Evaluation of Semantic Fisheye Zooming to Provide Focus+Context

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A concept map is a diagram that consists of nodes that contain individual concepts or pieces of information. These nodes are connected by lines that represent relationships between the information.

Large concept maps are difficult to explore and navigate using current digital display interfaces. As users zoom in on a desired node, connections between the node of interest and surrounding nodes become hidden from the user. A combination of fisheye zooming and semantic zooming mechanisms to maintain the visual connections between the nodes was implemented, and a user study to determine whether this technique helps users learn from the map was conducted.

The user study revealed that participants were able to recall more information presented in a concept map, with practically no difference in the amount of time spent using the map, despite the novelty of the semantic fisheye interface.

INTRODUCTION

It is difficult to display large amounts of information in a manner that is easy for users to access and understand. A concept map—a diagram consisting of nodes that represent individual concepts connected by lines that show connections between the concepts—is a way to organize information visually into a networked format. Users who desire to develop an understanding of the connections between the nodes of a concept map need to have both a focus on the information contained in individual nodes and a contextual understanding of the connections between the nodes.

The Visual Understanding Environment (VUE) application aims to provide students with an alternate, more visual method for organizing concepts discussed in their courses. By using digital library repositories, VUE provides students with visual concept maps that display the relationships between various topics in one summarizing interface connected to various digital libraries (VUE, n.d.)

A concept map within VUE is a collection of digital library objects represented as nodes. These nodes are organized by the user on a project space where users can draw or create objects within a virtual canvas, connected with user-defined relations, represented as lines with endpoints at each connected node.

By presenting a collection of digital library objects together, students can learn concepts in relation to one another. Students can also access the digital resource associated with each node by clicking on the representative node to open the hyperlinked media. The intention is that students will be able to develop an overall understanding of information more easily because of the ease of visually grouping related objects together within a given concept. Teachers can create concept maps and distribute them to students, or students can create their own concept maps. Both scenarios are likely uses of VUE.

IMPROVING INFORMATION VISUALIZATION IN VUE

While VUE has many advantages, there are certain drawbacks to visualizing concept maps that limit VUE's effectiveness. Through initial heuristic evaluations, the main drawback was identified as VUE's basic zooming tool. With the standard zooming interface to VUE, students and teachers could feasibly study concept maps in VUE that contain dozens of nodes. It is difficult to view large concept maps effectively without some type of advanced zooming functionality.

Although the basic zooming tool in VUE allows the user to zoom in on a particular set of nodes, reducing clutter, it eliminates the global view of all the nodes within the concept map. This simple zoom tool reduces the effectiveness of concept maps by eliminating the global perspective of all the nodes surrounding a given concept. In addition, the basic zooming tool does not provide any more information on a given node. It simply magnifies the view geometrically.

A more effective solution is needed in VUE to visualize graphical data, giving users access to more information on any given node while still maintaining the global view. This is an important feature because, without it, concept maps would contain the same flaws as conventional web access to digital library objects.

FOCUS+CONTEXT

VUE endeavors to show an area of interest with more supplementary information, while still displaying the surrounding context on limited computer display space. The principle of focus+context targets this problem. It involves incorporating the detailed view the user needs in the focus area and the necessary contextual information with less detail integrated into the same display space (Furnas, 1982). Two zooming techniques that have supported focus+context are fisheye zooming and semantic zooming.

Fisheye zooming allows the user to zoom on a focal node, while keeping a global view of all the data by shrinking the surrounding area (Furnas, 1986). One approach to implementing the fisheye concept allows the user to expand the point of interest in place, while still allowing for the preservation of node order and arrangement (Sarkar& Brown, 1992).

Semantic zooming involves displaying more information as the magnification level increases, and has been implemented in various applications, such as Pad++ (Bederson & Hollan, 1994). Semantically zooming in on a specific area

displays more information about it, so semantic zooming can be used as a primary mechanism to retrieve more information of nodes in concept maps.

