Dual Coding and Conjoint Retention: Past, Present, and Future

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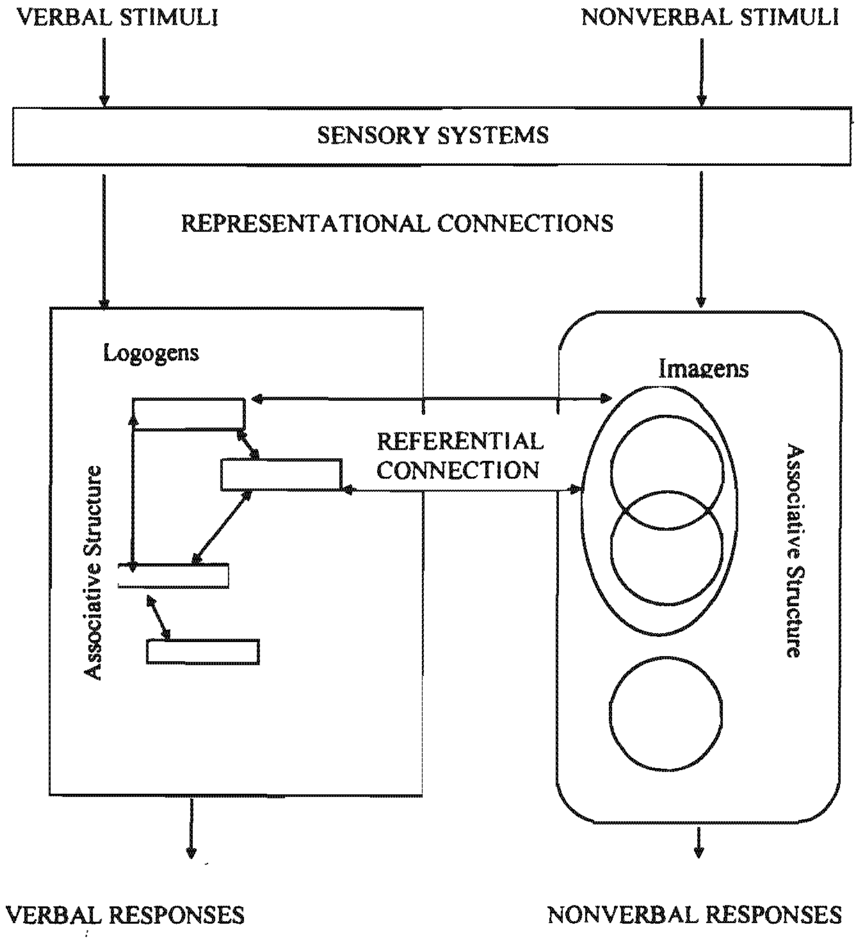
Introduction

Educators and psychologists have researched theoretical models of text or image representation and recall for decades (Anderson 1976; Klatsky 1980; Mclleland, Rumelhart & PDP Research Group 1986; Paivio 1971). In the early 1980's, Raymond W. Kulhavy and his colleagues (Dean & Kulhavy 1981; Kulhavy, Lee & Caterino 1985) embarked on a research agenda concerning whether the use of organized spatial displays in conjunction with textual information increases recall. The purpose of this paper is to review the theoretical framework of Kulhavy's Conjoint Retention hypothesis (CR) and provide a review of the research based on this hypothesis over the past two decades. Finally, a discussion of current and future directions of the research is provided.

Conjoint Retention Hypothesis: Extending Paivio's Dual Coding Theory

Paivio's ([1971] 1986) Dual Coding model of knowledge representation in long-term memory (LTM) is based on the idea that information is stored in two distinct codes, the verbal code and the non-verbal code (Figure 1). Many models of cognition include both verbal and nonverbal representations (Anderson 1983; Kosslyn 1986; Simon 1989). In Paivio's model, the two codes are functionally separate and distinct with one representing verbal information (propositions) and the other representing spatial information (images). The verbal code is concerned with the processing and representation of verbal information and the nonverbal code is concerned with the generation and representation of images in memory.



