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How Does Creating a Concept Map Affect Item-Specific Encoding?

Phillip J. Grimaldi, Laurel Poston, and Jeffrey D. Karpicke
Purdue University

Concept mapping has become a popular learning tool. However, the processes underlying the task are poorly understood. In the present study, we examined the effect of creating a concept map on the processing of item-specific information. In 2 experiments, subjects learned categorized or ad hoc word lists by making pleasantness ratings, sorting words into categories, or creating a concept map. Memory was tested using a free recall test and a recognition memory test, which is considered to be especially sensitive to item-specific processing. Typically, tasks that promote item-specific processing enhance free recall of categorized lists, relative to category sorting. Concept mapping resulted in lower recall performance than both the pleasantness rating and category sorting condition for categorized words. Moreover, concept mapping resulted in lower recognition memory performance than the other 2 tasks. These results converge on the conclusion that creating a concept map disrupts the processing of item-specific information.

Keywords: concept mapping, episodic memory, learning, free recall, recognition

Since their introduction nearly 35 years ago (Novak, 1979), concept maps have become a popular learning tool among educators. A concept map is a two-dimensional spatial representation of knowledge, where individual concepts are represented as nodes in the map, and the relationships among nodes are represented as lines with linking phrases (see Figure 1). Despite the popularity and widespread usage of concept mapping, the tool has been the subject of surprisingly few experimental studies. Even fewer studies have examined the theoretical underpinnings of concept maps. Some researchers have claimed that the act of making a concept map can itself be seen as an important learning event (Freeman & Jessup, 2004). Thus, pinpointing the processes that are involved in concept map creation could allow educators and researchers to identify situations in which concept mapping would be effective. The purpose of the present study was to examine concept mapping in a controlled laboratory setting to deepen our theoretical understanding of the encoding processes afforded by the task.

What are the processes that might occur during the creation of a concept map? Because of the inherent organizational nature of the task, one obvious candidate is *relational processing*. During the creation of a concept map, students must take individual concepts and form an organizational structure by evaluating the relationships among all of the concepts. Indeed, concept mapping researchers typically appeal to the organizational nature of concept mapping as an explanation of its effectiveness (Fraser, 1993). In an influential report, Novak and Cañas (2006) stated, ". . . one of the reasons concept mapping is so powerful for the facilitation of meaningful learning is that it serves as a kind of *template* or *scaffold* to help to organize knowledge and to structure it . . ." (p. 7). This explanation certainly seems reasonable. Cognitive scientists have long understood that organization and relational processing are important for memory (e.g., Köhler, 1941; Mandler, 1972). Thus, it could be reasonably argued that concept mapping improves learning because it enhances relational processing.

One learning process that has yet to be considered in the concept mapping literature is *item-specific processing* (Eysenck, 1979). Whereas relational processing refers to processing of common features of multiple items, item-specific processing refers to processing of the unique features of an individual item. Thus, to provide a comprehensive understanding of a set of materials, it is necessary to promote learning of both relational and item-specific information. To our knowledge, no studies have examined the relationship between concept mapping and item-specific processing. A primary goal in the present article is to establish how creating a concept map affects the processing of item-specific information. In the following section, we review the theoretical role of both relational and item-specific processing in learning.

Item-Specific and Relational Processing

A large number of studies have shown that encouraging both relational and item specific processing produces better learning than either process by itself (Hunt & McDaniel, 1993). Therefore, it is particularly important to determine which of these processes concept mapping affords. To illustrate how the two processes complement learning, we will describe an influential study by Einstein and Hunt (1980). In Experiment 2 of their study, subjects

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Phillip J. Grimaldi, Laurel Poston, and Jeffrey D. Karpicke, Department of Psychological Sciences, Purdue University.
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Correspondence concerning this article should be addressed to Phillip J. Grimaldi, Department of Psychological Sciences, Purdue University, 703 Third Street, West Lafayette, IN 47907-2081. E-mail: pgrimald@purdue.edu

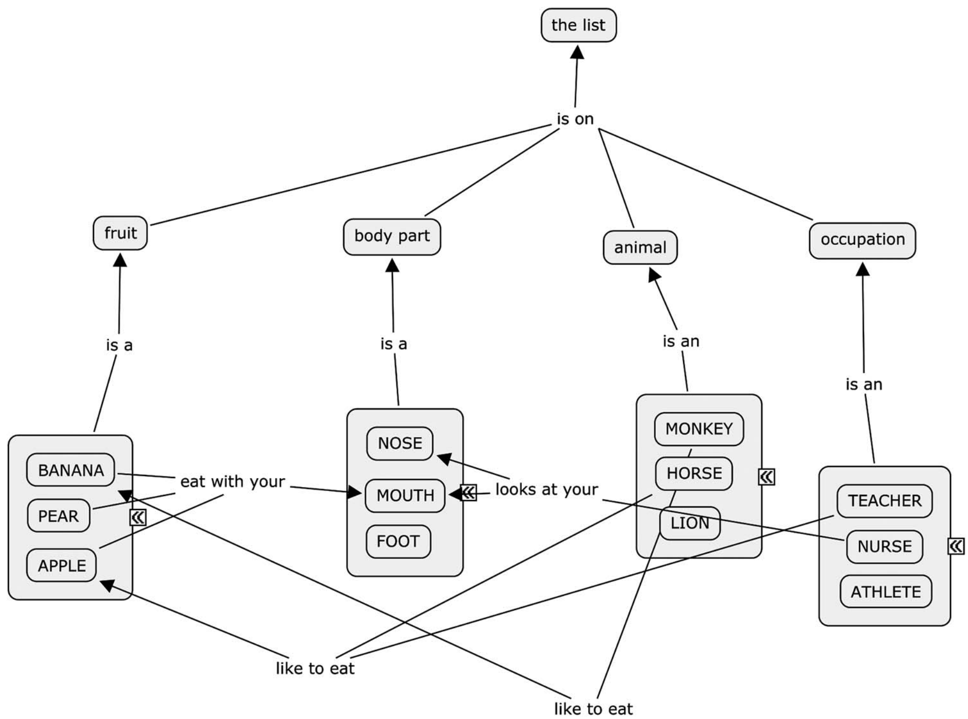

Figure 1. Example of a concept map. This map was used as an example during training of subjects in Experiment 1.

learned lists of words by performing either a relational processing task (category sorting) or an item-specific processing task (making pleasantness ratings). The structure of the word list was manipulated so that the list either had a salient categorical structure (a categorized word list; *fruits*, *animals*, etc.), or had a nonobvious categorical structure (an ad hoc word list; *things that are green*, *things that fly*, etc.). For the ad hoc word list, category sorting produced better free recall performance than making pleasantness ratings. The explanation was that the ad hoc list naturally afforded item-specific processing, so item-specific processing in the pleasantness rating task was redundant with the list, whereas relational processing from category sorting was complementary. For the categorized word list, making pleasantness ratings produced better free recall performance than category sorting. The explanation for this finding was that the categorized list naturally afforded relational processing, so the item-specific processing from pleasantness ratings was complementary to the list, whereas the relational processing from category sorting was redundant. These basic findings have been replicated many times since the original study (e.g., Einstein, McDaniel, Bowers, & Stevens, 1984; Hunt & Einstein, 1981).

