Journal of Interactive Online Learning
www.ncolr.org/jiol
Volume 5, Number 3, Winter 2006
ISSN: 1541-4914

Effects of Concreteness and Contiguity on Learning from Computer-based Reference Maps

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Abstract

Today's technology has reached new heights that have not been fully implemented. One of the areas where technology has not yet reached its full potential is in education. This study examined the effects of concreteness of location names and contiguity of location names with textual information on learning from computer-based reference maps. The research was designed to be a 3 concreteness (concrete vs. abstract vs. non-familiar) X 2 contiguity (non-contiguous vs. contiguous) with six treatment levels. One hundred and sixty-seven college students studied a digital reference map presented to them. The results indicate that participants in the contiguous condition recalled significantly more feature-related facts than those in the non-contiguous condition. The results also indicate that the participants' performance in recall, matching feature-fact pairs, as well as in the inference was significantly more for concrete features names and abstract feature names than the non-familiar feature names. A significant interaction effect was also observed for the matching of fact-feature pairs. The findings are not thoroughly consistent with the concreteness and conceptual peg effects associated with Paivio's dual coding theory (DCT). More research needs to be done to continue investigating this phenomenon. However, this study will assist teachers and designers better understand how to design cognitive maps and spatial displays that facilitate learning.

Maps

Participants are used to learning maps from textbooks or atlases in which they have to turn pages every time to find facts about a location. Multimedia maps overcome this annoyance. Though there are a number of definitions of multimedia. For this paper Mayer & Anderson's (1991) definition of multimedia is used: "multimedia is presentation of material using both words and pictures." When a geographical map is presented in a way where the graphical map and facts are presented on the computer screen, it becomes a multimedia map. There are different ways in which a multimedia map can be designed. One way is to have feature-to-fact contiguity where feature names and facts are placed contiguous to each other with respect to time. Also, it is not uncommon for participants to recall facts about certain locations better than others. This paper investigates the effects of concreteness of map feature names and the effects of feature-to-fact contiguity on learning from computer-based maps. This study has theoretical and practical implications for those involved in geography instruction and instructional design.

Theoretical Framework

The location of feature-related facts in relation to a map is an important consideration that may influence learning from a map and corresponding text. In most studies involving learning from reference maps, the maps are placed on separate sheets of paper from their feature-related facts (Kulhavy, Stock, & Kealy, 1993). In addition, the facts are written in an integrated narrative format with transition statements linking all of the feature-related facts together to describe the overall map. This was the best way to present maps and related information in the print medium, as seen in books and atlases. The computer, however, provides the capability by using hyperlinks for embedding feature-related facts directly within map features. This allows for spatially or temporally locating facts contiguous to their corresponding features on a map. Thus, instead of feature-related facts being linked to other facts through transition statements in a separate narrative, they are directly linked to the features they represent on a map creating an integrated multimedia presentation (Mayer & Moreno, 2003). According to Mayer and Anderson's (1992) contiguity principle, multimedia instruction is more effective when words and pictures are presented contiguously in time or space. This suggests that words and corresponding pictures are either temporally or spatially contiguous. However, it is not possible for words and pictures to be spatially contiguous without also being temporally contiguous. Therefore when words and pictures are presented simultaneously within a static map, they are temporally as well as spatially contiguous. In other words, their relationship can be described as possessing spatiotemporal contiguity. Mayer and Anderson’s (1992) contiguity principle has been tested for scientific content that include animations. The visual impacts of those animations have been high under contiguous conditions.

Paivio and his colleagues have studied the implications of dual coding theory (DCT) in instructional design and its key role in the learning process (Clark and Paivio, 1991; Sadoski and Paivio, 2001). DCT contends that learning is facilitated by the combined action of verbal and non-verbal subsystems that are specialized in processing linguistic and non-linguistic information respectively. Another implication is that verbal information that is concrete will be more easily remembered than verbal information that is abstract. According to Paivio (1971), concrete and abstract words are distinguished primarily on “their differential capacity to evoke concrete images as associative reaction” (p. 60). Concrete information is better comprehended and integrated in memory than abstract information because concrete information makes it easier to evoke mental images enabling encoding of the information in both verbal and visual memory codes. The positive effect of concreteness has been well-established in the research literature on recall and recognition of words and phrases (see Paivio, 1971, 1986), and comprehension of sentences, paragraphs, and text chapters with a variety of text types (Sadoski & Paivio, 2001). On the other hand, the effects of concreteness on paired associate learning resulted in Paivio’s conceptual peg hypothesis (Paivio, 1971, 1986), which suggests that mental images play an important role in episodic memory by acting as “conceptual pegs that link, integrate, and unify memories” (Sadoski & Paivio, 2001, p. 110). A large body of research now enables us to predict that “with all else equal, concreteness will be the best predictor of comprehension and recall” (Sadoski, Goetz, & Fritz, 1993, p.292).

