Differences in Concept Mapping, Hypertext Architecture, and the Analyst–Intuition Dimension of Cognitive Style

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There is now evidence to suggest that the degree to which hypertext or web-based instructional systems facilitate recall of information appears to be contingent on an individual’s cognitive or information processing style. Concept maps also reflect the way in which individuals process information and therefore it is possible that cognitive style and hypertext architecture might influence concept map drawings produced by hypertext users. In this study, 55 participants were assigned to one of three hypertext conditions and were required to recall information and produce maps of the hypertext. Cognitive style was assessed using the analyst–intuition dimension of cognitive style. The findings confirmed earlier research that individuals possessing different cognitive styles differed in recall performance when using different hypertexts. Furthermore, the concept maps produced by participants with different cognitive styles differed between architecture conditions. The findings are explained partly as being due to differences between individuals’ perceived ease of use of hypertext.

Introduction

Several studies have shown that the structure of a hypertext architecture can influence subsequent recall of instructional material from that architecture. For example, there is evidence to suggest that recall performance is enhanced when mixed hypertext architectures are employed (McDonald & Stevenson, 1998; Mohageg, 1992). Furthermore, it has also been shown that individual differences in cognitive or information processing style can influence recall performance (Melara, 1996), and that certain hypertext architectures are more efficacious to the recall performance of

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individuals possessing particular cognitive styles. For example, field-independent individuals outperform field-dependents in the recall of verbal information from hypertext (Lin & Davidson-Shivers, 1996), and the performance of field independents is also superior to field-dependents when explicitly structured hypertext is used (Korthauer & Koubek, 1994). Differences have also been observed in the hypertext navigational strategies employed by individuals possessing different cognitive styles. Beishuizen, Stoutjesdijk, and van Putten (1994) and Verheiji, Stoutjesdijk, and Beishuizen (1996) used the Dutch Inventory of Learning Styles developed by Vermunt and Van Rijswijk (1987) which identifies individuals as either deep or surface processors of information. They asked participants to search for information in a hypertext document and their findings revealed that search strategies were related to differences in cognitive style, with individuals identified as deep processors adopting a global strategy to navigate through the text, while individuals identified as surface processors adopted a more step-by-step approach.

More recently, studies have employed cognitive style constructs referred to as wholist–analytic (Riding, 1991, 1997) or intuition–analyst (Allinson & Hayes, 1996). Typically wholists or intuitives process information as complete wholes; in other words, they tend to perceive entities as being single items, whereas analytics or analysts tend to process information in discrete parts, breaking up the information they receive into a collection of parts. Furthermore wholists or intuitives tend to process more information but on a surface level, whereas analytics or analysts tend to process less information but at a deeper level. In terms of learning from hypertext, Graff and Byrne (2002) and Graff (2003) have demonstrated that hypertext architecture can be matched to cognitive style as measured in terms of wholist/analytics, in order to facilitate recall performance.

Because cognitive style influences how information is processed and the strategies individuals adopt for such processing, then it is also possible that cognitive style may affect the way in which an individual mentally represents a hypertext architecture. Such mental representations may be investigated using a concept mapping technique.

**Concept Maps**

Concept mapping can be traced to the work of Ausubel (1968) and Novak (1977). It involves a method in which individuals are required to outline diagrammatically how the information within a particular subject domain is arranged. In order to do this subsequent to using a hypertext document, users need to have acquired and internalised a visual representation of the hypertext, in terms of the spatial configurations of the pages and the links between them. Therefore a concept map can provide an reliable indication of how effectively an individual has learned about the interrelationships between the concepts within a subject domain.

