived by the viewer as a diagram of a transportation system rather than as a map per se. The point is, concomitant with the experiences people have of maps they generally have an expectation that it will be drawn to scale with an accuracy appropriate for the task for which it is intended. The essence of a map's usefulness, Korzybski notes, lies in its structural similarity to the territory it represents (cited in Robinson & Petchenik, 1976). Hence, a map perceived as "authentic" will, in all likelihood, also connote consistency and reliability in how it spatially corresponds to its referent.

FIELD OF REFERENCE AND PROSE PROCESSING

In the current study we predicted that two virtually identical graphic displays would yield differences in how an accompanying aural prose was processed when the displays differed in their fields of reference. One display was identified as a map and the other as a diagram. By contrast, we expected two displays with the same field of reference (both maps) to also produce differential processing of related prose due to differences in how their components were configured; in one instance, they were evenly distributed over the display's surface while in the other they were simply listed. In the first case, we anticipated better recall of a narrated story when an adjunct display was presented in a map-like context versus a diagrammatic one. This was based on the fairly robust finding that maps enhance memory for accompanying prose material that is thematically related to components shown on the map itself (Abel & Kulhavy, 1986; Amlund et al., 1985). Diagrams, on the other hand, have not been shown to be similarly effective in facilitating prose learning (Winn & Holiday, 1982). In the second case, our prediction of poorer prose recall by those with maps whose components were listed rather than spatially configured, was in line with the findings of several similar past studies (Schwartz & Kulhavy, 1981; Mastropieri & Peters, 1987; Abel & Kulhavy, 1989).

The context within which a display is interpreted, cartographic or diagrammatic, was also expected to influence whether subjects employ simultaneous or sequential encoding processes. According to the general model of dual coding, graphic data are processed simultaneously while verbal information is encoded sequentially (Paivio, 1971). During simultaneous processing all parts of a graphic image are perceived and processed at the same time with no one part being more accessible than another. Conversely, verbal information is sequentially processed since random encoding of, say, words in a sentence, would result in decreased comprehension. Even so, as Paivio (1986) points out, a graphic display "is capable of sequential processing as well if a response sequence is intrinsic to the imagery (e.g., imagining oneself walking down a familiar road or street, passing familiar buildings and other "signposts" in their natural sequence)"(p. 37). In the case of map encoding, Robinson and Petchenik (1976) proposed a two-stage theory whereby both simultaneous and sequential processes work in tandem; the first quickly identifies important information (rejecting irrelevant information), while the second is used more deliberately to recognize target information.

Extending this theory, we anticipated a greater degree of sequential processing for displays interpreted within a cartographic field of reference. In particular, we believed a significant interaction would occur between the interpretive context of a display (map or diagram) and whether or not its components were sequentially arranged in the same order as their appearance in the accompanying story. Subject's ability to recall the order of this information in the story was expected to be more severely impaired by an incongruently organized display only when it was viewed in a map-like context, not a diagrammatic one.

Finally, we surmised that subjects who processed a congruent display- prose set of stimuli in a map context would exhibit recall for parts of the narrative closer in proximity to where display components were mentioned. Maps have been shown to aid recall of text only when it is propositionally related to the features on the display (Abel & Kulhavy, 1986). However, no research has shown whether prose recall decreases in proportion to its distance from feature-related material. Supporting this possibility is evidence that ideas closer to main themes are remembered better than more distant ones both in text (Kintsch, 1975) and in aural narration (Meyer & McConkie, 1973).

METHOD

Design and Subjects

Three levels of symbolic context for encoding figures were crossed with two levels of how display components were organized relative to their appearance in an accompanying story and two levels of proximity between where a display component was mentioned in an audio narration (referred herein as a "keyword") and subsequent related information that subjects were asked to recall later. Thus, the base design was a 3 Symbolic Context (map-diagramlist) x 2 Component Organization (congruent-incongruent) x 2 Keyword Proximity (near-far) factorial with repeated measures on the variable dealing with the relative distance of target material in the story to its associated keyword.