Zizi and Beaudouin-Lafon (1995), Keahey (1998), Van Ham and van Wijk (2004), and Janecek & Pu (2002, 2005) found that zooming techniques that combine semantic zooming and fisheye zooming can be effective in showing more information without losing a sense of the global structure and maintaining screen size. The combination of fisheye zooming and semantic zooming technique is called "semantic fisheye zooming" (Janecek & Pu, 2002). Janecek & Pu (2005) conducted a user test of the effectiveness of this visualization technique, and found that participants using the semantic fisheye interface found more concepts, were more successful when searching for specific concepts, and were more confident about their findings.

EVALUATION OF THE SEMANTIC FISHEYE ZOOMING INTERFACE

As VUE is intended to be a tool for learning, we wanted to evaluate its semantic fisheye zooming interface not for search tasks, but for tasks that simulate its use in an educational environment as a teaching tool. An experiment was conducted to determine whether the semantic fisheye zooming functionality in VUE improved the user's ability to master information displayed in a concept map. The usage scenario where students start with a given map (instead of building it themselves) was chosen for this experiment because conversations with intended users of the system revealed that this was the most likely usage scenario.

Hypothesis

The technique of integrating displays (done here through semantic fisheye zooming) will result in increased retention because users are able to devote the capacity of their working memory to integrating information and they are not required to do so across displays. Increased retention can lead to improved understanding and increased learning because of the benefits of a reduced cognitive load. Cognitive load theory postulates that limitations of working memory should be taken into account when designing tools for teaching and learning so that human ability to learn is maximized (Chandler & Sweller, 1991; Sweller, 1989; Sweller et al., 1990). Cognitive load theory has split cognitive load into two parts: intrinsic cognitive load and extrinsic cognitive load. Intrinsic cognitive load refers to the cognitive load imposed by the complexity of the information, while extrinsic cognitive load refers to the cognitive load imposed by the display and interface used to present and provide access to the information (Sweller et al., 1990). Cognitive load theory seeks to minimize extrinsic cognitive load so that cognitive resources can be applied to the intrinsic cognitive load so that the information associated with the intrinsic cognitive load can be understood.

Specifically, we expected the results of this study to coincide with the results from studies evaluating fisheye zooming and semantic zooming separately; participants would complete the experimental task faster (Gutwin & Skopik,

2003; Schaffer et al., 1993, 1996), report greater satisfaction with the interface (Bederson, 2000; Lamping, et al., 1995; Gutwin & Skopik, 2003; Schaffer et al., 1993, 1996), and remember more information (Hornbæk, et al., 2002). (Hornbæk et al. (2002) found that an interface that mimics semantic zooming can aid rapid browsing at the cost of comprehension, but used an overview window rather than fisheye to provide context.)

With the exception of the recall task, we did not expect the semantic fisheye interface to help users complete the task with a higher accuracy because previous experiments involving fisheye zooming did not find this result (Gutwin & Skopik, 2003; Schaffer et al., 1993, 1996).

Participants

Seventeen participants were recruited through an e-mail announcement or had volunteered for the experiment. All participants were 18 years and reported having normal (20/20) or corrected-to-normal (20/20 with the aid of glasses or contact lenses) vision. All participants used computers on a daily basis. Participants were naïve to the subject matter of the concept map and the experimental task.

Equipment

So that a direct comparison could be made, two concept map interfaces were created for this experiment: a control version and an experimental version.