Shapiro (1998) employed such a technique, comparing the map drawings of participants in three hypertext architectures. In her study, Shapiro used a measure of density, which was derived by dividing the total number of links in each concept
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map by the total number of nodes multiplied by the number of nodes minus one (Klein & Cooper, 1982). This measurement sought to assess the degree to which participants were able to integrate the concepts within the hypertext. However, she found no significant effect of hypertext architecture on the concept map density scores of participants. Shapiro did demonstrate that the presence of system links influenced participants’ internal representations of the hypertext, in that participants who were exposed to the hierarchical and unstructured conditions produced concept maps that largely reflected the system links in each of these structures. Considering these findings in the light of the differences in information processing rationale outlined above, it is likely that individuals possessing an analyst cognitive style will produce maps of higher density because they are more likely to apprehend the hypertext in discrete parts, whereas individuals possessing an intuitive cognitive style will perceive the hypertext as a complete entity and produce maps of lower density. Furthermore, users of more complex hypertext structures such as relational architectures should produce maps of greater density.

Concept maps may also be assessed in terms of map complexity. This is a measure of the breadth of a concept map; the formula for its calculation is given as links drawn divided by number of nodes drawn (Johnson, Gregory, & Smith, 1986). Using this as a measurement, it is suggested that individuals possessing an intuitive style will produce maps of greater complexity than individuals possessing an analyst cognitive style, because intuitive individuals attempt to see the hypertext as a whole entity. Additionally, this effect should be more prevalent with more intricate hypertext structures such as a relational architecture.

Hypertext Usability

Hypertext usability refers to the ease with which individuals judge they can use a hypertext document. McDonald and Stevenson (1996) used three hypertext architecture conditions which corresponded to linear, hierarchical, and non-linear to assess users’ judgements of perceived usability. They assessed participants’ estimates of the hypertext document size and their feelings of disorientation and found that participants in the linear condition rated themselves as having experienced significantly fewer navigational problems than participants using a hierarchical architecture condition, who in turn rated themselves as having experienced fewer navigational problems than participants using the non-linear architecture condition. They suggested that participants in the linear condition experienced less disorientation because they were only required to move back or forwards within the document.

It is also conceivable that individual differences in cognitive style, which influence the way in which individuals mentally represent information, may also account for differences in perceived usability between users. For example, intuitive individuals may judge the size of the hypertext more effectively, as they attempt to gain an overview of the whole system. Furthermore, disorientation occurring in more complex hypertext architectures such as relational architectures may also be experienced
more by intuitive individuals. Analysts will focus on only one link at a time and thus experience less disorientation.

**Aims**

The aims of this study are threefold: first, to attempt to confirm previous findings on recall performance by users with different cognitive styles in different hypertext architecture conditions; second, to investigate differences in the density and complexity of the concept maps produced by individuals possessing different cognitive styles; and finally to investigate differences in perceived usability of different hypertext architectures.

**Method**

**Participants**

In all, 55 participants took part in this study: 46 males and 9 females, mean age 22.93, SD 6.21, minimum age 19, and maximum age 47. All participants were first year undergraduate students from three classes, studying computer science. Participants were assigned to one of the three conditions (described below) and this was carried out according to which particular class they attended for one of their first year subjects.

**Hypertext**

The three hypertext documents used in this study were each architecturally different corresponding to linear, hierarchical, and relational. A description of each architecture is outlined below. Diagrams of the hypertext architectures employed are shown below in Figures 1 to 3.

![Figure 1. Linear architecture](image-url)
In the linear architecture, the hypertext pages were linked such that the user could move only to the next or the previous page. Each page however had a link to the first page, and the first page had a link to the top page of each of the four general sections within the structure. In this way the linear architecture resembled a book-like structure, in that the user could start at a contents page, and move to the beginning of any chapter, and similarly from the middle of any chapter could jump back to the contents page again (see Figure 1). The linear architecture comprised 66 links between pages.

The hierarchical architecture was designed so that a user could move from reading a page at one level, down to a page below it in the hierarchy, or back to a page above it in the hierarchy. In the hierarchical architecture, general concepts subsumed more detailed ones. Users could move up and down the hierarchy,
exploring subordinate and superordinate relationships. However, no facility was provided for lateral moves (see Figure 2). The hierarchical architecture was comprised of 62 links.

