Verbal Ability and Structured Navigation on Learning with Hypertext

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Abstract

Learners bring their unique individual perceptions, preferences, and abilities to a learning situation. The effect of individual differences on learning depends in part on how the instructional system accommodates for these differences. The current study examined the role of individual differences and structured navigation in hypertext learning. It was predicted that learning outcome would depend on how well the hypertext design operates together with the learner's individual attributes. Ninety-seven participants participated in one of four groups of a 2 X 2 between-subjects factorial design, which focused on the interaction between the levels of the navigation structure (unconstrained or expert constrained) and the levels of the participants' verbal ability (high or low). General support was found for the hypothesis. Overall, learners with high-verbal ability performed better on an unconstrained navigation structure than those with low-verbal ability; whereas in an expert-constrained navigation this difference between verbal ability levels was smaller. The results have implications for the design of hypertext-based learning systems.

Keywords: Learning; Individual Differences; Human Factors and Human-Computer Interaction; Knowledge Representation

Introduction

Reading hypertext can be seen as an interaction between the learner and the machine (Dillon, 1994). The learning outcome will depend on how well the hypertext design operates together with the reader's individual attributes. Both design and individual differences will influence this interaction. The current study examined this interaction. In particular, how do learners' verbal ability and navigational constraints affect learning from a hypertext system?

In hypertext, learners control the order in which they receive information. Learners move between topics selecting their own learning sequencing. They may choose a sequence based on previous knowledge, personal styles, needs, or learning goals. Although flexibility and active participation may benefit learning (Bruner, 1990), such flexibility would seem to demand more cognitive resources and hence adversely affect comprehension. Therefore, hypertext requires a different balance of processing resources than does traditional text. This additional cognitive load is affected by the lack of coherence in a hyperdocument due to the responsibility of the learner to perform additional navigation among the units (Foltz, 1996).

Individuals will bring a variety of resources to learning environments. High-verbal ability readers, in particular, are good at predicting the next word or words in text because of their prior knowledge (Massaro, 1989). High-verbal ability learners can also hold more verbal information in working memory and integrate that information into long-term memory more efficiently than low-verbal ability learners.

Therefore, a high-verbal ability learner is not affected by text fragmentation as much a low-verbal ability learner. High-verbal ability learners are more likely to connect hypertext units together (i.e., organize and build internal connections) at the net-level, and are less likely to lose the coherence of the document. For this reason, high-verbal ability learners should have several advantages over low-verbal ability learner in a hypertext environment. If a learner has high-verbal ability, he/she will tend to have better comprehension skills in general and will be less affected by the lack of coherence in the material. Therefore, a hyperdocument that imposes a large amount of navigational and cognitive load on the learner will put learners with low-verbal ability at a disadvantage (Foltz, 1996).

In particular, learners with low-verbal ability will have a greater amount of task interference from the additional task of navigating among the units, due to the possible lack of coherence among the units, and therefore have poorer comprehension. Since high-verbal ability learners comprehend text easily at the node-level, they may have more cognitive resources to devote to comprehending the organization of the document at the net-level. Specifically, they will have more resources to devote to navigating and so are less likely to become disoriented in a hypertext environment. In contrast, since low-verbal ability learners are less efficient at selecting, organizing and integrating information, their cognitive resources will be more easily depleted, and navigating choices will likely overwhelm them. Therefore, too much control might result in disorientation

One possible resolution to the navigational problem faced by low-verbal ability learners is to restrict their navigational freedom. By limiting the number of links available to a learner, an author could better insure that bridging inferences between links occur.

Interactive overviews are one method for providing structure to hypertext systems, particularly in terms of navigation. Interactive overviews have the organization of the material embedded in the hypertext itself. One method for developing a structured interactive overview is by using experts' knowledge representations of the concepts. According to Trumpower & Goldsmith, "semantically structured interactive overviews provide a means for learners to integrate content by visually observing important conceptual relationships depicted as hyperlinks" (p. 429-430, 2004). Further, another possible benefit is that an interactive overview would constrain the presentation order of the material to interrelated concepts. By doing so, coherence can be maintained and comprehension aided. This is especially true for those learners who have difficultly maintaining coherence on their own (i.e., low-verbal ability).

Many findings indicate that high ability subjects do well regardless of the method, while less-able subjects benefit from tailoring an instructional approach (Cronbach & Snow, 1977). An expert-constrained navigation structure may be one way to benefit learning.