The control version, seen in Figure 1, displayed additional information about nodes in a separate display window. When the user clicks on a node in this interface, a pop-up window, not shown in the figure, obscures the concept map. Navigating the control concept map required the participant to move the mouse to the node of interest, and click on the node to display the additional information about it. More information about the node was displayed in a pop-up window. This pop-up could be closed by clicking the mouse on the main picture in the pop-up.
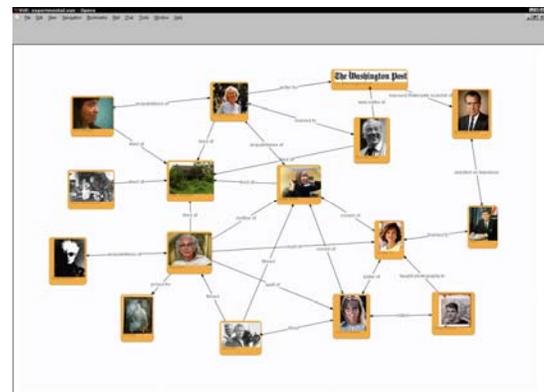
Figure 1. In the control interface, VUE renders the semantic content with the associated image as a thumbnail.

The experimental version, seen in Figure 2, had semantic fisheye zooming. In Figure 2, the node at the top center of the concept map has the focus, and it is shown larger and with more information than the other nodes in the interface. Navigating through the experimental concept map required the

participant to move the mouse over the node of interest. No clicking was required to access the additional information because the semantic fisheye zooming dynamically changed based on the location of the mouse pointer on the display.
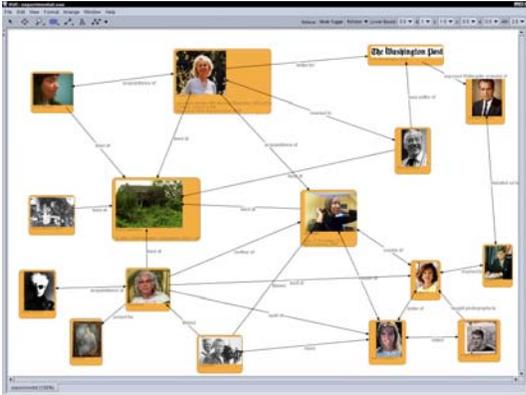

Figure 2. In the experimental interface, nodes are rendered differently in VUE at each zoom level.

The semantic information accessible through the concept maps was identical between the control and experimental interfaces. The information displayed in the pop-up window in displayed and the control version is identical to the information displayed in the node of interest at its greatest zoom factor in the experimental version.

Procedure

Participants were randomly assigned to one of two groups: one that used the control interface and one that used the experimental (semantic fisheye) interface.

Participants were asked to answer questions in four different sets that simulate different types of learning possible with a concept map. They used the concept map to gather information necessary to answer questions. They were able to use the concept map while they answered questions from the first three sets. The times that participants took to complete each of these sets of questions were recorded. The first three sets of questions are as follows:

- Question Set 1: One-item questions, or questions that can be answered with information from a single node only. There were 8 questions in this set.
- Question Set 2: Questions that require users to compare and contrast information from two or more nodes. There were 8 questions in this set.
- Question Set 3: Questions that require users to develop an overall understanding about the material presented in the concept map. These questions attempted to simulate the kinds of real learning and thinking that a student would do with VUE. There were seven questions in this set.

Time restraints were not placed on participants when they answered questions from the first three question sets. Some previous studies involving concept maps have allowed users to work without time limits (Edwards & Fraser, 1983), and the assumption that learning should be allowed to happen without obvious time constraints was made. Despite this, it was expected that participants who used the semantic fisheye zooming interface would complete the task faster than participants who used the control interface because other studies evaluating focus+context and fisheye zooming interfaces found this result.

In addition, participants were asked to answer questions from a Question Set 4. These nine questions were similar to the questions in Question Set 3 in that they required users to develop an overall understanding of the material presented in the concept map, except participants were not able to refer to the concept map for these questions. These questions simulated the deeper understanding that is possible with concept maps, and also provided data to determine whether using an interface with an integrated display results in higher recall of information contained in a concept map. The time that participants spent answering these questions was not logged because only the retention of information is important in this case. If participants could recall the information, even after an extended length of time attempting to recall it, then the interface was successful in helping them retain information. Participants only received credit for questions answered completely correctly, and no prompting was given.