Adapted from Paivio (1986)

Figure 1

When stimuli enter the sensory system, Paivio contends that verbal stimuli in the form of propositions are stored in the verbal code and visual stimuli are stored in the non/ verbal code. For example, when a person forms the image of the word dog, the word creates both a visual and verbal representation. The two representations improve the chance of the word being recalled later, because there are two representations to assist retrieval. This memory improvement results when a visual image and a word are learned together and is an instance of 'two codes are better than one' (Paivio 1986). Further, the codes may be activated in a singular or parallel operation and referential connections exist between the two codes.

Within each code, associative links relate information together. For example, questions about my desk evoke the image of my desk and all of the immediate surroundings in a probabilistic fashion. I can also survey my desk without the continuity being broken (Paivio 1986). More importantly, theoretically and functionally, information that is stored in the verbal code can be linked to related information in the non/ verbal code and vice versa. These referential connections (between code connections) make it possible for information in one code to cue activation and retrieval of information in the other code, thereby both codes can have 'additive effects' on recall (Paivio 1986:77. In addition, referential or cross code connections provide additional retrieval cues which increase learning (Kulhavy & Stock 1996; Verdi *et al.* 1997).

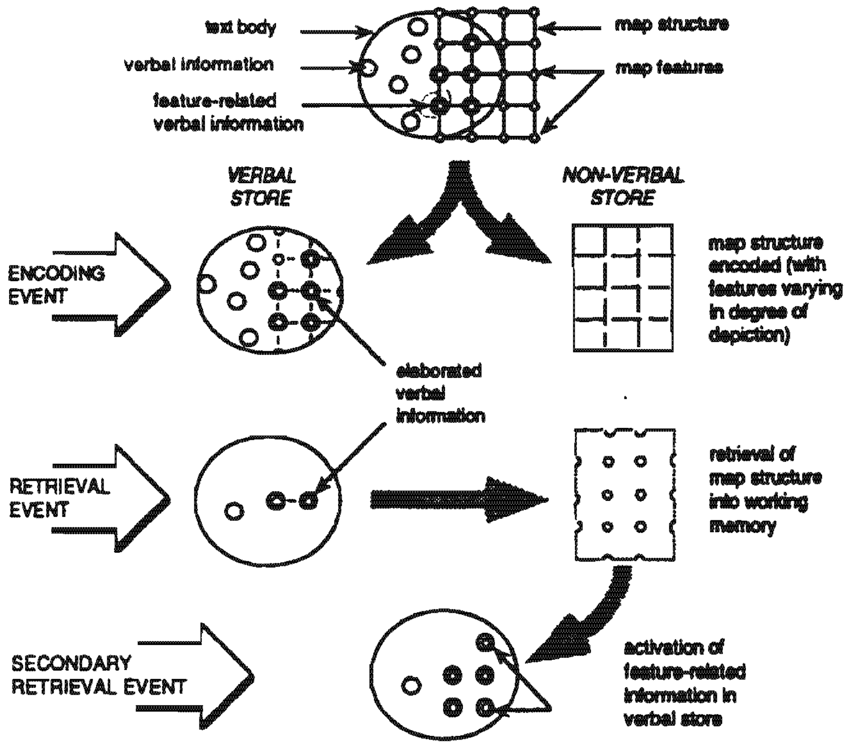
Kulhavy and his colleagues (Kulhavy & Stock 1996; Kulhavy, Stock, Verdi, Rittschoff & Savenye 1993) have extended Paivio's dual code theory to explain the acquisition of text material using organized spatial displays, specifically maps. Kulhavy, Lee and Caterino (1985) state that the conjoint retention hypothesis is an expansion of the dual coding approach in the sense that linguistic/verbal and perceptual/spatial representations in the cognitive milieu are treated as separable coding processes, at least portions of which are nonoverlapping in memory. They believe that much of discourse content is stored in a linguistic/verbal mode with few perceptual referents (Anderson 1978), whereas, the geography of a map is stored primarily as a perceptual/spatial representation which possesses pictoral characteristics (Kosslyn & Pomerantz 1977). When we view an image (e.g., map) we encode the components of the image (features and their location). If we then read textual material about the image, we form cognitive links (based on the referential connections) between the information in the image, which is stored in the non/ verbal code, and the matching information in the text, which is stored in the verbal code. These cognitive links facilitate the retention of information. Kulhavy and colleagues argue that due to these links formed between the two codes, verbal and non/ verbal information can be utilized independently or in conjunction with one another. Then at recall, the person is able to draw on both types of conjointly retained cognitive representations, thereby increasing the probability of remembering elements from each. The dual pictoral/linguistic representation provides a richer cuing base and retrieval base for the learner to draw from during recall. Finally, they believe that the possession of the conjoint representations may work to reduce the amount of interpassage interference at recall, by acting in some fashion to modify the functional characteristics of the incoming stimuli, and consequently increasing their availability in memory (Kulhavy *et al.* 1985).