As a general rule, learning is enhanced when encoding processes are complementary to the materials being learned. However, the benefits of relational and item-specific processing also depend on the nature of the retrieval problem to be solved. In a free recall scenario, the task is to recall the words from a list without any explicit cues provided. Relational information is particularly important when faced with this type of retrieval problem, because recognizing relationships among items helps form general cues that can be used to guide the search process and improve the probability of successful recall. However, in a recognition memory scenario, subjects are presented with old words that were in the list as well as new words that were not, and the task is to determine whether or not a given word was presented in the original list. Item-specific information is important when faced with this retrieval problem, because having processed the unique features of items helps subjects discriminate between new words and old words. Relational processing does not typically help solve this retrieval problem, as knowing how words in a list were related does not help discriminate between new and old words. Indeed, a number of studies have shown that making pleasantness ratings produces higher hit rates and reduces false alarm rates relative to category sorting (Hunt, 2003). In summary, item-specific processing is very important when recognition is required at retrieval, whereas relational processing is not as beneficial.

A final point to consider regarding the role of relational processing and memory is that sometimes too much relational processing can hurt learning. As mentioned previously, one of the reasons why relational processing is important is because it establishes cues that can be used to limit the search set at retrieval. For instance, knowing that several items on a list were "fruits" can help to constrain the search process. However, the effectiveness of a cue to elicit recall of any one item diminishes as the number of items subsumed under a cue increases, a phenomenon known as cue overload (Watkins & Watkins, 1975). Thus, the effectiveness of any relational encoding task depends in part on whether the relational cues that are being developed specify an optimal number of items. If too many items are related to a particular cue, that cue will not be very effective at later retrieval.

Introduction to the Experiments

The above discussion illustrates how memory performance can vary greatly depending on the structure of the materials, the nature of the retrieval problem to be solved, and the extent to which an encoding task affords relational or item-specific processing. Thus, to determine how effective concept mapping will be for a given set of materials or retrieval task, it is critical to know the processes involved in the creation of a concept map. Concept mapping is presumed to afford some degree of relational processing (Novak & Cañas, 2006), because a major component of the task is to find and label as many relationships among a set of concepts as possible. However, the degree to which concept mapping affords item-specific processing is less clear. Concept mapping could promote item-specific processing by using cross category relationships to differentiate items within a related category. For instance, when a subject begins creating a concept map, they create clusters of highly related concepts. However, students are then encouraged to determine whether items within different clusters in the map are also related (Novak & Gowin, 1984). Identifying these extra relationships might serve to distinguish a concept from other highly related concepts within its parent category. In this sense, subjects may focus on what makes an item unique from other highly related items. On the contrary, emphasizing how items within a set are related may draw attention away from processing the unique features of the items, because the task emphasizes finding shared features among items. Additionally, creating a concept map requires several actions that may be considered nonessential to learning (e.g., arranging nodes, creating links, typing relationships, etc.), and these actions may draw cognitive resources away from processing item-specific information (Geraci & Rajaram, 2002; Joordens & Hockley, 2000).

The purpose of the following experiments was to examine the processes involved in the creation of a concept map, using the logic and design of Hunt and Einstein (1981; see too Einstein & Hunt, 1980). In each experiment, subjects learned a list of words by making pleasantness ratings, sorting the words into categories, or creating a concept map of the words. Subjects learned an ad hoc word list in the first experiment and a categorized list in the second experiment. Subjects returned to the lab 1 day after the learning period for surprise free recall and recognition memory tests. The recognition memory test was included because it is considered to be a particularly sensitive measure of item-specific processing (e.g., Burns, 2006). The 24-hr delay was inserted to reduce performance on the recognition memory test, which is typically quite high on lists of this length. Thus, in each experiment, the processes afforded by the encoding tasks could be complementary or redundant with the materials. By comparing concept mapping to pleasantness and sorting tasks, which are known to afford item-specific and relational processing, respectively, we were able to make inferences about the processing afforded by concept mapping.

The concept mapping task was modeled on widely used instructions for creating concept maps. According to Novak and Gowin (1984), construction of a concept map should follow the following stages: (a) define the topic or focus, (b) identify the important or general concepts, (c) order the concepts hierarchically from general concepts to most specific, (d) add links to form a preliminary map, (e) add linking phrases to describe the relationships, and (f) look for and create cross links that link together concepts in different subdomain. To create a concept map of a word list, subjects followed the following steps: (a) identify "the list" as the general focal point of the materials, (b) identify related words and create category clusters, (c) arrange the category clusters at the bottom of the computer screen and put "the list" at the top, (d) create a new node that names the category clusters and create links to form the preliminary map, (e) label the links, and (f) attempt to identify as many cross category relationships as possible and create a link between them. Subjects in the present experiments created concept maps with CmapTools, a popular software program for creating concept maps (Cañas & Novak, 2008).

According to past research, tasks that promote relational processing enhance free recall of ad hoc lists, while tasks that promote item-specific processing enhance free recall of categorized lists. Thus, we expected the sorting condition to outperform the pleasantness condition on free recall of the ad hoc list in Experiment 1, and we expected the pleasantness condition to outperform the sorting condition on free recall of the categorized list in Experiment 2 (replicating Hunt & Einstein, 1981). If concept mapping promotes relational processing, then concept mapping should produce better free recall of ad hoc lists relative to making pleasantness ratings in Experiment 1. Note that free recall of ad hoc lists should not be especially sensitive to differences in item-specific processing among the tasks, because the list itself is already presumed to afford item-specific processing. Therefore, if concept mapping has any influence on item-specific processing, it may not be observable in the free recall task of Experiment 1. However, differences in item-specific processing should be observable in free recall of the categorized list in Experiment 2. If concept mapping affords item-specific processing, then it should also produce better free recall relative to sorting the words into categories. If concept mapping has no effect on item-specific processing, then it should produce free recall equivalent to sorting. If mapping disrupts item-specific information relative to sorting, then concept mapping should produce worse free recall than sorting.

With regard to recognition memory performance, tasks that promote item-specific processing typically enhance recognition memory relative to relational processing tasks, regardless of list structure (Hunt & Einstein, 1981). Therefore, we predicted the pleasantness condition would outperform the sorting condition on recognition memory in both experiments. If concept mapping enhances item-specific processing, then it should produce better recognition memory than sorting. If concept mapping has no effect on item-specific processing, then it should produce equivalent recognition memory to sorting. Finally, if concept mapping disrupts item-specific processing, then it should produce worse recognition memory than sorting.

Experiment 1

In Experiment 1, subjects learned a list of words by creating a concept map of the words, sorting the words into categories, or making pleasantness ratings. The word list in Experiment 1 was an ad hoc list, meaning that the list had an underlying categorical structure, but the structure was not immediately apparent. All subjects took a surprise free recall and recognition memory test after a 24-hr retention interval.

Method

Subjects and design. There were 120 Purdue University undergraduates who participated in exchange for course credit. There were three experimental conditions: concept mapping, sorting, and pleasantness. Forty subjects were randomly assigned to each condition.

Materials. An ad hoc word list (e.g., Hunt & Einstein, 1981) was drawn from the Van Overschelde, Rawson, and Dunlosky (2004) category norms. The list contained a total of eight categories (*liquids*, *things women wear*, *things that can fly*, *things that make noise*, *things that are green*, *things made of wood*, *things that are feared*, and *things that melt*), with 10 words per category (80 words total). For each subject, a random five words were selected from each category to be used as targets (40 target words per subject). The remaining 40 words were used as distractors in the recognition memory test. We used a yoked counterbalancing procedure to ensure that each word was used as a target and distractor an equal number of times in each condition. Finally, a practice list of 12 words was also used, which did not use any categories or words from the list of targets.