In the case of map studies (Crooks et al., 2006; Ou et al., 2005), it has been recorded often that participants tend to remember certain facts related to maps more than others. It is also noticed that they are able to recall certain feature-names in the maps more often than other feature-names. Based on DCT it is evident that participants have been able to form connections between feature names and their associated structures. Does a concrete word that conjures an image in the mind of the reader have the same impact that animations have? Based on DCT it can be assumed that words that are highly concrete are easier to recall because they create a visual mental image. The visual impact of concrete and familiar words in the map learning context under static conditions has not been much researched. Is it easier to recall names and their facts if the names are concrete words or familiar words? However, it would be a good instructional strategy to promote learning of facts as related to non-familiar words (non-familiar and non-concrete). This is important because numerous names in maps are non-familiar words. There are a number of abstract words and words that are non-familiar. A design that considers this aspect of maps is required as it would help students in map learning irrespective of whether the names of places are concrete or abstract. The contiguity principle should be helpful in these learning situations as it would involve the effective use of the available cognitive resources for comprehension. In the current research the applicability of the contiguity (temporal) principle in an instructional situation (i.e., map learning) involving concrete, abstract and non-familiar names of locations in the map was studied.

The research questions for this study were:

1. What effect does contiguity (non-contiguous vs. contiguous map features) have on the name-recall, fact-recall, matching of name to fact, and inference performance of participants studying a computer-based map?

2. What effect does feature-name type (concrete vs. abstract vs. non-familiar) have on the name-recall, fact-recall, matching of name to fact, and inference performance of participants studying a computer-based map?

3. Is there an interaction between contiguity and feature-name type on name recall, fact recall, matching of name to facts, and inference performance of participants studying computer-based map?

Method

Design and Participants: This experiment studies the effects of feature-name type and contiguity on learning from reference maps. Feature-name type (concrete vs. abstract vs. non-familiar) and contiguity (non-contiguous vs. contiguous) were examined between subjects to form a 3 X 2 factorial design. The participants consisted of 167 undergraduate students from a large southwestern university who were enrolled in an undergraduate course focused on computer literacy. They received bonus credit for participation. Each participant was randomly assigned to one of the six experimental conditions. All statistical tests were performed with alpha at .05.

Materials

The materials consisted of three versions of a fictional map depicting 16 feature-names (concrete, abstract and non-familiar words) from the island of Malta and two manipulations of a 470-word text (non-contiguous and contiguous) consisting of facts about the features. The displays and the text were created using Macromedia Director© 8.5 for presentation on a 17-inch computer monitor. Each version of the text consisted of 16 one-sentence facts paired with feature names. There was one fact associated with each feature name. A list of 130 words was given to participants to norm them as concrete, abstract and non-familiar words. Sixteen words that were considered highly concrete, sixteen words that were considered highly abstract, and sixteen words that were considered highly non-familiar were chosen for this study. The concrete versions of maps had names of locations that were concrete, like temple, apple, etc. The abstract versions of maps had names of locations that were abstract, like kindness, wonder, etc. The non-familiar versions had names of locations that were non-familiar and hence participants would not be able to tell whether they were concrete or abstract like nandina, erbium, etc. However, the locations of the places were consistent across all maps as shown in Figures 1 and 2. The same location would have a concrete name in the concrete versions, an abstract name in the abstract versions and non-familiar names in the non-familiar versions. Those studying under the contiguous condition viewed feature-related facts by clicking on a feature and facts related to that particular feature would be displayed contiguous with respect to time on a different screen. The delay of less than a fraction of a second makes it temporally contiguous. Participants studying non-contiguous materials viewed all the feature-related facts together in a narrative format on a separate screen from the map. So, the six treatments were contiguous-concrete, contiguous-abstract, contiguous-non-familiar, non-contiguous-concrete, non-contiguous-abstract, and non-contiguous-non-familiar.