A second extension of the dual code theory states that non/ verbal information (images) has two characteristics that contribute to the improvement of memory for textual information. These characteristics can be generically labeled feature and structural information (Kulhavy, Stock, Verdi, Rittschof & Savenye 1993). In the specific case of a map, the feature information may be landmarks, objects, paths, verbal labels, and other point designations. Feature information also includes what Bertin (1983) calls the 'retinal variables' such as size, shape, and color, which are used to further delineate individual features. Features may be depicted by different types of marks, including icons, boxes, etc. and Homa and Viera (1988) observed that memory for these individual entities is fairly accurate. Finally, Schwartz (1997) argues that it is the feature information found in maps that activate prior knowledge and allows the learner to process and interpret the map. Kulhavy and colleagues define structural information as the spatial characteristics across an image space. Structural information deals with the metric and spatial relations found between the individual features on a map including direction, borders that can be used as reference points for features, and distance. It is the structural information that allows the learner to create intact images. For a neurological explanation of this phenomenon, see Tippett (1992).

Images within Kulhavy's model enjoy a privileged status when compared to propositions. Propositions are processed and stored serially (Van Dijk & Kintsch 1983), whereas images are processed and stored as a whole unit (Reynolds 1968). Because images are stored in a whole or intact form, the information contained within the image is simultaneously available, and therefore, it is possible to switch attention from one feature to another feature within the intact image without using all the resources available in working memory (Larkin & Simon 1987). Propositions do not share this advantage due to the fact they are stored and retrieved sequentially (Anderson 1983).

Therefore, images have a computational advantage over propositions especially in working memory where there is limited capacity (Miller 1956).

Figure 2 provides a graphical representation of the CR model. The figure shows the model in terms of encoding, retrieval and secondary retrieval of map-text information. The top view of the figure shows the relationship between map and text and illustrates the overlap between feature-related verbal information and the map features contained within their structural framework. At the encoding stage, the two representations are incorporated into separate memory stores, with the feature-fact associations denoted as elaborated units. At retrieval, both the verbal and image codes are pulled into working memory, and map information is used to cue secondary retrieval of associated verbal events.



Also, based on Thorndyke and Stasz (1980), Kulhavy and colleagues have described how people process maps based on three processes: attention, encoding and control. Attention includes partitioning and sampling. Partitioning is used to restrict attention to a subset of image information. When an image is too large to learn all at once, partitioning is accomplished with spatial or conceptual categories. Sampling, the pattern of attention shifts between image elements, may be conducted in one of several ways. Systematic sampling shifts between processes using a decision rule criterion. Stochastic sampling shifts attention to adjacent elements. Random sampling involves haphazard shifts. Memory-directed sampling involves shifting attention to elements not recalled during previous recall attempts.

Encoding processes serve to maintain information in working memory. These processes include rehearsal, counting elements that share a specific property, mnemonics, and association or elaboration. Rehearsal is used to learn both spatial and verbal information while the other processes are used with verbal information only. Spatial information is encoded using four procedures: (a) visual imagery which forms a mental picture of the map or a portion of it, (b) labeling which generates a verbal cue in relation to a spatial configuration, (c) pattern encoding which specifies shapes, and (d) relation encoding which refers to spatial relation between map elements. In addition to these four procedures, schema application may be applied to either spatial or verbal information. Schema application involves associating map information with a prototypical configuration. Within encoding, prior knowledge becomes important. According to Schwartz (1997), 'Maps are not simply encoded into long term memory as images, verbatim'. Indeed, one of the things learners do when processing a map is to relate what they know about the area's geographic space to the stimulus map. In short, a person's prior knowledge about the area or subject depicted on a map plays a large role in how the learner processes the map. Lowe (1993) observed that those who had experience with meteorological maps had superior recall of both the number of markings and their accuracy when compared to a control group. Schwartz (personal communication) has recently observed that when the learner's prior knowledge about the area depicted was inconsistent with what was displayed on the map, map learning was dramatically reduced. Allen, Schwartz, Graham, Knight and McLaughlin (1998) found that when subjects have a prior knowledge of the geographic domain discussed in the passage, the presence of a geographic map played a small part in the students' ability to recall the passage. In short, when given a choice, students choose to study what is most familiar and therefore easier to learn.