Procedure. The experiment consisted of two main phases, a learning phase and a final test phase. The learning phase and final test phase were separated by a 24-hr retention interval. Subjects learned a list of target words during the initial learning phase by performing a concept mapping task, a sorting task, or a pleasantness rating task, depending on condition. Subjects were not told they would be tested on their memory. Before starting the learning phase, all subjects received a brief practice period for their respective tasks, using the 12-word practice list.

The list of target words was always presented in a pseudorandom order. Specifically, we constructed the list by first randomly sampling a word from each of the eight categories, shuffling these eight words, and placing them in the list. Another set of words was then sampled, shuffled, and placed at the end of the list. This procedure continued until all words from each category were placed in the list. This method ensured that words from each category were distributed throughout the list. We also ensured that two words from the same category were never presented together. The purpose of this pseudorandomization was to reduce the relational processing afforded by the list, allowing us to make better inferences regarding the relational processing afforded by the orienting tasks.

For the concept mapping task, subjects were first given practice using the CmapTools software (Novak & Cañas, 2006). During the practice period, subjects were shown the practice list and an example concept map of the practice list (see Figure 1). The experimenter then recreated the map using CmapTools and gave real time step-by-step instructions. Then, each subject created their own concept map of the practice list while the experimenter provided tips to the subjects and encouraged them to create as many links as possible. After completing the practice map, the list of target words appeared on the left side of the screen and subjects were given 10 min to create a concept map of the words. Subjects were encouraged to identify as many relationships among the words as possible in the allotted time period.

For the sorting task, subjects first sorted the list of practice words into categories. During practice, the words appeared on the left side of the screen and four boxes, each labeled with a category name, were displayed on the right side of the screen. Subjects sorted the words by dragging the words into the boxes. After sorting the words, subjects then sorted the list of target words. As with the practice list, the list of target words appeared on the left side of the screen and eight boxes with category labels were displayed on the right side of the screen. After all the words were sorted, the words were randomized anew and presented on the left side of the screen to be sorted again. Subjects were given 10 min to sort the words and engaged in the task the entire time period.

During the pleasantness rating task, subjects first rated the list of practice words for pleasantness. The practice words were shown on the screen with five radio buttons, labeled 1 to 5, beneath each word. Subjects were told to rate each word for its pleasantness by clicking on the appropriate radio button, with 1 being very unpleasant and 5 being very pleasant. After all the practice words were rated, subjects rated the list of target words. After all the target words were rated the words were randomized anew and presented on the screen to be rated again. Subjects were given 10 min to rate the words and engaged in the task during the entire time period.

At the end of the study task, the subjects were dismissed and returned to the laboratory for the final test phase 24 hr later. During the final test phase, all subjects completed both a free recall test and a recognition memory test. The order of the two tests was counterbalanced, with a 5-min filler task between the tests. For the free recall test, subjects were given 5 min to recall as many target words from the learning phase as possible. Subjects recalled the words by typing them into a box in the center of the screen. When the subjects pressed “Enter,” the word was submitted to a list on the right side of the screen. Words could not be removed from the list once they were submitted. Subjects were told that they could recall the words in any order, and that they should avoid typing words they did not see in the learning phase and to avoid typing words twice. For the recognition memory test, target words and distractor words were presented to subjects one at a time in a random order. Beneath each word were six radio buttons labeled “Definitely Old,” “Probably Old,” “Maybe Old,” “Maybe New,” “Probably New,” and “Definitely New.” Subjects were instructed to click “Old” if they saw the word in the learning phase and “New” if they did not and to use the scale to indicate their confidence. The recognition memory trials were self-paced, with a 500 ms intertrial interval. At the end of the experiment, the subjects were debriefed and thanked for their participation.

Results and Discussion

We report standardized mean differences (*d*s) and 95% confidence intervals (CI) around the effect size estimates (see Cumming, 2012), which were calculated using the MBESS package for R (Kelley, 2007). We analyzed the following results by examining either the first test only (free recall first or recognition first), or by collapsing across counterbalance order (free recall first and recognition first). The pattern of results did not change either way. All data presented below are collapsed across counterbalance order.

Free recall. The left portion of Figure 2 shows the proportion of words recalled on the final free recall test. Between group comparisons revealed that the sorting condition recalled more words than both the mapping condition, $t(78) = 2.93$, $d = 0.66$, 95% CI [0.20, 1.10], and pleasantness condition, $t(78) =$

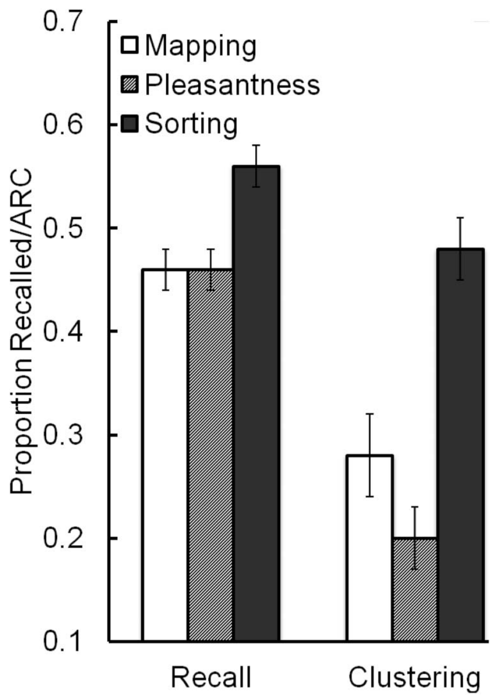

Figure 2. Recall and ARC scores as a function of condition in Experiment 1. Error bars represent *SEM*.

3.59, $d = 0.80$ [0.34, 1.26]. There was no difference in recall between the mapping and pleasantness conditions, $t(78) = 0.16$, $d = 0.04$ [−0.40, 0.47].

The finding that sorting an ad hoc list into categories produced better recall than making pleasantness ratings replicates past research (e.g., Burns & Hebert, 2005; Hunt & Einstein, 1981). The typical explanation for this finding is that the ad hoc list naturally afforded item-specific processing, and the sorting task provided complementary relational processing. Conversely, making pleasantness ratings did not enhance recall performance, because its item-specific processing was redundant with the list. Most important, concept mapping did not enhance recall relative to the pleasantness condition. This finding was unexpected, because concept mapping is thought to promote relational processing, similar to the sorting task. However, as mentioned in the introduction, the value of relational processing depends in the extent to which the cues developed during initial processing aid later recall. In the following analyses, we explored the manner in which subjects in the mapping condition created their maps and how this affected their recall.