The relational architecture was similar to the hierarchical architecture, in that users could move up or down the hierarchy. However, this structure also contained additional links, which meant that the user could move laterally to other locations within the architecture, related by subject matter (see Figure 3). The relational architecture comprised 62 hierarchical links plus a further 32 lateral links.

The subject matter of the hypertext document was taken from various pieces of historical information and edited; names dates and events were altered so that users would not have any prior knowledge of the information content, although consistency between names and dates was maintained.

Assessment of Cognitive Style

The Cognitive Styles Index (CSI; Allinson & Hayes 1996) is a self-report test designed to identify whether an individual possesses an analyst or intuitive cognitive style. The term “intuitive” is used to describe an individual who makes judgements based on feelings and who adopts a global approach to processing information, whereas the term “analytic” describes an individual who makes judgements based on reason, and who focuses on specific detail when processing information. The test contains 38 statements, to each of which a respondent must indicate a true/uncertain/false answer. The CSI has a theoretical maximum score of 76. Higher scores indicate a more analytical cognitive style and lower scores indicate a more intuitive style. The psychometric properties of this instrument are documented in Allinson and Hayes (1996).

Procedure

Participants were taken from three undergraduate computer science classes, and were assigned to one of the three hypertext architecture conditions (described above) on the basis of the class they attended. They were given up to 20 minutes to read through the hypertext pages in any order they chose, provided that this reading order could be accommodated by the hypertext architecture to which they were assigned. They then completed 10 recall questions to assess how well they had learned from the hypertext, before attempting to draw a map of the structure of the hypertext they had used. Only 44 of the 55 participants attempted the map drawings.

Next, participants completed questions that assessed their perceived usability of the hypertext. The five questions used and the possible responses to each on a five-point scale are outlined in the usability questions in Figure 4.

Finally, participants completed the CSI, which assesses cognitive style on the analyst–intuition dimension (described above).
Data Analysis

For the purpose of data analysis, cognitive style was defined according to three style categories based on scores from the CSI as follows. Intuitives were individuals scoring ≤ 35 on the CSI \((n = 17)\), intermediates scored between 36 and 45 \((n = 22)\), and analysts scored ≥ 46 \((n = 16)\). The decision to subdivide into these three style categories was made on the basis of attempting to keep an equal number of participants in each category while maintaining a spread of scores. For the map drawing part of the study, because only 44 participants completed the map drawings, the number of participants in each cognitive style category were as follows: 14 intuitives, 20 intermediates, and 10 analysts.

The recall test employed in this study was scored by simply adding up the number of correct answers to questions about information from the hypertext document.

The concept maps produced by participants were scored in terms of density and complexity according to the following. Calculation of map density, as given by Klein and Cooper (1982), was links / nodes (nodes – 1). The calculation of map complexity, as given by Johnson et al. (1986), was links drawn / nodes drawn.
Results

The results are presented in three sections: for recall, for the concept mapping task, and finally for the hypertext usability scores.

Recall

A one-way $3 \times 3$ (architecture) ANOVA was carried out for the recall scores. There were 19 participants in the linear condition, 18 in the hierarchical condition, and 18 in the relational condition. No significant main effects could be observed for architecture or cognitive style, although a significant interaction effect was observed ($F[4, 46] = 3.04$, $p = .02$). Figure 5 illustrates that analysts scored highest in the hierarchical hypertext condition, intermediates scored highest in the relational condition, and intuitives scored highest in the linear hypertext condition.

Concept Mapping

A $3 \times 3$ way (architecture $\times$ cognitive style) MANOVA was calculated for map density and complexity scores. There were 13 participants in the linear condition, 14 in the hierarchical condition, and 17 in the relational condition.