> Control processes are inferred rather than observed, and direct shifts between the other processes, including selecting and terminating which of the procedures are to be used. Thorndyke and Stasz (1980) identified differences in the procedures used by good and poor map learning. Good learners used systematic attentional procedures, a variety of encoding procedures, and frequently and accurately evaluated their performance. Poor learners did not use partitioning, and were limited in the variety of encoding procedures used with spatial information, and were less accurate than good learners when evaluating what they had learned.

Research Observations: What We Have Witnessed

This section provides observations based on research completed using the conjoint retention hypothesis developed by Kulhavy and his colleagues. There are seven themes across the research: Stimulus Characteristics, Edge Effect, Stimulus Order, Accuracy/Prediction, Thematic Maps, Individual Differences, and Task Demands. Within each theme, relevant research studies are provided.

Stimulus Characteristics

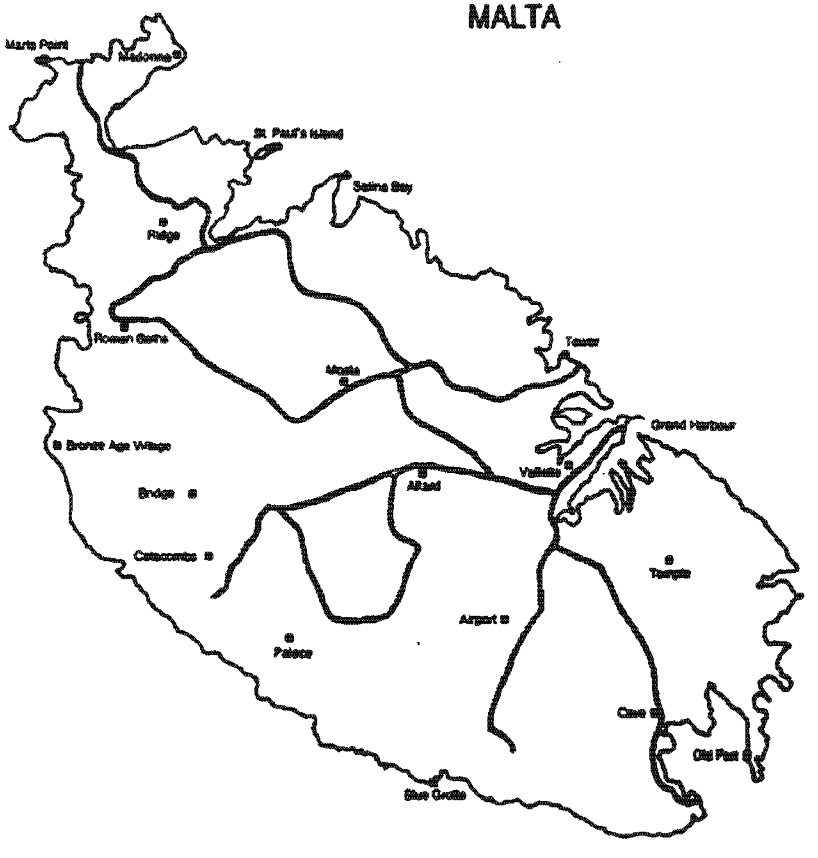
Several studies by Kulhavy and his colleagues have focused on manipulating the characteristics of the spatial display and to a lesser degree the textual material. Early studies focused on the iconic concreteness of map features and how that influences how maps are remembered. Kulhavy and Schwartz (1980) reasoned that the degree of iconicity of a feature (varying from a full mimetic to a label only) would impact how the map was recalled. They argued that figural characteristics work to maintain relational context and this helps in the case in which a recall task demands performance that is spatially isomorphic with the original stimuli. In their study, only participants who were provided maps with mimetics were able to retain the spatial characteristics of the maps. This study helped provide evidence for the advantage of structural information of maps for learning related prose.