Organization. We analyzed the organization of recall output by calculating an *adjusted ratio of clustering* (ARC) score for each participant (Roenker, Thompson, & Brown, 1971). Briefly, ARC scores are a measure of category clustering in recall output, which corrects for the proportion of words recalled by a subject. ARC scores range from 0 (*chance clustering*) to 1 (*perfect clustering*). It is possible to obtain negative ARC scores, but negative scores are difficult to interpret (Murphy & Puff, 1982). For this reason, 10 subjects with negative ARC scores (4 in the mapping condition, 5 in the pleasantness condition, and 1 in the sorting condition) were excluded from the analysis. ARC scores for each condition are shown on the right side of Figure 2. The sorting condition showed greater clustering than both the mapping condition, $t(73) = 3.56$, $d = 0.82$ [0.35, 1.29], and pleasantness condition, $t(72) = 6.09$, $d = 1.42$ [0.90, 1.93]. There was a small difference in category clustering favoring the mapping condition over the pleasantness condition, $t(69) = 1.53$, $d = 0.36$ [−0.11, 0.83].

From the ARC score data, it is clear that subjects in the sorting condition were using the categorical structure of the list to guide their recall, whereas subjects in the other two conditions were not. The fact that concept mapping subjects showed lower ARC scores than category sorting is not surprising, as ARC scores were calculated using the predefined categories of the list, and the nature of concept mapping is to create one's own subjective organization. To examine whether subjects in the mapping condition used their own subjective organization to guide recall, we computed "subjective ARC scores" for each subject by using the categories they created in their map. Three subjects were excluded because of negative ARC scores. The mean subjective ARC score in the mapping condition was .49 (*SEM* = .04). More important, subjective ARC scores were higher than standard ARC scores (.49 vs. .32), $t(35) = 4.26$, $d = 0.71$ [0.34, 1.07], indicating that subjects were more likely to use the subjective categories from the maps to guide recall than the predefined categories of the list. Moreover, the subjective ARC scores in the map condition were higher than standard ARC scores in the pleasantness condition (.49 vs. .24), $t(70) = 5.19$, $d = 1.22$ [0.72, 1.72]. The subjective ARC scores were equivalent to the ARC scores in the sorting condition (.49 vs. .49), $t(74) = 0.20$, $d = 0.05$ [−0.40, 0.50]. Thus, when using the subjective ARC scores for the mapping condition, there was no difference in the degree of clustering between the mapping and sorting conditions, indicating that both conditions seemed to produce equivalent levels of relational processing.

Concept map analysis. Concept mapping did not enhance recall performance as would be expected of a relational processing task. Moreover, the ARC analysis indicated that although recall strategies used by concept mapping subjects deviated from the intrinsic organization of the list, the subjects did use the subjective organization of their maps to guide recall. Why did the relational processing during concept mapping fail to enhance recall performance like the sorting condition? To answer this question we analyzed the maps that subjects created in an attempt to determine how features of the concept maps themselves were related to recall performance.

For this analysis, we counted the number of vertical links, horizontal links, total links, and cluster size for each item in the final concept map from subjects in the concept mapping condition. Vertical links were the number of links from an item to a superordinate concept. Horizontal links were links from an item to other items within the same level but in a different category cluster. Total links were the sum of all links connected to that item. Finally, cluster size was the total number of items within a particular item's category cluster. A detailed description of how the maps were scored, including examples, is shown in the Appendix.

A summary overview of mapping performance is shown in Table 1, which shows the average number of vertical links,

Table 1
Description of Concept Maps Created by Subjects in Experiments 1 and 2

	Vertical links	Horizontal links	Total links	Cluster size
Experiment 1	1.5 (0.8)	0.2 (0.8)	1.7 (1.2)	6.6 (4.2)
Experiment 2	2.2 (0.8)	0.2 (0.7)	2.5 (1.1)	5.0 (0.3)

Note. *SD*s are in parentheses.

horizontal links, total links, and cluster size of all items in the concept maps. A representative example of a concept map made by a subject in Experiment 1 is shown in Figure 3. Subjects made about 1.5 vertical links per item. In an ideal map, each item should include two vertical links, the link to the category name and top-level "list" concept. Thus, it seems subjects had trouble completing the map—either they did not fit an item into a cluster or did not link the cluster to a higher-level concept. Subjects made about 0.18 horizontal links per item. The most interesting aspect of the maps in Experiment 1 was cluster size. The average cluster size was 6.6, and the *SD* was 4.2, indicating that cluster size was not very consistent across subjects. Note that the default organization of the list used 5 words per category. A visual analysis of the maps revealed that subjects would often create a mixture of large and small clusters in their maps (see Figure 3). Thus, subjects structured their maps very differently from the actual structure of the list, which is reflected in the ARC score results.

To examine how the features of the concept maps were related to recall performance, we conducted a binary logistic regression analysis with the four factors described above as predictors of recall on the final test. The results of the analysis are shown in Table 2. The main variable of interest in Table 2 is the odds ratio (OR), which is computed from the exponential function of the regression coefficient *B* for each factor in the model. The OR represents the relative odds of recalling an item given an increase in the factor, accounting for all other factors in the model. Thus, an OR of 1 indicates that increases in the factor do not affect the odds of recall, an OR greater than 1 indicates that increases in the factor improve the odds of recall, and an OR less than 1 indicates that increases in the factor reduce the odds of recall. The Wald χ^2 statistic tests the odds ratio against 1. As can be seen in Table 2, only cluster size was a significant predictor of recall. The odds ratio of cluster size was 0.91, indicating that as the cluster size increased the odds of recalling an item decreased. This pattern is consistent with the principle of cue-overload (Watkins & Watkins, 1975) and suggests that one of the reasons concept mapping was not