Therefore, we expected that an interaction would occur between a hypertext navigational structure and a learner's verbal ability. Learners with high-verbal ability were expected to perform better on an unconstrained hypertext structure than low-verbal ability learners; whereas in expert-constrained navigational structure this difference in performance between the two levels of verbal ability was expected to be smaller.

Methods

Participants

Ninety-seven (33 male, 64 female) undergraduates from the University of New Mexico received course credit for their participation. Participants were randomly assigned to one of two groups: expert-constrained navigation (EN) or unconstrained navigation (UN). Participants' level of verbal ability was determined from their performance on the *Gernsbacher Comprehension Battery* (Gernsbacher, Varner, & Faust, 1990). A median split was used to categorize participants: high verbal (n=49) and low verbal (n=48).

Materials

The materials consisted of a participation questionnaire, familiarity ratings on each of the 10 domain concepts, two types of hyperdocuments of the learning material, concept relatedness ratings, a definitional knowledge test, a procedural knowledge test and the Gernsbacher Comprehension Battery.

The participation questionnaire contained demographic questions and also asked about their knowledge of and prior courses in statistics. Participants also rated the familiarity of each of the 10 statistics concepts using a five-point Likert scale ranging from "less familiar" (1) to "more familiar" (5).

The learning material came from a statistics textbook (Pagano, 2001). The material was segmented according to central concepts. Psychology professors and graduate students (who showed expert proficiency in the area) rated the relatedness of 45 concept pairs based on a five-point Likert scale ranging from "less related" (1) to "more related" (5). Based on these relatedness ratings, the navigational structure for the expert-constrained navigation was determined through a Pathfinder analysis (Schvaneveldt, 1990). The use of an expert navigational structure to guide naive learners was justified in part from a study that showed that experts offer the best referent structure against which to assess the knowledge structures of naive students (Goldsmith, Johnson, & Acton, 1991; Trumpower & Goldsmith, 2004).

The learning material was then presented in one of two types of hyperdocuments (see Figure 1). In the expert-constrained navigation (EN), each node represented one of the ten concepts. The student chose a concept by clicking on the concept node. This caused the concept's information to appear in the space below the list of concepts. The concept's information included: its definition, the formula and an example. However, at that point his/her navigation was constrained to only those other concepts that were linked according to the expert structure. The navigational choices would change based on which link the learner chose. However, the participant was able to navigate through the information in a large number of different paths. In the second type of hyperdocument, the unconstrained navigation (UN), the student chose a concept by clicking on the concept node; below the list of concepts was the definition, formula and example of the concept. However, regardless of what concept was selected, the same navigational choices were available at every situation. In other words, the learner received the same menu of choices regardless of the previous choice.

The Gernsbacher Comprehension Battery (Gernsbacher, Varner, & Faust, 1990) was used to classify participants into high and low-verbal ability. The correlation between verbal SAT scores and performance on the Comprehension Battery was .64 (Gernsbacher, 1990). The battery consisted of four stories that were presented in written format. Each story was about 600 words long. After reading each story at their own pace, participants answered 12 multiple-choice questions about the story.