Subjects were 132 undergraduates volunteers from a large university in the southwestern United States. Subjects were randomly assigned, 22 to each between-subjects condition, in the order of their appearance for the experiment.

Materials

Keywords used in 1he audio narration consisted of twelve 5-letter nouns carefully selected from the Battig and Montague (1969) category norms. Each began with a different letter and was chosen from a different category close to the center of the associative distribution, A 900-word fictional prose passage about an archeological expedition was constructed containing factual information about the life and customs of the Sumerians in Mesopotamia about 5000 years ago. In this passage, each of the 12 nouns served as the topic or theme for three consecutive 25-word sentences. Only in the first sentence was the keyword actually mentioned; the second sentence was propositionally related to the keyword sentence while the third sentence was propositionally related to the second. In this way, a prose structure was developed in which target information was relatively near or far from the keyword referent both propositionally and when it appeared. In its final form, the passage was audio-recorded (running time: 7 min. 30 s) on a cassette by a trained narrator.

Keywords were also incorporated as components in a graphic display (see Fig. 1) that subjects studied prior to hearing the story. The design consisted of 11 thick .16 cm black horizontal and vertical straight line segments of a continuous line that conformed to an imaginary 2 x 3 grid of squares such that all 12 points of the grid were connected. Each square of the grid measured 3.81 x 3.81 cm with the resulting array measuring 7.62 cm wide by 11.43 cm high. At each grid intersection, a small, thin-lined rectangle (1.27 x .64 cm) was superimposed. The grid was surrounded by a thin borderline, 2.54 cm from its sides and 1.59 cm above and below it. Finally, 13 horizontal hairline segments, .64 cm apart, were drawn beginning 1.91 cm below the bottom border. Each of the completed graphic displays were printed on a 21.59 x 27.94 cm vertically oriented sheet of white paper.

Using this procedure, four variations of the graphic display were created to serve as different treatment versions for ruling out possible design-related effects. In the experiment. use of the four versions was distributed equally among the three between-subjects conditions.

In the Map condition, the words NORTH, EAST, SOUTH, and WEST were printed directly above, right, below, and left of the display, respectively. The distance of an individual line segment was marked on the bottom-left section of the border and identified by a dimension arrow and the words "40 meters." For the Diagram condition, map cardinal headings were substituted by the words TOP, RIGHT, BOTTOM, and LEFT and the measured line segmen1 at the bottom of the display was labeled "40 millimeters." Figures used in the List condition were identical to those of the Map and Diagram groups minus labels showing scale and orientation.

The graphic displays were used to develop two study booklets, Trial I and Trial 2, for subjects in the different experimental conditions. A 130-word introduction appeared on the first page of every booklet along with 12 story keywords and instructions for using them to label a graphic display on the second page. The same display appeared on the third page, but with the keywords already printed in their proper locations. The fourth or last page of a booklet again showed 1he display without the keywords. To keep booklet information concealed until the proper time, a yellow sheet was placed between stimulus pages.

For the Map condition, the introductory paragraph identified the 12 words shown as relics found at an archeological site and the display on the second page as a map of the trench dug as well as the places in the trench where the relics were found. By contrast, in the Diagram condition, the nouns were simply identified as keywords that would be mentioned in a forthcoming story and that the display on the following page was a diagram designed as a mnemonic device for remembering story details. Meanwhile, subjects in the List group read the same introduction as those in the Map condition.

Studies with maps and text have stressed the importance in ensuring subjects actively process the graphic and linguistic materials used as experimental stimuli (Dean & Kulhavy,