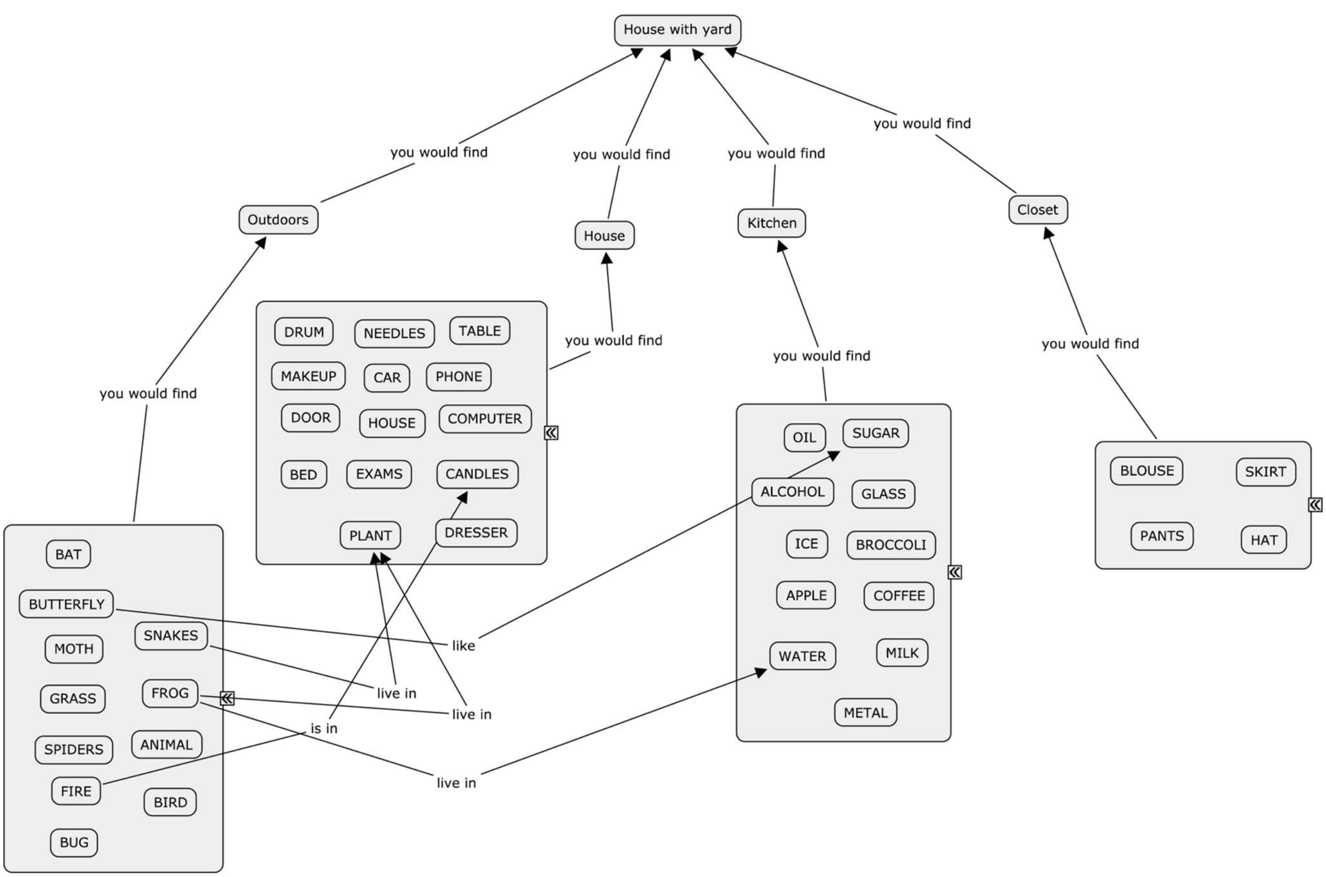

Figure 3. Representative example of a concept map created by a subject in Experiment 1.

Table 2
Binary Logistic Regression Table Predicting Recall of an Item From the Number of Vertical Links, Horizontal Links, Total Links, and Cluster Size

	B	*SE*	Wald χ^2	OR	95% CI for OR
Experiment 1					
Vertical links	−0.28	0.36	0.63	0.75	[0.37, 1.52]
Horizontal links	0.04	0.37	0.01	1.04	[0.50, 2.17]
Total links	0.43	0.36	1.44	1.53	[0.76, 3.07]
Cluster size	−0.09	0.02	39.21	0.91	[0.89, 0.94]
Experiment 2					
Vertical links	−0.53	0.47	1.25	0.59	[0.23, 1.49]
Horizontal links	−0.34	0.46	0.55	0.71	[0.29, 1.75]
Total links	0.58	0.45	1.72	1.79	[0.75, 4.28]
Cluster size	0.04	0.20	0.03	1.04	[0.70, 1.53]

Note. *B* is the estimated increase in the log odds of *Y* per unit increase in X_i. *SE* is the standard error of *B*. *Wald* χ^2 is the test statistic. OR is the odds ratio. An OR of 1.00 indicates there is no relationship. The only reliable predictor of recall was cluster size, in Experiment 1.

effective at improving recall was because subjects were creating large, overloaded retrieval cues.

Recognition. Recognition memory was analyzed using d', and the results are shown in the top half of Table 3. Between group comparisons revealed that the pleasantness condition produced better recognition memory than both the mapping condition, $t(78) = 7.79$, $d = 1.74$ [1.22, 2.25], and sorting condition, $t(78) = 3.47$, $d = 0.78$ [0.32, 1.23]. Moreover, the sorting condition produced slightly better recognition memory than the mapping condition, $t(78) = 2.81$, $d = 0.63$ [0.18, 1.08].

While d' takes into account both hit rates and false alarm rates, we also analyzed each measure separately. Hit rates and false alarm rates in the pleasantness condition were near ceiling and floor, respectively, despite the 24-hr retention interval. According to Levene's test, variance in the pleasantness condition was significantly smaller than it was in the other two conditions for each measure, $F(2, 117) = 7.39$ and $F(2, 117) = 2.89$ for hit rates and false alarm rates, respectively. This issue could not be resolved by conducting arcsine transformations (Howell, 2010). For this reason, we did not perform statistical comparisons between the pleasantness condition and the other conditions. However, the fact that hit rates were so high and false alarm rates were so low in the pleasantness condition is meaningful itself. With regards to the mapping and sorting conditions, hit rates in the sorting condition were higher than they were in the mapping condition, $t(78) = 2.29$, $d = 0.51$ [0.06, 0.96]. There was no meaningful difference between false alarm rates in the mapping and sorting conditions, $t(78) = 1.13$, $d = 0.25$ [−0.18, 0.69]. Thus, the difference in recognition memory performance between the sorting and mapping conditions was driven primarily by differences in hit rates.

The finding that subjects in the pleasantness condition had better recognition memory than subjects in the sorting condition is consistent with past research (Hunt, 2003; Hunt & Einstein, 1981) and illustrates the benefit of item-specific processing for subsequent recognition memory. More important, subjects in the mapping condition had far worse recognition memory than subjects in the pleasantness condition, suggesting that the mapping task did not promote item-specific processing. The magnitude of this difference was large, with an effect size of $d = 1.74$. Interestingly, the subjects in the mapping condition also had worse recognition memory than subjects in the sorting condition. Taken together, the results of Experiment 1 suggest that creating a concept map may have disrupted item-specific processing of words within the list, relative to the relational processing task.

Experiment 2

The results of Experiment 1 suggest that concept mapping disrupted item-specific processing relative to category sorting. In addition, creating a concept map also produced relatively ineffective relational processing. Subjects in the mapping condition tended to overload their organizational cues, which could explain the poor levels of free recall performance. Thus, it seems there were two factors contributing to poor performance in the concept mapping condition on both the recall and recognition tests: increased cue overload and disrupted item-specific processing. In Experiment 2, we used the same conditions and procedures as Experiment 1, except we had subjects learn a list of words with a very obvious categorical structure. To make the structure as obvious as possible, the word list was blocked by category so that words from the same category were presented next to one another (Cofer, Bruce, & Reicher, 1966). We reasoned that with an obvious category structure, subjects in the concept mapping condition would be more likely to create maps that corresponded to the structure of the list and less likely to create maps with overloaded cues.

Method

Subjects and design. Ninety-six Purdue University undergraduates participated in exchange for course credit. None of the subjects had participated in Experiment 1. There were three between-subjects experimental conditions: mapping, sorting, and pleasantness. Thirty-two subjects were randomly assigned to each condition.

Materials. Experiment 1 used a categorized word list containing a total of 80 words, drawn from the Van Overschelde, Rawson, and Dunlosky (2004) category norms. The list contained a total of eight categories (*animals*, *body parts*, *vegetables*, *clothing*, *furniture*, *geographic formations*, *tools*, and *professions*), with 10 words per category. For each subject, a random set of five words

Table 3
Recognition Memory as a Function of Condition in Experiments 1 and 2

	Mapping	Pleasantness	Sorting
Experiment 1			
d′	2.09 (.12)	3.28 (.09)	2.64 (.17)
Hit rate	.85 (.02)	.97 (.00)	.90 (.03)
False alarm rate	.20 (.02)	.12 (.02)	.17 (.03)
Experiment 2			
d′	1.19 (.11)	2.72 (.13)	1.68 (.12)
Hit rate	.77 (.03)	.93 (.02)	.84 (.03)
False alarm rate	.36 (.02)	.17 (.02)	.30 (.02)

Note. *SE*s are in parenthesis.

was selected from each category to be target items (40 target words per subject). The remaining 40 words were used as distractors in the recognition memory test. We used the same counterbalancing procedure used in Experiment 1.