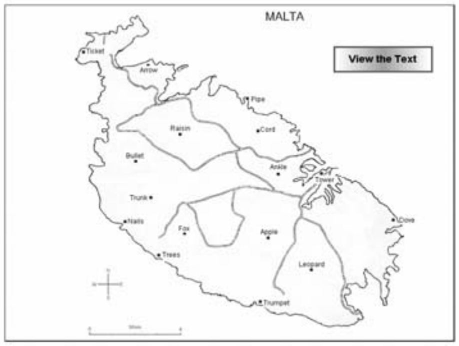
Figure1. **Screen shot of temporal contiguity treatment.**

Map Display

Text Display

Figure 1. **Sample screens showing how the Malta map and text information was displayed in the temporal contiguous condition.**

Figure 2. **Screen shot of no-contiguity treatment.**



Map Display Text Display

***Figure 2.* Sample screens showing how Malta map and text information was displayed in non-contiguous condition.**

Criterion Measures: The criterion measures consisted of two retrieval measures, an inference measure and an attitude survey. The retrieval measure was a free recall test designed to assess participants' retention of the display feature names and related facts. The participants were instructed to write down all that they could remember from their study of the Malta map. Scoring this measure gave scores for three dependent variables which included number of feature names recalled, number of feature-related facts recalled, and number of feature-fact pairs matched. Two points were given if a name recalled was correct, and one point was given if the name was correct but phonetically wrong. For fact recall, one point was given if facts recalled were correct. Points were given for getting just the gist of the fact without full sentences. For matching, one point was given if the names matched with the precise fact. The map reconstruction asked the participants to mark the locations of all the places on the blank paper that had the outline of a computer screen. Map-reconstruction was not scored for this study as it will be studied along with another study on similar lines.

The inference measure contained an 11-item constructed-response test (16 points possible) that was designed to assess the participants' ability to make inferences requiring higher-order thinking level. To correctly answer the items, the participants were required to infer information about Malta that was not specifically stated in the materials. This measure was scored by giving one point for each item answered correctly. The attitude survey was not scored for this study. to participate. This study was held in a computer lab containing 25 IBM-compatible computers. Attendance at each experimental session ranged from 20 to 25 participants. All participants

Procedure: Participants volunteered were given verbal instructions, guiding them to learn as much of the map as possible. All participants were given 10 minutes to study the map. Ten minutes was considered sufficient for this study because the text had 21 sentences with a total word count of 470. An example of a sentence from the text is: "Tower is decorated with several beautifully tended gardens." The issue of ecological validity was also considered while developing this short map study. Most people would spend on an average 15-20 minutes on a map or on an encyclopedia. The average attention span of students is not more than 15 minutes. In the real-world environment, students tend to lose focus when longer lessons are involved. Hence, in order to make this study more generalizable it was decided that a 10 minute lesson would support ecological validity.

After studying the map, participants were given four paper-based instruments with two retrieval measure, one inference measure, and an attitude survey to determine the effects of the treatment conditions. One retrieval measure was a free recall of map names, facts, and their match for which they were given eight minutes to complete. Participants were required to only write the names of the places and a key word about the specific place. A second recall measure was map-reconstruction for which they were given five minutes to complete. For this measure, participants had to visualize the Malta map and mark the locations of the places. For the 11-item inference test participants were given five minutes. Participants had to read the questions and answer to the best of their ability. An example of an inference question used was, "Susan is conducting research on the religious life and history of Malta. Which place/places should Susan visit to help her with her research?" This question had three answers. The answers also depended on which version the participant had. For the concrete version the answers would be: Trumpet, Fox, Nails; for the abstract version the answers would be: Belief, Disgrace, Because; and for the non-familiar version the answers would be: Hafnium, Kalmia, Erbium. Some inference questions had one answer; some had two, while some had three answers.

Results

Cronbach alpha reliability coefficient for feature recall was .761, for fact-recall .731, for matching fact-feature .762 and for inference it was .768. The two-way ANOVA for fact recall yielded significance on the contiguity factor, $F(1, 161) = 15.432$, $p = .000$. The contiguous condition recalled significantly more feature-related facts ($M = 11.024$) than those in the non-contiguous conditions ($M = 8.8941$). The two-way ANOVA on the concreteness factor yielded significance for both name recall $F(2, 161) = 49.788$, $p = .000$ and matching of fact-feature $F(2, 161) = 8.868$, $p = .000$. Scheffe tests on the concreteness factor showed that participants in both concrete ($M = 16.75$) and abstract ($M = 16.00$) conditions recalled more names than those in the non-familiar word condition ($M = 6.54$) and matched more feature-fact pairs in concrete ($M = 7.07$), abstract ($M = 6.1071$) conditions than those in the non-familiar condition ($M = 3.5$). The ANOVA conducted on the inference test reached significance on the concreteness factor, $F(2, 161) = 10.581$, $p < .01$. Scheffe multiple comparisons revealed that participants in the concrete ($M = 5.25$) and abstract ($M = 5.96$) conditions performed significantly better on the inference test than those in the non-familiar condition ($M = 3.3793$). Table 1 gives a detailed description of the means and standard deviations of all the six treatments for the four criterion measures.