When students are presented with an intact map rather than a list map or segmented map they recall more information. Students who were given an intact map recalled more text information than those who were given a list map (the features were listed on the side of the map, the intact map had features distributed across the map surface) (Schwartz & Kulhavy 1981). Kulhavy, Stock, Verdi, Rittschof and Savenye (1993) used a map of Rome where subjects viewed either the intact map of Rome with twenty features or viewed twenty maps each with one feature and found that those who viewed the intact map had superior recall of information. More recently, subjects in one group viewed a map that contained the five landmasses and features of the Molluca islands and another group viewed each island individually (Schreiber, Verdi, Patock-Peckham, Johnson & Kealy in press). Those subjects who viewed the five islands intact recalled more text information than those who saw the islands individually. The key component of that study was encoding the map as a whole unit and processing it as a whole, thereby giving the intact group a computational advantage.

Text fact recall is enhanced when text information is directly related to map information. Subjects read a narrative that contained features which were located on the map and features that were not located on the map and then were asked to remember information on a cued and free recall test (Schwartz & Kulhavy 1981). For both cued and free recall tasks, subjects remembered more features that were located both on the map and in the text than features only located in the text, thus providing more evidence for the argument that 'two codes are better than one'.

Adding perspective to a map may enhance recall of features of the map. Traditionally, the research had focused on plan view (flat map) maps but in the mid1990's the research branched out into perspective maps. In cartographic terms a plan view represents three degrees of freedom in terms of symmetry: the plane is symmetrical about the X, Y, and Z axes. Tipping one edge of the plane, in this case the Z plane, results in a one-point perspective view. Therefore, a one-point perspective has two degrees of freedom in terms of symmetry: the Y and Z axes (Figures 3 and 4).

Subjects in one experiment viewed either a plan map or a one-point perspective map of the ancient city of Rome (Johnson, Verdi, Kealy, Stock & Haygood 1995). Those participants who viewed the perspective map recalled significantly more features and located more features correctly on the map reconstruction task than those who viewed the flat map. Johnson and colleagues argued that the increased dimensionality of the perspective map provided a rich encoding base for the structural relations among features and reference points. Schreiber, Verdi, Patock-Peckham, Johnson and Kealy (in press) tried to replicate this observation by having participants view a flat, one-point perspective, or two-point perspective map of the island of Malta.



They observed that those who viewed the flat map recalled more information than those who viewed the perspective maps. The key for the disparity may actually be the clustering of items on the maps. On the Malta map, the features appear to be more evenly spread across the map than on the Rome map. Nine of twenty-three labelled features are located in the bottom quarter of the Rome map, which may have given the illusion of a richer encoding base.

With regard to textual information, early research was concerned with the difference between hearing or reading the text and recall. Abel and Kulhavy (1986) observed no significant difference between participants who heard the text or read the text. A part of this study was replicated in the mid 1990's by Johnson, Schreiber, Verdi and Arici (1996) with similar results. Simply, it appears that hearing or reading the text does not make a difference within the model.

Because of incredible work by B.J.F. Meyer and B.B. Armbruster and others concerning structural aspects of text material, the manipulation of the physical text has also been researched. Schreiber, Verdi, Patock-Peckham, Johnson, and Kealy (in press) had subjects read different text organizations after seeing a flat or perspective map (discussed above). No differences were observed between text types regardless of map type. They also had students read a randomly ordered text or an ordered text after viewing an intact or segmented map. By ordered, the authors meant that the text information would match the scanning pattern of the map. In western civilization it is recognized that literate individuals organize and read text from a top to bottom and left to right format. According to Winn (1991), items on a map would also be encoded in this fashion. Students who read a top-to-bottom text after viewing an intact map recalled more map and text information than those who viewed the same intact map but read a random text.

Edge Effect

The study of map perspective has enabled researchers to begin to examine what elements in the map are used to process and learn the map. This research has resulted in what is called in the literature, 'The Edge Effect'. The Edge Effect refers to the phenomenon that subjects learn more features found at the edge of a map than in the interior. Several studies have examined why and how this occurs. Rossano and Morrison (1996) ran a series of five experiments that examined how information is acquired from viewing a map. In a typical experiment, subjects were asked to study an experimental map for 10 minutes. At the end of the study period, subjects were given a blank piece of paper and asked to redraw the map they had just studied. One week later, subjects returned and were asked to draw the map again. The results of the studies showed that border features, those close to the edge, were remembered more often and more accurately than interior features. In addition, the researchers found that subjects learned and remembered the maps in an outside-in pattern. Namely, features located along the border of the map were learned and remembered before features in the interior. One exception was found when interior lines were present. In these cases, these interior lines served as a border and these features were learned along with the edge features.