Procedure. The procedure was identical to that of Experiment 1 with one exception. The list of target words was always presented in a blocked order, instead of using the pseudorandom ordering procedure of Experiment 1. Specifically, words from the same category always appeared together, but the order of categories and the order of words within the categories were random. Other than this change in presentation order, the tasks were exactly the same as those used in Experiment 1.

Results and Discussion

We analyzed the results by examining either the first test only (free recall first or recognition first), or by collapsing across counterbalance order (free recall first and recognition first). The pattern of results did not change either way. All data presented below are collapsed across counterbalance order.

Free recall. The proportion of words recalled on the final free recall test is shown in Figure 4. Between group comparisons revealed that the pleasantness condition recalled more words than both the mapping condition, $t(62) = 4.52$, $d = 1.13$ [0.60, 1.66], and the sorting condition, $t(62) = 2.30$, $d = 0.58$ [0.07, 1.07]. Moreover, the sorting condition recalled more words than the mapping condition, $t(62) = 2.41$, $d = 0.60$ [0.10, 1.11].

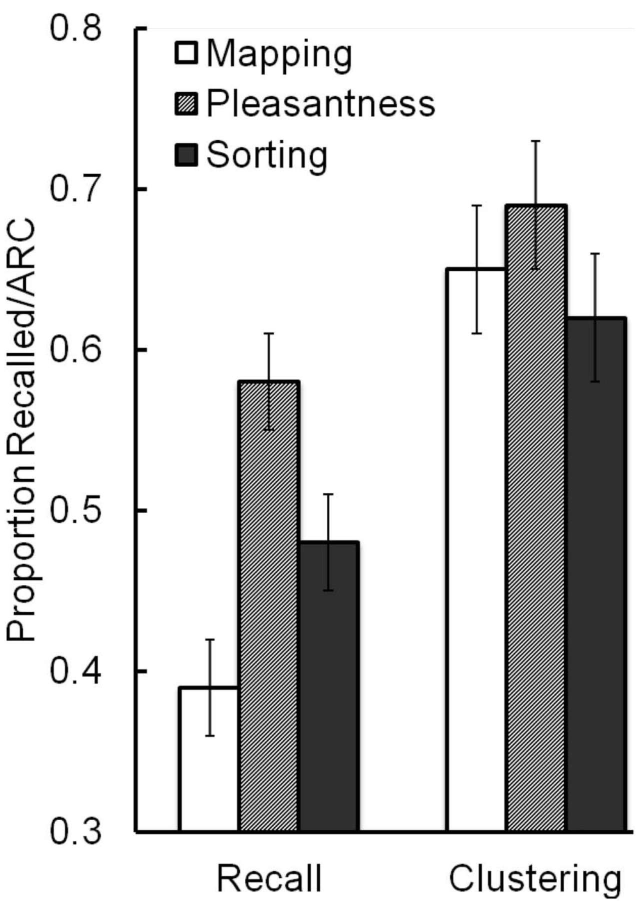

Figure 4. Recall and ARC scores as a function of condition in Experiment 2. Error bars represent *SEM*.

The finding that making pleasantness ratings produced better recall than category sorting replicates past research (e.g., Einstein & Hunt, 1980) and illustrates the benefit of item-specific processing when learning a highly structured list of materials. Free recall in the concept mapping condition was much worse than it was in the pleasantness rating condition ($d = 1.13$), suggesting that concept mapping did not afford item-specific processing. More interesting was the fact that subjects in the concept mapping condition also recalled fewer words than subjects in the sorting condition. Consistent with the findings in Experiment 1, the recall results in Experiment 2 suggest that concept mapping disrupted item-specific processing relative to a standard relational processing task.

Organization. ARC scores for each condition are shown on the right side of Figure 4. Two subjects in the map condition and one subject in the pleasantness condition had negative ARC scores and were excluded from the analysis. The pleasantness condition showed slightly greater clustering than both the mapping condition, $t(59) = 0.60$, $d = 0.15$ [−0.35, 0.66], and sorting condition, $t(61) = 1.13$, $d = 0.28$ [−0.21, 0.78], and clustering was slightly greater in the mapping condition relative to the sorting condition, $t(60) = 0.53$, $d = 0.13$ [−0.37, 0.63]. Overall, the differences in clustering scores among the three conditions were very small. This result suggests that the subjects in each condition were aware of the categorical structure of the list and used the categories to guide their recall.

As in Experiment 1, we also computed subjective ARC scores for the mapping condition. The mean subjective ARC score was .67 (*SEM* = .04). Two subjects were excluded for having negative scores. Unlike Experiment 1, subjective ARC scores in the mapping condition were only slightly larger than standard ARC scores, (.67 vs. .65), $t(29) = 1.09$, $d = 0.20$ [−0.16, 0.56], indicating that the subjective categories used to guide recall overlapped substantially with the natural organization of the list. There was essentially no difference between the subjective ARC scores in the mapping condition and standard ARC scores in the pleasantness condition, (.67 vs. .69), $t(59) = 0.24$, $d = 0.06$ [−0.44, 0.56]. Subjective ARC scores of the mapping condition were slightly higher that standard ARC scores of the sorting condition, (.67 vs. .62), $t(60) = 0.86$, $d = 0.22$ [−0.28, 0.72]. In summary, there were only small difference in category clustering among the conditions, and the results were the same when analyzing based on subjective ARC scores in the mapping condition. Thus, the list structure afforded similar levels of relational processing in all conditions, indicating that the differences in recall performance can be attributed to differences in item-specific processing.

Concept map analysis. A summary overview of mapping performance is shown in Table 1, which shows the average number of vertical links, horizontal links, total links, and cluster size of all items in the concept maps. A representative example of a concept map made by a subject in Experiment 2 is shown in Figure 5. In contrast to the maps created in Experiment 1, the maps created in Experiment 2 were much more standard and uniform. Subjects made about two vertical links per word, which was typically the word's link to the category name and top-level "list" concept. Subjects made about 0.2 horizontal