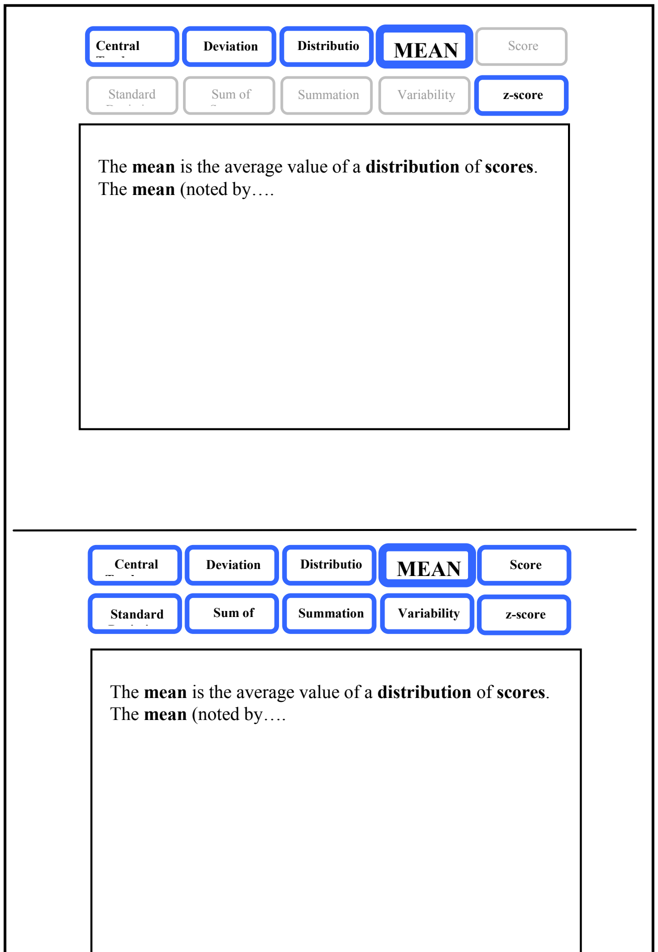

Figure 1: An example of the expert-constrained navigation (top) and unconstrained navigation structures (bottom) used in experiment.

Procedure

Participants' first task was to rate the relatedness of each of the 10 concepts paired with each other. Next, they were randomly assigned to an EN or UN hyperdocument. They were allowed to read and study the concepts at their own pace. However, only after they viewed all of the terms at least once *and* 15 minutes had passed were they allowed to proceed to the assessment part of the study.

Participants' knowledge of the concepts were assessed in three ways; definitional, procedural, and conceptual tests. First, students once again rated the relatedness of the 10 concept pairs in the same way as before the study phase. These post relatedness ratings took approximately 5 minutes to complete. Next, students' definitional knowledge of the 10 statistic concepts was tested by showing a definition of one of the terms and then asking students to select the matching term from a list of the 10 concepts. The order of the questions was randomized individually for each subject. Participants were instructed to complete the questions at their own pace. The definitional test took approximated 5 minutes to complete. Finally, students' procedural knowledge of the concepts was tested using 15 multiple choice questions that required participants to use the studied concepts to solve a problem or make a prediction. The order of the items was randomized separately for each subject. The procedural test lasted approximately 15 minutes.

After participants completed the assessments, they were given the *Gernsbacher Comprehension Battery* test.

Results

Only 30% of the participants had any previous background in statistics, which for the majority (28%) included a single introductory course in statistics. However, there were no significant differences in performance on the assessments based on the participants' background in statistics. Students were generally unfamiliar with the ten concepts. These results suggest that participants came in with low prior knowledge on the learning domain and this was the case regardless of which ability level they were categorized. Therefore, the learning they demonstrated in the performance assessments can be associated with the learning done through the learning conditions.

Number of Nodes Visited

A trace of the sequence of path nodes each participant followed as he navigated through the hypertext was recorded. Low-verbal students visited significantly more nodes then high-verbal learners in the UN (p=.017). However, in the EN the number of nodes visited did not significantly differ between the two levels of ability (p=.988). (See Figure 2).

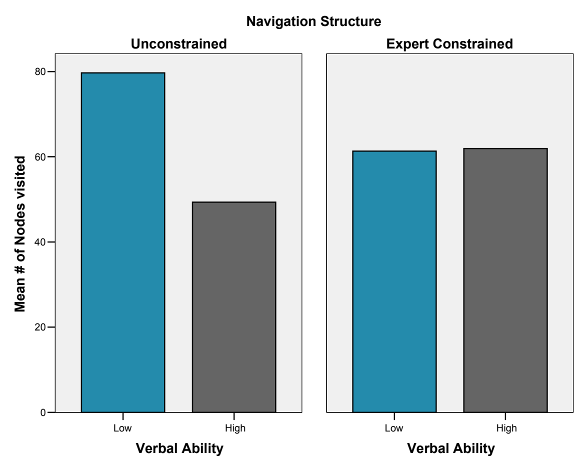

Figure 2: Mean number of nodes visited.

Knowledge Assessments

Definitional. An ANOVA showed that high-verbal students performed significantly better than low-verbal students (*F* (1,93) = 12.474, *p* = .001, M = 75.9 and 62.7, respectively) and students in the UN performed (marginally) significantly better than those in the EN (*F* (1,93) = 3.224, *p* = 0.076, M = 72.1 and 66.7, respectively). (See Figure 3).