Johnson, Kulhavy, Stock, Stamm and Verdi (in submission) found that the stronger the edge of a visual display (such as a map) is enhanced, the better those features located near those enhancements are learned. In addition, learning these features enables students to make appropriate connections with the facts associated with those features within a related text. Finally, Verdi, Stamm, Johnson and Jamison (2001, Experiment 2) had subjects view one of four experimental maps of Tasmania. Two levels of border (present vs. absent) were crossed with two levels of feature location (edge vs. interior) to form four experimental groups: border present with edge features only, border present with interior features only, no border present with edge features only, and no border present with interior features only. The results of the study showed that students were able to learn more features, accurately recall more facts from the text, and were better able to reconstruct the map when they viewed maps with features located along the edge than within the interior. There was little difference in those students viewing a map with a border and those viewing a map without a border. It should be noted that this border vs. no border finding is contradictory to most other findings in similar situations (e.g. Johnson 1996). This was due to the fact that the arrangement of features in this study allowed for students to create borders when they were not present, and, therefore, the missing border did not affect the subjects' ability to create images (a complete explanation of this phenomenon can be found in Verdi *et al.*, 2001). Recently, Verdi, Crook and White (in submission) have demonstrated that the 'edge effect' is also clearly visible when the map is presented in a computer format as well in traditional paper and pencil format. Schwartz (1997) asserted that it is the intactness of an image that enables students to use the image as a vehicle to aid in learning related text. The research presented here supports the position that it is the 'edge effect' that makes maps viable for forming images.

Stimulus Order

One of the most important observations of the research conducted concerns the order of the stimulus. Originally, studying both a map and a text was important to the recall of information. However, the computational advantage aspect of the conjoint retention model predicts that when structural information is encoded from the map it should produce an asymmetry in retrieval success, depending on which type of stimulus is first learned. This asymmetry suggests greater recall when the map is learned before the text. When students learn a map before a text, they encode both feature and structural information into an image. Because the map is represented as a structurally intact unit, it can be held in working memory without exceeding the capacity of the system. When reading a related text presented later, students bring the map image into working memory and use it to form associations with the facts contained in the text. These map-text associations can then be used to increase retrieval success during recall. Stock, Kulhavy, Webb, Pridemore and Verdi (1993), Verdi, Peterson, Webb, Stock and Kulhavy (1993), and Verdi, Johnson, Stock, Kulhavy and Ahern (1997) observed that participants who viewed a map before reading the text recalled significantly more information than those who read the text before viewing the map. Essentially, those who see the map first form an image that retains spatial information found in the map that is stored in long-term memory as a single unit. When a subject views a text, it is encoded as a series of propositions (Van Dijk & Kintsch 1983). Each time the student reads about a fact or feature in the text, an image of the map can be brought into working memory and associations between the map and text are formed. Those that read the text first process it as a series of propositions so when they are presented with the map a laborious process begins. They expend effort searching long-term memory for each individual proposition previously encoded and then bring them into working memory.

Accuracy/Prediction

Given the conjoint retention model predicts that structural characteristics of a person's map image will be closely tied to the number of text facts recalled correctly, there should be a technique to test this prediction. One way to test this is by the calculation of conditional probabilities. The resulting form is P(correct fact recall| accurate feature location) or P(fact|feature). Table 1 provides mean values of P(fact|feature) for seven published experiments and one unpublished. The values range from .53 to .85 indicating a close relationship between location accuracy of map reconstruction features, an indicator of structural organization) and memory for associated textual facts. The more accurately a subject reconstructed information on the map the more information the subject recalled. In the Kulhavy, Woodard, Haygood and Webb (1993) and Schwartz and Kulhavy (1981) studies both probabilities were over .73 and specifically fact recall fell sharply when the feature was not located correctly or was absent from the map construction—an average of .37 as compared to an average of .80 when accurately located (cited in Kulhavy & Stock 1996). Arici and Schreiber (1997) observed similar results with a probability of .71. Kulhavy, Stock, Woodard and Haygood (1993), had students learn a map of a city over three trials prior to reading the text. On each of the three map trials, students studied the map for one minute and then attempted to reconstruct it from memory. The number of times that a feature was correctly located on the reconstruction (0-3) was used as an index of the structural accuracy.