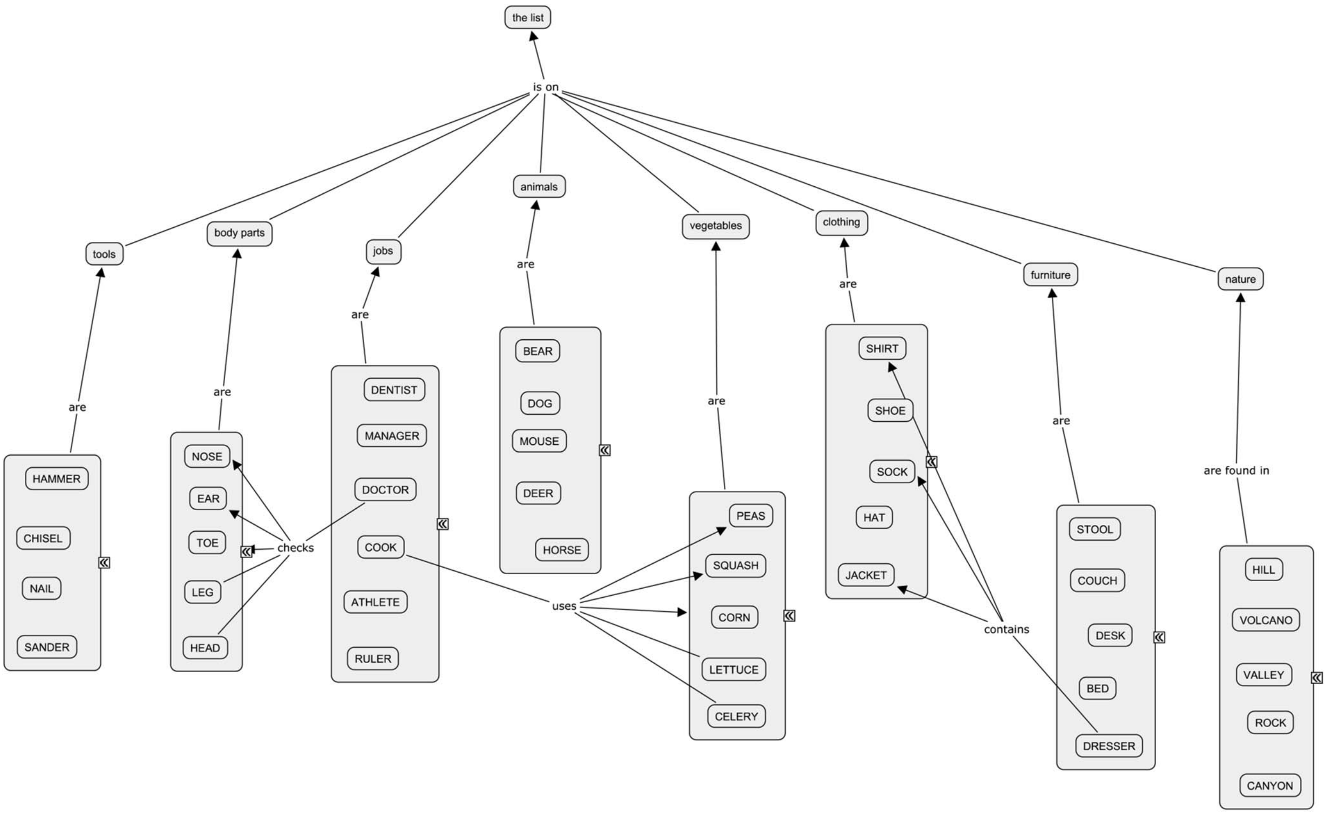

Figure 5. Representative example of a concept map created by a subject in Experiment 2.

links per word, indicating that subjects did not make horizontal links for most words in the list. More important, the average cluster size in Experiment 2 was 5.0, and the *SD* was smaller than it was in Experiment 1 (0.3 vs. 4.2). This indicates that subjects created their concept maps largely following the categorical structure of the list, which contained five items per category.

As in Experiment 1, we examined how map features predicted recall on the free recall test using a binary logistic regression analysis. The results of the analysis are shown in Table 2, which shows that none of the ORs for the four factors were reliably different from 1.0. Thus, neither the number of links associated with an item nor the size of an item's cluster influenced the likelihood of recalling that item. The finding that cross category links did not improve recall is interesting, because if such links promote item-specific processing, then items with more crosslinks should have been more likely to be recalled. However, this effect was not observed.

Recognition. Recognition memory was analyzed using d', and the results are shown in Table 3. Between group comparisons revealed that the pleasantness condition produced better recognition memory than both the mapping condition, $t(62) = 9.06$, $d = 2.27$ [1.63, 2.89], and sorting condition, $t(62) = 5.78$, $d = 1.45$ [0.89, 1.99]. Moreover, the sorting condition produced better recognition memory than the mapping condition, $t(62) = 3.01$, $d = 0.75$ [0.24, 1.26].

As with Experiment 1, we performed separate analyses on the hit rates and false alarm rates. Again, hit rates for the pleasantness condition were near ceiling, violating the assumption of homogeneity of variance. According to Levene's test, variance in the pleasantness condition was significantly smaller than it was in the other two conditions, $F(2, 93) = 4.35$. We were able to meet the assumption of heterogeneity of variance by applying an arcsine transformation to the hit rate data (Howell, 2010). The following hit rate analyses were conducted using this transformed data. Between group comparisons revealed that the pleasantness condition had higher hit rates than both the mapping condition, $t(62) = 6.30$, $d = 1.58$ [1.01, 2.13], and sorting condition, $t(62) = 5.00$, $d = 1.25$ [0.71, 1.78]. Moreover, the sorting condition also had a higher hit rate than the mapping condition, $t(62) = 2.31$, $d = 0.58$ [0.08, 1.08]. For false alarm rates, the pleasantness condition produced lower false alarm rates than both the mapping condition, $t(62) = 6.46$, $d = 1.62$ [1.04, 2.18], and sorting condition, $t(62) = 3.76$, $d = 0.94$ [0.42, 1.45]. There was a small difference between the mapping and sorting condition on false alarm rates, $t(62) = 1.86$, $d = 0.46$ [−0.03, 0.96].

As in Experiment 1, subjects who made concept maps showed the worst performance on the recognition memory test, worse than both the pleasantness and sorting conditions. Replicating Experiment 1, the difference in recognition performance between the sorting and mapping condition was driven primarily by differences in hit rates, although the mapping condition did show a slightly greater tendency to falsely recognize new words as old. In summary, subjects who created concept maps had a difficult time recognizing words from the study list, which suggests that making a concept map disrupted item-specific processing relative to a relational processing task.

General Discussion

Across two experiments, we examined item-specific processing during the creation of a concept map. In both experiments, subjects who made concept maps displayed poorer recognition memory than subjects who completed standard item-specific and relational encoding conditions. Moreover, when learning a categorized word list, rather than improving recall performance, which would indicate enhanced item-specific processing, concept mapping actually produced worse recall performance. The results converge on the conclusion that making a concept map disrupts the processing of item-specific information, relative to a relational processing control.

Why does making a concept mapping disrupt item-specific processing? One possibility is that subjects did not create enough cross category links to differentiate items within categories (Novak & Cañas, 2006). Our analyses of the concept maps revealed that subjects made very few cross category links. However, our analysis also revealed that there was no relationship between the total number of links and the probability of recall. Thus, there was no evidence to suggest that creating more cross category links would have improved performance.

A second explanation is that the cognitive demands of making the concept map interfered with subjects' ability to process item-specific information. Making a concept map required subjects not only to engage in processes that are important for learning, such as evaluating relationships, but also to engage in extraneous processes, such as arranging the words on the screen, creating the links and clusters, and so on. Compared with simpler tasks like making pleasantness ratings or sorting into categories, concept mapping required additional activities that may have drawn attention away from effective encoding processes. Indeed, past research has shown that dividing attention during encoding negatively affects item-specific processing (Geraci & Rajaram, 2002; Joordens & Hockley, 2000). Parallels can also be drawn to the distinction between "germane" and "extraneous" processing that is central to cognitive load theory (Sweller, Van Merriënboer, & Paas, 1998). Concept mapping may involve extraneous cognitive load that demands attention but may not afford germane cognitive load (improvements to item-specific and relational encoding) that would promote learning.