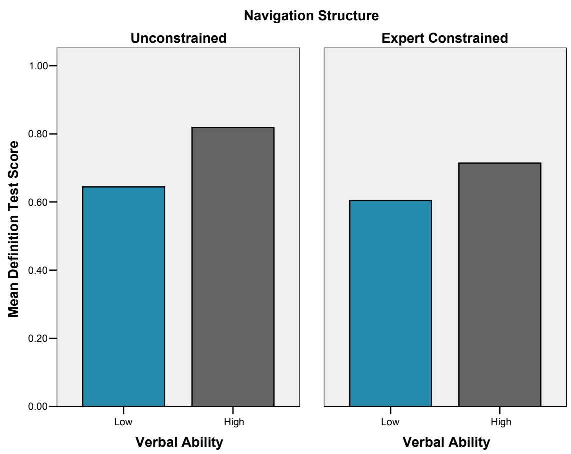

Figure 3*:* Graph of the definitional assessment performance.

Procedural. An ANOVA showed that high-verbal learners performed significantly better than low-verbal learners (*F* (1,93) = 7.211, *p* = .009, M = 73.3 and 64.9, respectively). However, the difference between UN and the EN was not significant (*p*= .850, M = 68.9 and 69.4, respectively). (See Figure 4).

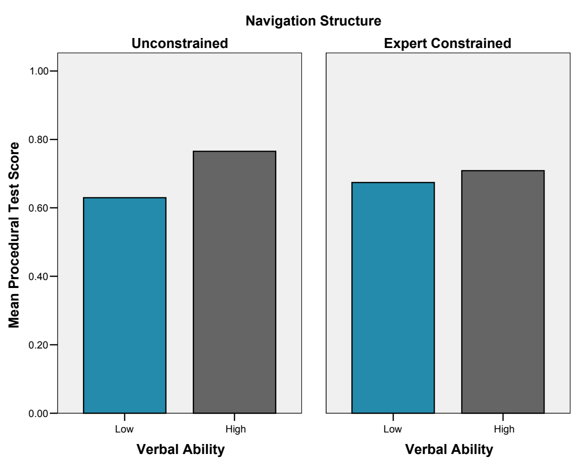

Figure 4: Graph of the procedural assessment performance.

Conceptual. A knowledge network was derived for each student's pre-learning and post-learning set of relatedness ratings using Pathfinder and then compared to the expert's knowledge structure using an index of similarity called PFSIM. An ANOVA on the post PFSIM scores showed that there was a significant interaction (*F*(1, 93) = 5.558 , *p* =.02) for navigation structure and verbal ability. Low-verbal students using the EN had higher PFSIM scores than the low-verbal students using the UN (*F*(1, 93) = 3.07, *p* =.083), although the results were marginally significant. There was no significant difference in the PFSIM scores between UN and EN for the high-verbal students (*p* = .118). Additionally, high-verbal learners had significantly higher PFSIM scores than low-verbal learners in the UN (*F*(1, 93) = 7.88, *p* =.006). However, in the EN, the PFSIM scores did not significantly differ (*p* =.595). (See Figure 5).

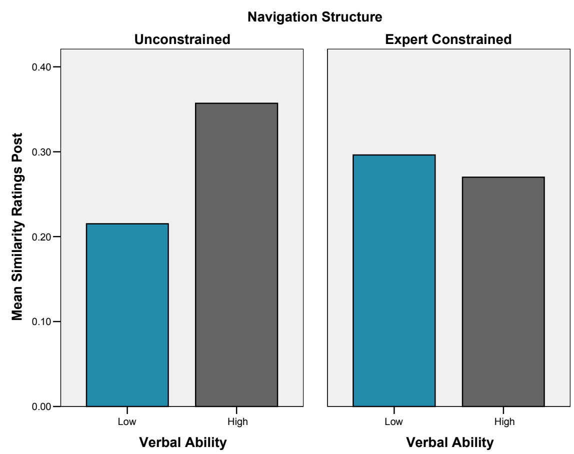

Figure 5: Mean PFSIM scores derived from post-similarity ratings.

Discussion

From an instructional perspective, it is conceivable that utilizing an appropriate hypertext structure should have the advantage of facilitating learning by logically representing the interrelationships between the different parts of information within the hypertext. Furthermore, there would appear to be a reasonable theoretical justification for suggesting that the extent to which hypertext systems influence learning will be dependent on an individual's level of ability. The major goal of this study was to investigate the relation between students' verbal ability and type of navigation used during learning a set of concepts in a hypertext environment. Learners with high-verbal ability were expected to perform better with an unconstrained hypertext structure than low-verbal learners; whereas performance differences based on verbal ability were expected to be smaller for the expert-constrained navigational structure. This study found general support for such a relationship between verbal ability and navigation structure. However, the effect sizes found were rather small (ranging from .024 to .118) and the significance levels were sometimes marginal. We speculate that this may be due to small sample size, as well as poor initial learning of the definitions. Perhaps, instruction in an environment that contains not only the navigational constraints, but also an *explicit* visible depiction of that expert structure would facilitate better learning of the concepts. This idea is currently being explored.