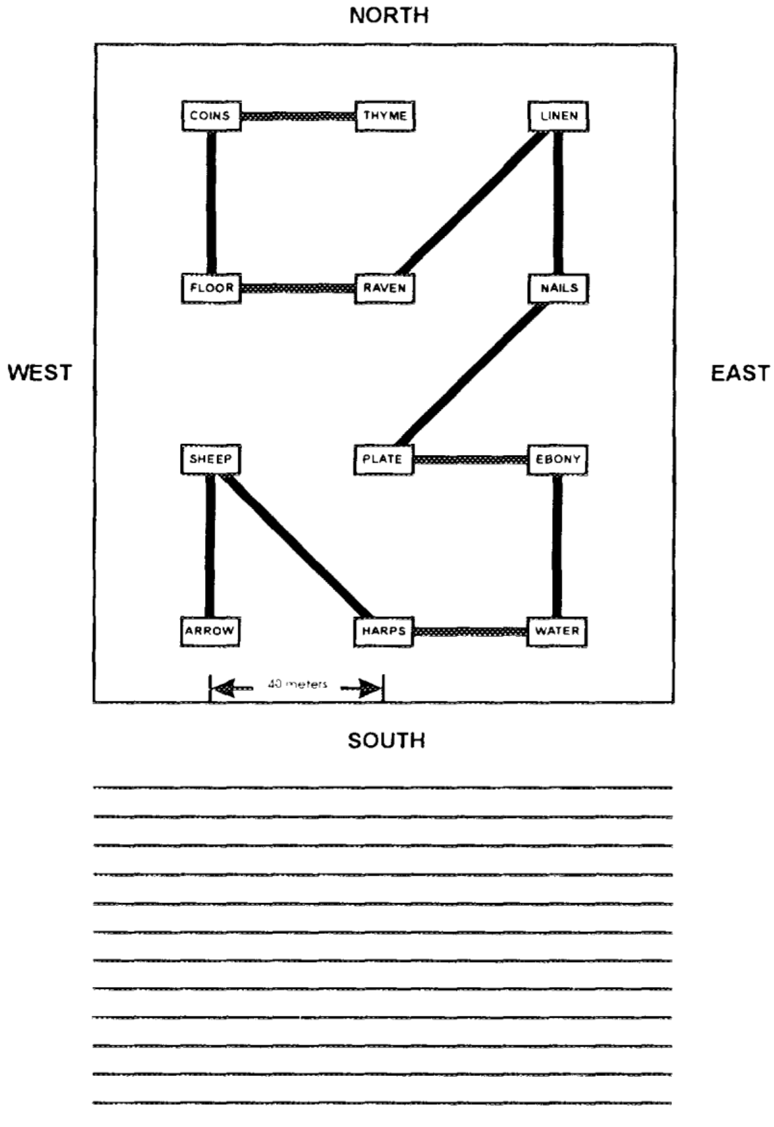

FIG. 1. Correctly labeled display studied by subjects in the Map condition (p. 3 of booklets studied in Trials 1 and 2 and during prose narration).

1981). To address this consideration, 12 sentences were added below the introductory paragraph that provided subjects with specific instructions for labeling the displays with the 12 keywords. Labeling instructions in the Map condition were given in terms spatially appropriate for a map: e.g., "COINS were uncovered 40 meters south of where 1he LINEN was found." In the Diagram condition, subjects were told to label the display using real-world metric and directional referents that corresponded to the actual page, e.g., "Write the word COINS 40 millimeters below where LINEN was previously written." Subjects in the List condition were told to write 1he name of each relic on one of the lines below 1heir map so that it fell at a specific location within the total list of words: e.g., "Write the word COINS on the third line above where LINEN is listed." Labeling directions in Trial 1 booklet differed from those in Trial 2 booklet, although the resulting arrangement of words on figures was identical.

When properly labeled, displays in half of 1he experimental groups were configured with labels spatially arranged in the same order as they appeared in the story. For Map and Diagram groups, this (Congruent) level of organization resulted in serial placement of display components along the length of the bending linear design. Congruency in the Lis1 condition was reflected by the serial position of the keywords. In the remaining Incongruent displays, keywords were configured so that there serial position or distribution on the figure was not in the same order as 1heir appearance in the audio narration. These two levels of Component Organization were counterbalanced with the four versions of display design and three 1ypes of Symbolic Context to yield a total of 24 experimental cells for the study.