Table 1: Summary Table of Conditional Probabilities of Correctly Recalling a Text Fact, Given the Associated Feature was Accurately Located on the Map Reconstruction.

Description of Map Used in Study	Probability of Joint Recall of Text Fact and Map Feature
Fictitious island with 14 features (Abel & Kulhavy 1986)	0.67
Fictitious countryside with 16 features (Kulhavy, Caterino & Melchiori 1989)	0.59
Island of Tasmania with 10 features (Stock, Kulhavy, Peterson, Hancock & Verdi 1995):	
Experiment 1	0.85
Experiment 2	0.73
City of Rome with 20 features (Kulhavy, Stock, Verdi, Rittschof & Savenye 1993)	0.53
Island of Bonaire with 18 features (Kulhavy, Woodard, Haygood & Webb 1993)	0.73
Fictitious island with 16 features (Schwartz & Kulhavy 1981)	0.84
Island of Malta with 21 features (Arici & Schreiber 1997)	0.71

The correlation between the structure index and associated fact recall was significantly different from zero with fact recall for high-index features being 18 percent greater than for low index features. Two studies (Kulhavy, Stock, Werner-Bellman & Klein 1993; Kulhavy, Stock, Woodard & Haygood 1993, second experiment) employed a different accuracy approach. Students were asked to learn a map of a city that had a compass rose at the centre of the map. At recall, the students were provided with a series of blank sheets of paper, each with a compass rose at the centre (in the same position as the one on the map). On each of these sheets subjects were asked to draw a line from the centre of the compass rose to the exact location of a feature from the city map. The name of the feature was given as a clue. They were also asked to write down the facts about that map feature from the text after drawing the line. By using the angle and length of the constructed lines, they were able to compute a goodness-of-fit index using the polar coordinates formula for Euclidean distance:

$$\text{Goodness of fit} = \Sigma \frac{(\text{Student distance} - \text{Objective map distance})^2}{\text{Objective map distance.}}$$

Average fact recall for subjects with higher goodness-of-fit values was 21 percent higher when compared to those with lower goodness-of-fit values. Kulhavy and his colleagues argue that these results further support the notion that the structural characteristics of the map image facilitate retrieval of associated text information.

Thematic Maps

Most of the research completed used maps that contain landmark features (e.g cities, banks, caves, palaces), but during the past decade thematic maps have also been incorporated into the research and the theoretical model (see Rittschof, Kulhavy, Stock & Hatcher 1993; Rittschof, Stock, Kulhavy, Verdi & Doran 1994). Rittschof *et al.* (1993) define thematic maps as a base reference map with one or more data themes distributed over the portions of the base map. With regard to the previous research and the conjoint retention model, such thematic maps are interesting because the thematic variables can be depicted in a variety of ways that vary in the extent that they depend on structural information. Therefore, thematic maps provide a way to examine the relative influence of structural and feature information on memory for related text. Rittschof *et al.* (1993) also argue that themes add meaning to the map in the sense that they allow levels of one or more variables to occupy the map space. In a 1993 study Rittschoff and his colleagues had subjects view one of four maps (3 thematic, 1 non-thematic) of Ceylon (present day Sri Lanka) and read a text based on information from the three themes. The thematic variables of agriculture, elevation, and rainfall were depicted using bounded areas that varied in their level of gray tone. The study demonstrated, in all cases, that people seeing a particular theme recalled more text facts related to that theme and that the theme distribution worked in a similar fashion as point designations had done in previous maps text research. Rittschof and Kulhavy (1998) found that college students could reconstruct similar amounts of map information from any of the four types of maps included in the study. More importantly, Rittschof and Kulhavy found that text recall from a fact-based text was facilitated by the themes presented on the thematic maps. It should be noted that in this case the authors used actual facts but placed them randomly with a given location.