Table 1
Means and Standard Deviations for Feature Recall, Fact Recall, Match Fact-Feature and Inference Test Performance

Dependent Variable		Concrete Features (n=56)			Abstract Features (n=53)			Non-familiar Features (n=58)		
		Non-contiguous (n=28)	Contiguous (n=28)	Total (n=56)	Non-contiguous (n=25)	Contiguous (n=28)	Total (n=53)	Non-contiguous (n=32)	Contiguous (n=26)	Total (n=58)
Feature Recall	Mean**	15.25	16.75	16.00	19.36	16.00	17.58	8.78	6.54	7.78
	SD	5.44	5.92	5.69	5.76	5.51	5.83	6.48	4.66	5.80
Fact Recall	Mean*	7.53	10.78	9.16	9.96	10.28	10.13	9.25	12.07	10.52
	SD	3.20	3.35	3.64	3.85	3.98	3.88	3.42	3.11	3.55
Feature-Fact Matches	Mean***	4.78	7.07	5.93	7.16	6.10	6.60	4.65	3.50	4.14
	SD	2.62	3.19	3.11	3.70	3.49	3.60	3.72	2.90	3.40
Inference Test	Mean****	4.50	6.00	5.25	6.44	5.53	5.96	3.78	2.88	3.38
	SD	3.22	2.37	2.90	3.24	3.60	3.43	3.62	2.43	3.16

Mean* represents significance on contiguity F (, 161) = 15.432, *p = .000*. Mean** represents significance on concreteness for feature recall F (2, 161) = 49.78, *p = .000*. Mean*** represents significance on concreteness for feature-fact matches F (2, 161) = 8.86, *p = .000*. Mean**** represents significance on concreteness for inference F (2, 161) = 10.58, *p* = . 1*000*.

An interaction effect was observed between concrete and contiguous conditions for the matching of fact-feature pairs with a significance of F (2, 161) = 4.883, p = .009. This can be seen in Figure 3.

***Figure 3.* Interaction plot between contiguity and concreteness.**

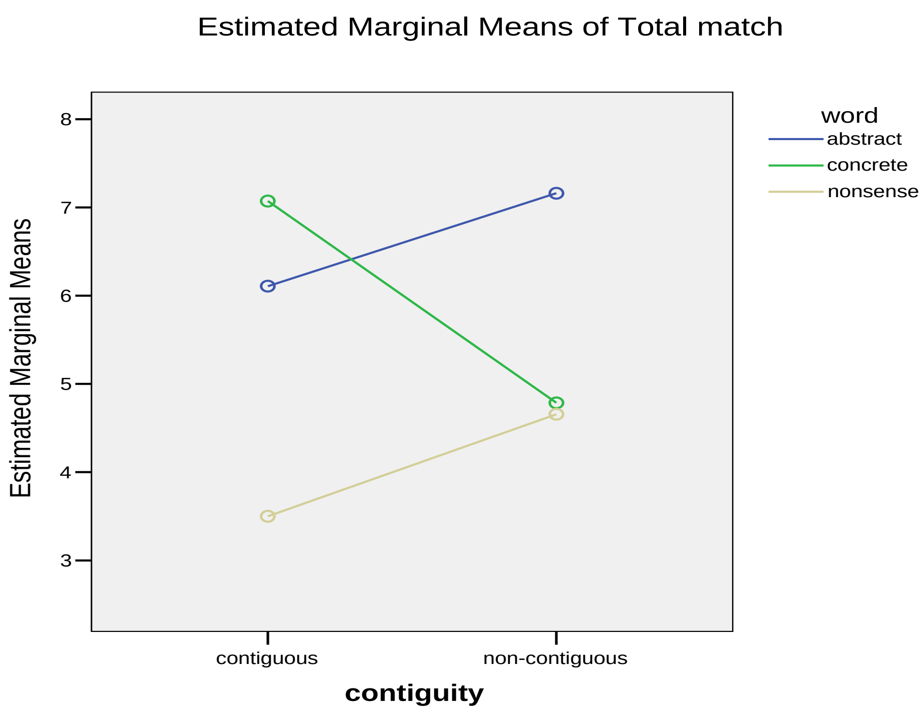


***Figure 3.* Interaction plot between contiguity and concreteness for the feature-fact match measure.**

Discussion

The results from the study show a clear contiguity effect for recalling facts, while a clear concreteness effect is shown in recalling of names, matching of feature names with fact recall and also a concreteness effect for the inference measure. Participants in the contiguous condition recalled more feature-related facts.