Test booklets contained 24 constructed response questions designed to measure recall of factual information from the aural narration. One question was written for each of the last two sentences associated with a particular keyword with questions printed individually on 21.59 x 13.97 cm sheets of white paper. Sets of these response sheets were randomly compiled for each subject by shuffling them interleaved with pages of yellow paper and stapled into booklets. Two Trial booklets and a Test booklet were placed in each experimental packet along with a seven-item questionnaire which asked subjects to rate, on a 4-point scale, the usefulness of the labeling activity and the display itself for recalling the keywords and the related story (I = hardly useful; 2 = fairly useful; 3 = highly useful: and 4 = extremely useful).

Procedure

Subjects participated in groups of about 24 with between-subjects conditions represented in about equal numbers. As subjects entered the testing room, they received a packet of stimulus materials and were assigned to seats placed several feet apart. Throughout the experiment, the subjects were monitored closely by a proctor. Subjects were told they would practice learning twelve 5-letter words along with a graphic display and then listen to an audio tape recorded story twice. The first part of the experimental session involved learning the 12 words and graphic display. Subjects removed the Trial booklets from the packets and studied a page explaining the labeling activity through an example. After everyone completed reading the instruction, subjects placed the practice sheets back in their envelopes and were permitted to ask any questions they had about the procedure described. On the experimenter's command, subjects then opened the Trial 1 booklet and followed directions for labeling the graphic display on the second page using the keywords from the first page. Subjects had 5 min to complete this task. When finished, subjects turned to the third page of the booklet and compared the figure shown with the one they had just completed labeling. If one or two labels were out of place, they were allowed to correct their work but if there were more than that they raised their hand and a proctor came by to check their protocol for flawed materials. Subjects then turned to the last page of the booklet and had 2 min to again label the same diagram with the keywords, but this time from memory.

After the booklets were put back in their envelopes, subjects repeated the same process using the Trial 2 booklets: labeling from written directions, checking work for accuracy, and labeling once more from memory. Upon completion of the labeling activity, subjects tore out the third page of the booklet (showing a correctly labeled display) and placed it face down in front of them, returning the remaining pages to the experimental packet. Subjects were told they were about to hear an audiotaped narration of an archeological expedition while they studied the display in front of them. They were told not to mark the display but only to "use it to follow along with the narrator." When signaled, subjects turned the sheet over and the narration began. At the end of the second audition, subjects put the study sheet in their envelope, removed the Test booklet, and completed three simple addition problems printed on its back cover. This was done to limit recall from working memory. Directions were then given for answering the 24 questions contained in the Test booklets about the story they just heard. Subjects were told to write the word or words that answered each question and specifically to try recalling the words and graphic display learned earlier as a way of remembering the various details in the story. Exactly 20 s was allotted for answering each question with a beep used to signal the turn of a page. After the last question, subjects had two minutes to list the 12 keywords in the order of their appearance in the story using the back cover of the Test booklet. Subsequently, subjects returned the booklets to the envelope and filled out the accompanying rating scale.

RESULTS

Four protocols were eliminated due to incompleteness or subject's failure to follow directions. Thus, 128 protocols were included in the analysis: 20, 22, 22, 23, 20, and 21 subjects in between-subjects cells associated with Congruent Map (CM), Congruent Diagram (CD), Congruent List (CL), Incongruent Map (IM), Incongruent Diagram (ID), and Incongruent List (IL) conditions, respectively. Subjects' performance on experimental tasks yielded three dependent measures: cued recall on a 24-item posttest, serial list recall of keywords in the narration, and ratings on the usefulness of experimental displays and procedures for learning and recall of story information. An alpha level of $p < .05$ was used in the analysis to reject the null hypothesis.

Recall Performance

A criteria of acceptable answers for each of the 24 items served as a guide for scoring the post-test. Post-tests were scored by two judges resulting in a 92% inter judge agreement. Means and standard deviations for the percentage of items correctly answered by subjects on the 24-item post-test are shown in Table 1. Raw scores were converted to the proportions shown for the purpose of better interpretability. For the subsequent analyses, an arcsin transformation was performed on the proportional data following the recommendations of Winer (1971, p. 399).