Individual Differences

Individual differences have also been examined within the map-text research. Specifically, differences between males and females and cognitive styles have been examined. Schwartz and Phillippe (1991) examined cognitive differences using the Group Embedded Figures Test (Oltman, Raskin & Witkin 1971) and recording whether the subject was male or female prior to the experiment. They observed that on map recall and map reconstruction, field-independent subjects outperformed field-dependent subjects. Finally, females remembered more of the map's features than males when asked to list them verbally, and outperformed males on map reconstruction. Rittschof, Griffin and Custer (1998) also conducted a study involving cognitive styles. They had students study one of four types of maps and then read a related text. The maps (a choropleth-shaded map, a proportional symbol map, a numerical data map, and a control chart) depicted book reading in Southwestern Oklahoma. The text that students read was related to the displays. Following the study of the materials, students were asked to recall what they could from the text and then to answer inferential questions concerning the map. The results of the study were quite robust and interesting. Students viewing one of the three maps as opposed to the control chart recalled 17% more county names and 45% more relative information. Moreover, more related text information was recalled than unrelated text information.

Task Demands

The instructions that the subjects are given about the task also influence recall. Text fact recall is enhanced when students are required to process map information. Dean and Kulhavy (1981) observed in their first experiment that those who were required to create a map based on the text material presented, recalled significantly more information than those who did not. In a second experiment they observed that when a person is forced to encode a spatial organizer prior to reading are more likely to retain the material studied. When Schwartz and Phillippe (1991) instructed subjects to learn map features by clustering them together, either by their semantic or spatial relationship, subjects recalled the information accordingly.

Present and Future Directions

Currently, there are five under-tapped areas of research in the map-text tradition. The first one study is the examination of eye scanning patterns of subjects while they view a map. One study is in preparation and will focus on the discrepancy between the perspective map studies discussed earlier. A second study which examines eye scanning patterns for subjects who see a map first versus those who see a text first will also be completed. There also has been a lack of research in other domains (e.g. biology). Some research has been conducted with science (e.g. Verdi, Johnson, Stock, Kulhavy & Ahern 1997) and math, but most of it is unpublished at this time. We hope that future research will begin to examine other domains. A third area is the manipulation of the textual material in the tradition of text structure researchers. A study is presently underway that manipulates the structure of the text in order to see if it will influence recall. Next, a conditional probability model for recall of each map feature model is currently under development based on all of the previous observationS and new considerations. Currently, the model stands as such:

$$P\,(C_{ri} |\, M_{fs}, E, L, C, T, R)$$

where,

* C_{ri} is the Correct recall of feature or fact i

* M_{fs} is whether the map was viewed first or second
* E was the item near an edge
* L was the item located correctly on the map reconstruction
* C was the item a concrete feature or abstract
* T was the text organized or random, and
* R recognition level of the item (word frequency book).
* Finally, work with computer generated maps is just beginning.

Computers have the

* potential to create layers of maps that are easily accessible where paper maps have to be
* switched. Obviously, this is a potentially rich research area.

Summary

In this article we have reviewed how maps improve the recall of associated text and have presented a review of a theoretical model that we feel explains the processing of map-text information. Twenty plus years of research have provided a great deal of information about how people process and recall information from maps and text within the conjoint retention hypothesis. The findings show that structural elements in maps, order of presentation or maps and texts, individual differences, accuracy and task demands all influence the recall of information and corroborate our model. Within the cognitive system, both the form of representation and the constraints imposed by resource limitation of working memory are highly influential in determining the level of information acquisition and recall. Yet there is still a pressing need for research aimed at helping geographers and others understand how various map configurations affect the way in which people use maps (Johnson, Verdi, Kealy, Stock & Haygood 1995). In this article, we have reviewed one way in which the content of maps can be assessed in terms of the cognitive relationship and the research observations over the past two decades. Research using the type of map-text stimuli reviewed here allows us to test how a pictorial display is likely to be represented and what sorts of tasks a person is able to perform using the representation. The information that is retained about the space of a map is dependent upon both the properties of the map itself and on the transformation selected by both the map maker and reader. It is hoped that the past research, the research that is underway, and the research yet to be designed and completed will continue to increase our understanding of how organized spatial displays, such as maps, can be used to increase recall and retention of text material and how we process pictorial and verbal information.

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