Although the times that each user spent to complete each set of questions were recorded, these numbers were divided by the number of questions in each question set because the question sets contained different numbers of questions. Based on the assumption that all questions in a question set have equal difficulty, this creates a "mean time per question" metric that was used to compare the time spent answering questions of different difficulties across different question sets.

RESULTS

Analyzing the participants' accuracy in the experimental task and the times it took them to complete the experimental task provided data that were useful in determining the types of tasks for which the semantic fisheye zooming provides a benefit for users.

Data from one participant were discarded because the values of the configuration variables used for the semantic fisheye zooming were different from the values for other participants. This resulted in the semantic fisheye zooming's behaving incorrectly and differently from the experience of other participants in the experimental condition. Discarding the data from this participant resulted in an equal number of participants in each condition: eight and eight.

Although users of the control interface were able to perform a straight zoom on the concept map, none did, because the entire concept map was always viewable in the browser and zooming provided no more information about the map.

An alpha level of .05 was used for all statistical tests. When *t* tests were performed, the data analyzed did not violate the assumptions of the *t* test.

Time Spent on Sets of Questions

t tests were performed on the times taken to complete each question set to see whether there was a difference between the times that participants spent using the two interfaces to complete question sets. Participants who used the

control interface completed Question Set 1 significantly more quickly than participants who used the control interface, $t(14) = -2.10$, $p = 0.0270$, an average of 53 seconds faster.

However, participants who used the experimental interface did not complete Question Sets 2 and 3 significantly more quickly than participants who used the control interface. Although there were slightly faster, these improvements in time were not statistically different, $t(14) = 1.53$, $p = 0.0742$ and $t(14) = 1.57$, $p = 0.0689$, respectively.

There was no significant difference between the mean times spent per question on the different question sets between the groups of participants, $F(2, 21) = 2.24$, $p = 0.1311$. This means that participants who used the experimental interface were slower to complete Question Set 1 than they were on Question Sets 2 and 3, and they were slower to complete Question Set 1 than users of the control interface. Figure 3 compares the average times per question for each question set between users of the two interfaces.
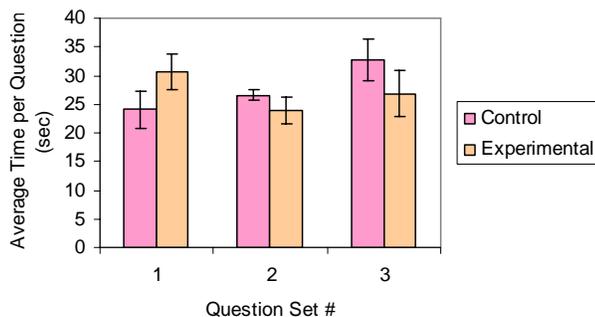

Figure 3. The mean times that participants took to answer Question Sets 1, 2, and 3 were calculated for each participant by summing the times the participant took to answer the timed question sets, and a *t* test was performed on these total times between the groups of participants to determine whether there was a difference between times participants spent using their respective interfaces. Error bars show one-half standard deviation above and below the mean.

Although the differences in average time for Question Sets 2 and 3 are not significant, the trend in Figure 3 may show that participants who used the experimental interface were unable to use it efficiently at first, but then developed a greater level of expertise using it and were able to complete Question Sets 2 and 3 faster than participants who used the control interface. Participants who used the control interface spent more time to answer questions as the questions increased in difficulty.

Total Times Spent on Question Sets

The total time that participants took to answer Question Sets 1, 2, and 3 was calculated for each participant by summing the times the participant took to answer the timed question sets. A *t* test was performed on these total times between the groups of participants to determine whether there was a difference between times spent using the control and experimental interfaces. There was no statistically significant difference between total times participants spent with the interface between the control and experimental groups, $t(14) = 0.25$, $p = 0.4028$. The mean total time for the control interface

was 10:35 (in minutes and seconds), while the mean total time for the experimental interface was 10:24. There was no statistically significant difference between total times participants spent using their respective interfaces, $t(14) = 0.25$, $p = 0.4028$.