A multivariate analysis of variance (MANOVA) revealed a significant main effect for the Keyword Proximity variable measuring differences in recall of information from either the second or third sentences in each paragraph of the narration, $F(1, 128) = 22.13$. While outcomes due to the effect of Symbolic Context were in the direction predicted, neither this main effect nor the one for Component Organization were statistically significant. Similarly, there were no significant second- or third-order interactions involving the two between-subjects variables and Keyword Proximity. In contrast to this finding, a significant interaction effect was noted for Symbolic Context X Component Organization, $F(2, 127) = 3.04$ (see Table 1). Figure 2 depicts this relationship by collapsing the Keyword Proximity variable since this distinction among post-test questions. (i.e.. whether derived from prose material located near or far from an associated keyword) had no apparent influence on the between-subjects variables. As Fig. 2 shows, recall performance increased or decreased as a function of the type of display processed (map, diagram, or list) and whether or not the display reflected the same keyword sequence as the aural prose. When the spatial organization of display components was

TABLE 1
PROPORTION OF CORRECT RECALL OF PROSE WITH KEYWORDS LEARNED FOR SYMBOLIC CONTEXTS

Component organization	Symbolic context	Keyword proximity: Near *M*	Near *SD*	Far *M*	Far *SD*
Congruent					
(same order in prose and display)	CM (Map)	.35	.22	.40	.23
	CD (Diagram)	.30	.21	.36	.17
	CL (List)	.25	.18	.33	.17
Incongruent					
(different order in prose and display)	IM (Map)	.26	.17	.28	.14
	ID (Diagram)	.35	.21	.45	.22
	IL (List)	.26	.15	.35	.17

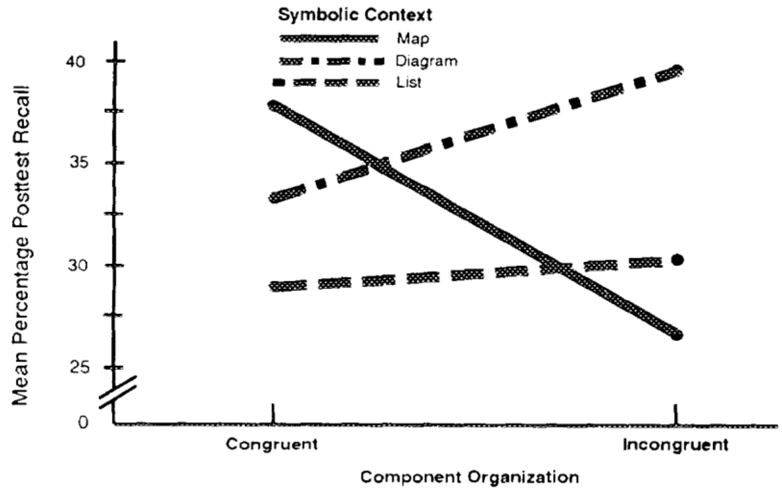

FIG. 2. Effect of graphic Symbolic Context (i.e., Map, Diagram, List) on cued recall for narrated prose (i.e., "Excavation of Alban") having keywords either Congruent or Incongruent with the spatial organization of components on an accompanying display.

incongruous with how they were arranged in the narration, subjects processing the information in the context of a diagrammatic symbol system exhibited greater prose recall than subjects in the map or list condition. By contrast, subjects encoding out-of-sequence keywords in a map-like context showed a marked decrement in post-test performance. To examine this further, a separate one-way analysis of variance (ANOVA) was executed for each of the two levels of Component Organization. In both cases, scores representing differences in Keyword Proximity were pooled. Results showed that the context in which subjects interpreted a display (map or diagram) made a significant difference in their ability to recall information from an accompanying story when arrangement of display components was incongruous with their order of appearance in the story, $F(2, 63) = 3.58$. Subsequently, a Tukey HSD pairwise comparison showed a significant decrement in cued recall performance by subjects in both the IM and IL conditions relative to participants in the ID group (ID > 1M = IL).