Theoretical Implications

The results from the present study suggested that learners with certain levels of verbal ability perform better in certain types of navigation structures. Low-verbal learners performed better in the expert-constrained navigation than in the unconstrained navigation structure as measured by the procedural and conceptual assessments. According to Gernsbacher et al., (1990) less skilled comprehenders need assistance in forming concept associations and building the inferences needed in order to form a mental representation of information. Additionally, they found that less-skilled comprehenders are less efficient at suppressing unrelated information.

The expert navigation structure may have supported the low-verbal learners in forming semantic associations between related concepts and also by suppressing unrelated associations. It provided the learner with an implicit channel to form an expert-like mental representation. This expert mental representation was then better able to convey the structural information necessary to perform the procedural and conceptual tasks. This suggests that the expert navigational constraints are important and can facilitate acquisition of knowledge for learners who have low-verbal ability.

In contrast, high-verbal learners tended to benefit less from the expert-constrained navigation. Since they have superior skills in selecting or focusing their attention to the important information, as well as organizing and integrating it, they were not disadvantaged as were the low-verbal learners in the unconstrained navigation environment. As discussed, it has been shown that high-verbal learners tend to do well regardless of the coherence level of the text (Cronbach & Snow, 1977). In fact, it was expected that it would be less of a disadvantage for high-verbal learners to be in the unconstrained navigation structure.

According to constructivism theory, the learner should actively build knowledge by reflecting on experiences to construct an understanding of the world (Bruner, 1990). Bruner suggested that learners should be allowed to pursue concepts on their own in order to gain a better understanding. New information can then be understood based on the knowledge already gained. Individuals with high-verbal ability are superior in learning tasks such as comprehension, because they find it easier to integrate new information with existing knowledge than those with low-verbal ability. Because they have superior skills, high-verbal learners may learn more from less coherent text, since it forces them to actively process the information by making additional inferences (McNamara et al, 1996).

Additionally, learning involves not only this integration among concepts but also differentiation among concepts. Learning how concepts are not related can be as valuable as learning how they are related. In the expert-constrained navigation, learners were only provided with direct links to concepts that were highly related to one another. In this navigation structure, navigation was encouraged between concepts that were related, and was discouraged between concepts that were not directly related. Since high-verbal learners are better at suppressing unrelated associations than low-verbal learners, it may have been the case that high-verbal learners were able to learn more from viewing all concepts and being allowed to integrate and differentiate among them. Consequently, expert-constrained hypertext may have been less advantageous for high-verbal students, than it was for low-verbal students. In contrast, the unconstrained navigation structure allowed high-verbal learners to actively study concepts in their own way. Hence, high-verbal learners were able to profit from the true non-linearity of hypertext.

Practical Implications

Research has found that over the course of learning, students' knowledge structures become more like an expert's structure. Further, students who have obtained better knowledge structures have a tendency to perform better on assessments (Jonassen, Beissner, & Yacci, 1993; Trumpower & Goldsmith, 2004). Trumpower and Goldsmith (2004) found that an expert knowledge structure offers a valid hypertext guide to aid students' learning. Further, they found that an expert knowledge structures allow learner's to generalize their knowledge to procedural tasks that required integration of the learned material in a manner that went beyond what was provided in the studied material. The current study's findings do suggest that the expert navigational constraints are important and can facilitate acquisition of structural knowledge, specifically in those with low-verbal ability. Together, these findings suggest that the use of structural learning aids in a hypertext environment provide a structure in which new information can be meaningfully integrated with pre-existing information and improve learning.

Therefore, text should be structured to support comprehension. The authors of hypertext should develop hyperdocuments to maximize reader comprehension.

Implementation of navigational constraints based on an expert's knowledge structure is one way of maximizing a learners' comprehension, especially those learners with low-verbal ability. The design of these systems should convey the interrelationships of the concepts through the structure of the interface itself. By doing so, it can accommodate to learners at different levels of verbal ability.

In conclusion, in order to learn and instruct effectively using hypertext technology, both learners and designers should gain new levels of knowledge that will enable them to take advantage of the benefits of learning with hypertext systems. The learning outcomes will depend on how well the hypertext design and the learners' individual attributes operate together.

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