Scores for Question Sets 1, 2, and 3

The scores for Questions Sets 1, 2, and 3 for each participant were calculated by dividing the number of correct responses by the number of questions in the question set. To determine whether there was a difference in the participants' scores between the control and experimental interfaces, the median test, coupled with Fisher's exact test, were used. No significant differences between the scores from participants in the control groups versus the experimental groups for Question Sets 1, 2, and 3 ($p = 1.0000$, 0.4000, 0.5000, respectively). Therefore, there were no statistically significant differences in participants' scores for Question Sets 1, 2, or 3.

Results of the Recall Task

A *t* test was performed on participants' scores on the recall task (Question Set 4) to determine whether there was a difference between the participants' recall of information after using their respective interfaces. Participants who used the experimental interface performed better in the recall task, $t(14) = -2.46$, $p = 0.0137$.

An analysis of covariance (ANCOVA) was performed to determine if the improvement in the experimental interface was because of a difference between the total amounts of time that participants spent with their respective interface. The control group spent an average of 11 seconds longer to complete Question Sets 1, 2, and 3 than the experimental group. The ANCOVA revealed that the improvement in recall scores for the experimental group is in spite of the total time spent using the interface, $p = 0.0260$. The improvement in recall using the experimental interface is probably not because these participants spent more time with the concept map, although there is a chance of some dependence, and the possibility that the act finding information to answer questions in Question Set 1 benefited participants using the experimental interface when they were on Question Sets 2 and 3.

DISCUSSION

Main Result

Overall, the semantic fisheye zooming interface resulted in increased recall and understanding of information presented in a concept map without an increase in the amount of time spent using the interface. This improvement can be explained by cognitive load theory. In the experimental interface, participants were able to extract more information from the system because they did not need to integrate information across displays. The working memory capacity freed up by display integration allowed participants to learn more information about the topic presented in the concept map.

Validity of Hypothesis

As hypothesized, participants who used the semantic fisheye zooming interface reported greater satisfaction with the interface and remembered more information than participants who used the interface without semantic fisheye zooming. Increased satisfaction with fisheye zooming interfaces and focus+context interfaces were seen in previous experiments (Bederson, 2000; Lamping, et al., 1995; Lank & Phan, 2004; Schaffer et al., 1993, 1996).

However, these participants did not spend less time with the interface as hypothesized. There was no significant difference in total time spent using the interface, unlike previous studies involving fisheye zooming by other researchers. However, the task in this experiment was different from the tasks given in other studies. This was not a steering task or just a search task, as in previous experiments (Gutwin & Skopik, 2003; Schaffer et al., 1993, 1996). The experimental task in this study required users to develop an understanding of the content of the concept maps, which required more short-term memory capacity than search and steering tasks of previous experiments (Gutwin & Skopik, 2003; Schaffer et al., 1993, 1996). In addition, results seen in studies evaluating just fisheye zooming might not apply here because of the combination of fisheye zooming and semantic zooming.

CONCLUSIONS

The evaluation demonstrates that the combination of fisheye view and semantic zoom enhances the learning capabilities of users in the concept map environment.

Optimizing the relationship between the amount of display space needed to display information about the focus versus the context is an area for possible future improvement, as are incorporating graphical/iconified representations of frequently used metadata. Another benefit of representing the same amount of information using graphics is that it reduces the amount of display space consumed by nodes, which allows more information to be displayed and reduces clutter on the display.

However, it must be emphasized not to overload semantic fisheye zooming with features that will ultimately disturb the user's process of learning. The primary goal of this technique is to provide more information under certain viewing conditions and not to provide any extra information that may be irrelevant. This goal should be accomplished very simply by reducing the number of steps users must perform to access information.

ACKNOWLEDGMENTS

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