Serial List Recall

Serial lists generated were scored by awarding one point for every word either preceded or followed by a word in the proper sequence. If a word was bracketed by words matching the correct order, two points were awarded. When the first or last word of a recalled list matched one from the correct list, one or two points were assigned depending on whether it was preceded or followed by a correct word. A total of 24 points were possible. Table 2 presents the means and standard deviations for this measure in each of the six conditions. As expected, a MANOVA revealed that subjects who studied displays with components organized congruently with respect to their appearance in the accompanying prose outperformed those whose displays were incongruously arranged, $F(1, 126) = 47.81$. Spatial context appeared to have no effect on serial list recall and, unlike cued recall, no Component Organization X Symbolic Context interaction was present.

While performance was virtually identical among all subjects studying congruently organized displays, a sharp decrease in serial list recall ability was noted for the IL group relative to those who processed either an incongruent map or diagram (Fig. 3). A one-way ANOVA pointed to a significant difference among the means of the three groups, $F(2, 63) = 3.05$ while subsequent a posteriori contrasts revealed a 1M = ID > IL relationship among the three incongruently organized adjunct displays.

Rated Usefulness of Materials and Procedures

Frequency distributions of the ratings by subjects in the six treatment conditions are shown in Table 3. Employing a chi-square analysis we discovered significant differences in ratings across treatment groups. Subjects viewing congruently organized displays differed significantly in rating the usefulness of remembering the names of display labels as a way of recalling details from the story, $x2 (6, N = 65) = 14.81$, with the map group (CM) providing the highest rating. These subjects also gave higher ratings on the usefulness of the labeling activity for recalling the story than did CD and CL groups, x^2 (6, N = 65) = 12.84. On the other hand, both CM and CD groups gave significantly higher ratings than those in the CL condition on the usefulness of making a mental image of the studied figure for recalling label order, X2 (6, N = 65) = 27.56, p < .01. Subjects

TABLE 2
SERIAL RECALL OF KEYWORDS FOR COMPONENT ORGANIZATION AND SYMBOLIC CONTEXT

Component organization	Symbolic context	*M*	*SD*
Congruent			
(same order in prose and display)	CM (Map)	16.05	6.83
	CD (Diagram)	15.76	8.16
	CL (List)	16.14	8.11
Incongruent			
(different order in prose and display)	IM (Map)	8.57	7.39
	ID (Diagram)	8.75	7.25
	IL (List)	4.43	3.98

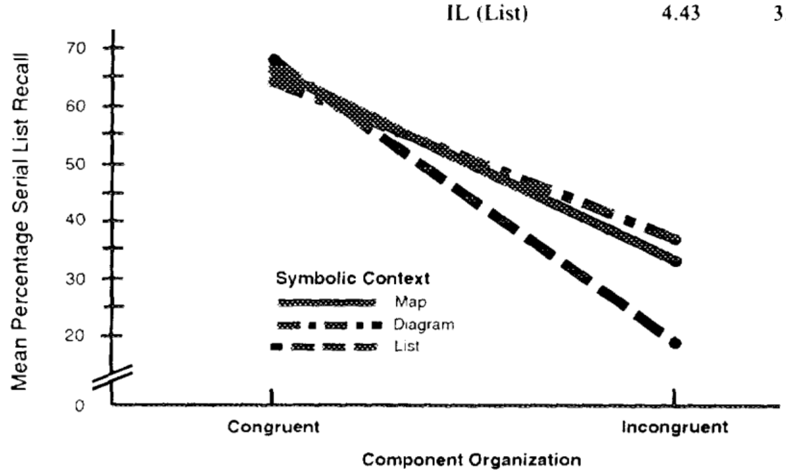

FIG. 3. Effect of graphic Symbolic Context (i.e., Map, Diagram, List) on serial recall of keywords in a narrated prose passage (i.e., "Excavation of Alban") that are either Congruent or Incongruent with their spatial organization on an accompanying display.

who studied incongruently organized displays significantly differed from one another across the three treatment levels of Symbolic Context on the usefulness of the stimulus figure for listing its labels from memory, x^2 (6, N = 64) = 23.23, p < .01. Although differences in ratings on the usefulness of the figure for recalling details from the narration were not statistically significant, it is nevertheless an important finding. Subjects in both the Diagram and List groups, regardless of how their display was organized, were notably more inclined to rate the figure as "hardly useful" in terms of its value in recalling information from the story (see Table 3).