In addition to disrupted item-specific processing, Experiment 1 also indicated that concept mapping may exacerbate cue overload (Watkins & Watkins, 1975). Whereas the category sorting task enhanced recall of ad hoc lists, concept mapping did not. Subsequent analyses of the maps revealed that subjects created fairly poor organizational schemes for the list. In particular, subjects demonstrated a tendency to create category clusters that contained a large number of words, and words from overloaded categories were less likely to be recalled than words from sparse categories. Note that subjects only created these overloaded categories in Experiment 1, when the organizational structure of the list was not obvious. In Experiment 2, when the categorical structure of the list was readily apparent, subjects did not overload their cues. Thus, overloading only occurred when the structure of the materials was ambiguous and the subjects were required to generate their own category cues. Indeed, subjects in Experiment 1 tended to select very general category cues (e.g., things found in nature, things found in a house), which represented large numbers of words in the list. Although these category cues successfully related many of the items in the list, they were ineffective as retrieval cues because they were not specific enough to effectively limit the search set during recall. Concept mapping is assumed to promote relational processing, and indeed the task does require students to encode the relations among items. However, the present results indicate that when the organizational structure of to be learned materials is ambiguous, concept mapping may lead to an overabundance of relational encoding, creating cue overload and poor learning.

One might wonder whether concept mapping performance would have been better if subjects were given training on how to create concept maps. There has been one series of controlled experiments examining whether training on concept mapping results in better learning. Blunt, Bauernschmidt, and Karpicke (2014) found that subjects who were given 75 min of extensive training on creating concept maps showed levels of learning that were identical to the performance of subjects who were given 5 min of training. The tutorial instructions in the present experiments were somewhat more extensive than instructions our laboratory has used in previous research (Karpicke & Blunt, 2011). In short, subjects in the present experiments were given a sufficient amount of instruction about the concept mapping tasks, and the present results cannot be attributed to training or experience with concept mapping.

A related question is whether subjects would have performed better if they were given more time in the concept mapping condition. We gave subjects enough time to go through the list thoroughly and create several links among the words. In that same 10 min period, subjects in the other conditions were able to complete the sorting Task 4.8 and 6.9 times in Experiments 1 and 2, respectively, and completed the pleasantness rating Task 7.2 and 8.5 times in the two experiments, respectively. Thus, the total amount of time we gave subjects to make a concept map was more than enough to effectively encode all the words on the list. It is possible that if subjects were given more time, they would have created additional links on their concept maps. However, our item analysis showed no relationship between item recall and the number of links created. It is unlikely that providing additional time for subjects to create additional links would have improved recall performance. And perhaps most importantly, additional time likely would not have solved the issue of cue overload demonstrated in Experiment 1.

An important point worth mentioning is that the present experiment used word lists, whereas concept maps are commonly used when learning more complex educationally relevant materials. We used word lists because they afford easier manipulation of item-specific and relational processing within an established experimental paradigm. However, additional research will be needed to determine whether the results of the present experiment also apply to concept mapping with complex materials.

Conclusion

The effectiveness of any encoding task depends on multiple factors, including the processes afforded by the task, the processes afforded by the materials, and the retrieval problem that ultimately needs to be solved (Jenkins, 1979). The present study sought to examine the encoding processes involved in creating concept maps, and the results point to the conclusion that concept mapping may disrupt the processing of item-specific information and produce cue overload. Concept mapping is used in many educational circles, and indeed it may be a useful pedagogical tool, but the present results point to a few features of concept mapping that might harm learning rather than improve it. Thus, one challenge for future work will be to design concept mapping activities that alleviate these encoding problems, which will likely involve altering the standard concept mapping instructions given to students and structuring the concept mapping task to reduce cue overload and emphasize the distinctiveness of individual items.

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(*Appendix follows*)

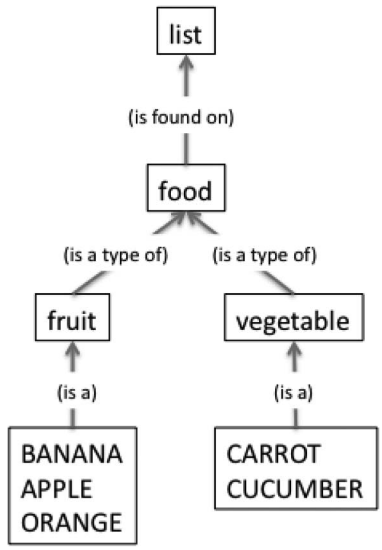
Appendix

Rules for Scoring Concept Maps

Rules for Scoring Concept Maps

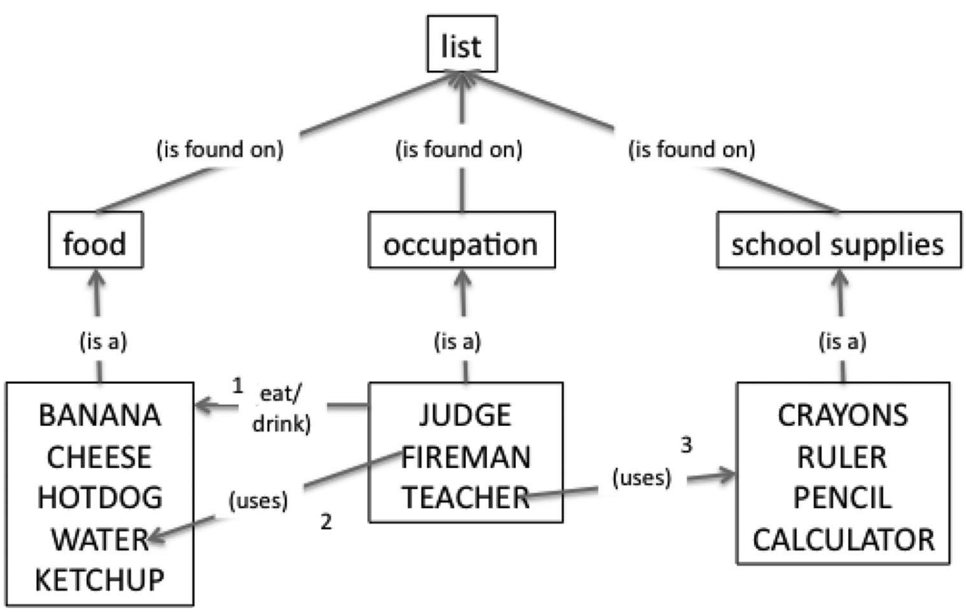
1. Vertical links for a word were defined as links from the word to a category name or any higher category to which the category name belongs.

- Example: *Banana* has three vertical links.



2. Horizontal links were defined as links that connect words of one category to words of another category. Links between words of the same category were not counted.

- Examples: Link 1 is not counted because Link 1 is not specific to any word. Link 2 counts as a horizontal link for both *water* and *fireman*. Link 3 only counts as a horizontal link for *teacher*.



(*Appendix continues*)

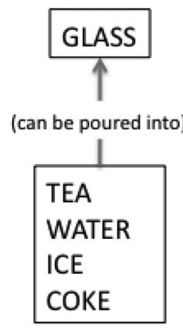
3. Total links were defined simply as the sum of the word's vertical and horizontal links.

4. Cluster size for a word was defined as the total number of words in its category, including itself.

- Example: The cluster size for each word below is three.

- Exception 1: The cluster size for a word on its own is zero.

- Exception 2: When the word from the list is used as a category name, the cluster size of that word is one. *Glass* is assigned a cluster size of one.



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