Contiguity: Contiguity effect for recalling facts shows that irrespective of the type of words used, contiguity assists in recalling facts. However, contiguity did not support feature name recall and inference measures. Contiguity effect is based on the fact that when corresponding words and pictures are presented near each other, learners are more likely to be able to hold corresponding words and pictures in working memory at the same time (Mayer & Moreno, 2003). This enables the process of integrating visual and verbal models, a key step in meaningful learning. Contiguity effect has not shown support for all criterion measures probably because of the effect of abstract and non-familiar words. Previously, studies not producing a contiguity effect, had used materials that were not visually rich such as application software screens (Chandler & Sweller, 1996; Sweller & Chandler, 1994) electrical schematics (Sweller & Chander, 1994), and chemical diagrams (Carlson *et al*., 2003). Concrete words when contiguous to facts strengthen the referential links between the visual image and verbal facts, thereby resulting in a greater recall and inference performance. The two forms of mental representation available for processing concrete features provide stronger referential links to associated facts in contiguous conditions and thereby improve both recall and inference (Paivio, 1971, 1986; Sadoski & Paivio, 2001). In the case of abstract words and non-familiar words, this dual form of representation links is not available and hence could have resulted in the lack of significance.

Concreteness: This finding supports the prediction based on dual coding theory that learning is easier with concrete and familiar abstract words rather than non-familiar words. Apparently, connecting links, or referential connections between visual and verbal material are stronger when these elements are processed together (contiguous) at the time of encoding (Mayer & Anderson, 1991, 1992; Paivio, 1986). This means that concrete words like tower, evoke a mental image, while abstract words like kindness would evoke some visual event connected to the word that make it easier for learners to connect the name of the location to a mental image. On the other hand, non-familiar words like nandina, do not evoke a visual image or a connection, and so learners have difficulty recalling the name which results in problems matching non-familiar names to their facts.

Interaction: The interaction effect on match recall also grabs attention. Contiguity has helped in matching concrete name labels to their corresponding facts but not so for non-familiar name labels. This is because concrete words contained within a graphic display (i.e. map) have a dual coding effect. For example, when learners read the name Tower in the map, they activate both a verbal and a visual image code within working memory. Dual coding theory maintains that referential links are formed between these two codes so that if, during recall, the verbal code cannot be activated directly it can be activated referentially through a link with the image code (Paivio, 1986). The basis of the current hypothesis is that referential links can only be exploited if the concrete name labels and their corresponding facts are studied concurrently in working memory. The two forms of mental representation available for processing concrete features provide stronger referential links to associated facts in contiguous conditions and thereby improve both recall and inference (Paivio, 1971, 1986; Sadoski & Paivio, 2001). Abstract words would not be able to produce the same dual coding effect. So, when abstract words are contiguous (or non-contiguous) to facts there are no referential links formed between a visual image and the verbal facts as there is no visual image that exists. This lack of referential linkage hinders recall and inference performances.

In summary, the current research provides evidence that instructional designers should consider contiguity as an effective strategy for promoting learning from computer-based maps, especially when dealing with verbal texts. From a theoretical standpoint, this research supports dual coding theory by highlighting the importance of mental images in individual map features. This study has again proved that concreteness is effective and if instructional designers can come with ways to include texts that have more concreteness to it, it would go a long way in helping the learning process.

Contiguity can be of many types and further research on this effect should investigate the effect of all the different types of contiguity. For example, it is possible to have same screen contiguity without being very close in space to the name label. It is common to see a corner of the screen used up by facts. The effectiveness of such a design is worth researching as it is commonly used. Further research should also explore the learning potential of reference maps that more fully realize the potential of modern computing. These could include three-dimensional, multi-layered, and virtual maps. Concreteness can also be studied by bringing in another factor such as the number of syllables and study it with different levels of concreteness, such as used in this experiment.

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