SUMMARY AND DISCUSSION

Large differences in recall performance were noted as a result of where target information was located in the narrative relative to keyword positions. Surprisingly, subjects recalled substantially more details of the story that were located two sentences from the keywords than information immediately following keywords. We believe a working memory model provides the most plausible explanation for this unexpected outcome. Upon hearing and recognizing a keyword in the first sentence of a given paragraph, subjects may have initiated mental rehearsal of the information and, in doing so, occupied short-term memory storage so that material in the second sentence was not processed. Realizing new information was being missed, subjects may have then reallocated their attention in time to encode the content of the third sentence. This hypothetical effect of primed words placed periodically in aural prose on the process-

TABLE 3
FREQUENCY DISTRIBUTION OF RATINGS ON USEFULNESS OF EXPERIMENTAL MATERIALS AND PROCEDURES

Rated item	Component organization	Symbolic context: List 1[a]	2	3	4	Map 1	2	3	4	Diagram 1	2	3	4
Usefulness of													
1. The figure for recalling details from the story	C[b]	7	6	5	2	12	8	1	1	17	3	1	1
	I	9	10	3	0	13	6	1	0	15	4	2	0
2. Remembering label names to recall story details.	C*	4	7	8	1	9	13	0	0	9	9	3	1
	I	9	10	2	1	5	13	2	0	11	5	4	1
3. Labeling activity to help recall of story details.	C*	5	8	3	4	10	11	1	0	9	12	1	0
	I	12	7	3	0	9	9	2	0	12	6	2	1
4. Labeling activity as a way of memorizng labels.	C	1	2	6	11	5	4	3	10	5	3	6	8
	I	2	6	11	3	1	2	11	6	4	6	7	4
5. Figure to list the label names in order from memory.	C	2	4	5	9	5	6	3	8	12	4	1	5
	I**	5	13	2	2	6	3	3	8	13	7	0	1
6. Making a mental image of figure to recall label order.	C**	2	5	5	8	0	8	4	10	14	1	2	5
	I	5	10	5	1	5	5	3	7	11	5	2	3
7. Remembering the label locations to recall their names.	C	0	8	7	5	1	9	3	8	4	4	8	6
	I	4	10	5	3	4	2	8	6	8	6	4	3

[a] Rating values: 1 = "hardly useful"; 2 = "fairly useful"; 3 = "highly useful"; 4 = "extremely useful."
[b] Component Organization: C, Congruent; I, Incongruent.
* $p < .05$.
** $p < .01$.

ing of adjacent material bears some similarity to the way embedded pre- questions operate in text: processing attention for nonemphasized material (i.e., text not directly related to the question) is usually diminished (Anderson & Biddle, 1975). Future designs should be constructed to test this assumption as well as the effects of multiple keyword positions within a prose passage.

Serial recall for story keywords and their order of appearance differed significantly as a function of whether they were spatially arranged or listed on the accompanying display but only in instances when the arrangement was incongruous with the prose. Post-test scores were the same for subjects who studied incongruently organized maps and diagrams while performance was significantly lower in the comparable List condition. Predictably, when the configuration of labels on a map, diagram, or list matched keyword order in the narration, correct serial recall was high and varied little across groups.

When component arrangement on displays was identical to that of the story, subjects varied in recall performance based on the context on which the displays were presented. Those who thought they were using a map outperformed subjects who believed they were using a diagram. The latter group, in turn, showed better recall than those who viewed a "map" in which components were simply listed below the display rather than dispersed as one might expect on a map. Although the expected differences among the treatment groups materialized, they were not significant by conventional standards.

By contrast, the context in which a display was processed had a large impact on recall when the spatial arrangement of display components was incongruous with their order of appearance in the narration. In the case of the Map condition, prose recall performance plummeted. Yet this was not so for subjects in the Diagram and List conditions who studied displays similarly organized. When incongruent displays were interpreted as dia- grams, performance by subjects actually improved. On the other hand, congruity of keyword order in the story and its display had virtually no effect on recall by subjects in the List condition.

The fact that incongruity between keyword distribution (in the narrative) and component configuration (on the display) only influenced recall performance of subjects in the Map condition suggests map encoding is at least partly sequential in nature. Robinson and Petchenik's (1976) hypothesis that map encoding involves sequential processing is compelling considering the experimental data presented herein and serial-like activities, like route planning, typically associated with maps. In the case of the current study, it is interesting to note that while subjects were plainly told their display was a map, many of the visual cues normally associated with a map were absent from the display including contour lines, geographical features, territorial boundaries, and so forth. Besides these syntactic characteristics, the extensive knowledge base people have for graphic displays probably embraces semantic ones as well including, among other things, notions about their capabilities, conventions, and appropriate uses. Merely informing a percipient that an image being viewed is, for instance, a map may be all that is required for one to activate a map-like interpretive framework and corresponding operations such as, in this case, sequential processing.

The relatively greater prior knowledge people have with map conventions, however, raises the possibility that differences between treatment groups may be attributed to a better understanding by those in the Map condition of how to apply their display to the task at hand. Compared to those viewing a diagram, subjects with a map had a more concrete field of reference on which to link their processing; labels on their display corresponded to real-world artifacts found by the archeologists. Therefore, it is possible that subjects with a map were, in a sense, better "trained" in the use of their display. By contrast, those told their display was a diagram had no guidelines for using it as "a mnemonic device."

Although, this interpretation does not account for intra-condition differences such as those resulting from display-to-prose congruity, examination of the ratings by subjects on the perceived usefulness of their display lends to this argument. If, for instance, processing differences between the Map and Diagram conditions can be attributed to better training of the former group in using their display, one would also expect them to produce correspondingly higher ratings on the perceived usefulness of their displays. When label positions on the display matched those in the story, twice as many subjects in the Diagram and List groups gave ratings of "hardly useful" as those in the Map group... but only for recalling display labels and the labeling activity itself as a means of remembering the story. Interestingly, ratings of Map and Diagram groups reversed when verbal information on the display was incongruous with the narration: an outcome that parallels the actual recall performance of the groups.

In light of other data, however, the evidence of a possible training effect appears less clear cut. The value of making a mental image of the figure, for example, for recalling the order of labels that were congruent with the story was rated equally high for Map and Diagram groups. Similarly, there was no significant difference between the two groups in terms of how useful they rated the figure for remembering label names. About the same number of subjects in both groups also considered the figure of no value for this task when displays were incongruous with the prose passage. Assuming the possibility that subjects in the Map group may have been better equipped to make use of their particular display, it is nevertheless surprising that the other groups were not able to realize the advantage of congruent displays over incongruent ones, especially when one considers the displays were available for study throughout the period of two narrations of the story, or about 15 min.

Of further surprise was the absence of notable differences in story recall between the Map and List conditions, particularly given the numerous studies that have reported greater prose learning when map features are spatially distributed versus merely listed (Abel & Kulhavy, 1986; 1989; Mastropieri & Peters, 1987; Schwartz & Kulhavy, 1981). A reasonable explanation for this finding is that criterion measures on the post-test were unrelated to the keywords that constituted the map features. In the studies cited, recall was significantly better for sections of prose that were directly related to features on the adjunct map. This would explain the low performance by subjects in the current study. Alternatively, the processing advantages that are normally found with maps may have been diminished because subjects did not perceive their displays to be sufficiently "map-like" to evoke such a response. Rating differences between Map and List groups on the usefulness of their respective displays supports this conjecture and suggests that, in the face of prior knowledge about a specific symbol system, the perceived authenticity of a display may be yet another type of non-graphic variable among graphic displays worth further study.

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