Map density scores show a main effect for architecture approaching significance ($F[2,35] = 2.80$, $p = .07$), with participants in the hierarchical architecture condition producing the least dense maps. No significant effects were observed for cognitive style, although the greatest variation in density scores occurs for the intermediates.

Regarding complexity, a significant main effect can be observed for hypertext architecture ($F[2,35] = 4.43$, $p = .01$). Participants performing in the relational architecture condition scored highest on complexity scores. Tukey’s test of post-hoc comparisons reveals significant differences in complexity scores between participants in the rela-
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(tional and hierarchical architecture conditions ($p < .01$); however, no differences were observed between relational and linear conditions or between hierarchical and linear conditions for complexity. No significant effects were observed for cognitive style.

**Hypertext Usability**

A Kruskal-Wallis test was performed on the differences in responses to each usability question for each architecture condition. Differences in the mean rank scores are shown in Table 1.

Several significant differences in response can be observed here. First, for Question 1, ($\chi^2[2] = 13.10$, $p = .00$) differences can be noted in how easy participants found it to work with the hypertext document. Participants in the linear condition found it easiest, followed by participants in the hierarchical condition, with partici-
pants in the relational condition finding it the most difficult. Question 2 asked how easy participants found it to locate specific information: those in the hierarchical condition found it most difficult, with little difference between the linear and relational conditions ($\chi^2[2] = 7.61, p = .02$). Question 3, asking about feelings of disorientation, shows that those in the hierarchical and relational conditions felt most disoriented ($X^2[2] = 7.58, p = .02$). No significant differences can be noted for Question 4, which asked whether participants made a complete search of the whole document ($\chi^2[2] = 1.14, p = .49$). Finally for Question 5, those in the linear condition found the tasks easiest to perform, followed by participants in the hierarchical condition, with participants in the relational condition reporting the tasks as being difficult to perform ($\chi^2[2] = 5.36, p = .06$).

Kruskal-Wallis tests were also performed on cognitive styles within each architecture condition, in order to investigate differences in usability. However no significant differences were noted. In general, intuitives produced lower scores, indicating that they found working with hypertext easier.

**Discussion**

<table>
<thead>
<tr>
<th>Question</th>
<th>Linear $n = 19$</th>
<th>Hierarchical $n = 18$</th>
<th>Relational $n = 19$</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. How easy was it to work with the hypertext document?</td>
<td>18.34</td>
<td>29.53</td>
<td>36.67</td>
</tr>
<tr>
<td>2. How easy was it to find specific information in the hypertext?</td>
<td>23.76</td>
<td>36.14</td>
<td>24.33</td>
</tr>
<tr>
<td>3. Did you feel lost or disoriented in the hypertext?</td>
<td>20.34</td>
<td>30.17</td>
<td>33.92</td>
</tr>
<tr>
<td>4. How confident are you that you made a complete search of the whole document?</td>
<td>31.42</td>
<td>26.42</td>
<td>25.97</td>
</tr>
<tr>
<td>5. How easy were the tasks you were asked to perform?</td>
<td>22.71</td>
<td>27.47</td>
<td>34.11</td>
</tr>
</tbody>
</table>

Figure 8. Typical concept map
The aims of this study were threefold: first, to attempt to confirm previous findings on matching hypertext architecture to cognitive style in order to facilitate recall; second, to assess the density and complexity of the concept maps produced by individuals possessing different cognitive styles when using different hypertext architectures; and finally to assess the perceived usability reported by individuals possessing different cognitive styles when using different hypertext architectures.

Recall

The results on recall of information are in accord with previous research, indicating that hypertext architecture can be matched to the cognitive style of an individual in order to facilitate recall performance (Graff, 2003; Graff & Byrne, 2002). More specifically, analysts scored highest in the hierarchical hypertext condition, intermediates scored highest in the relational condition, and intuitives scored highest in the linear hypertext condition. Typically, intuitives process information in complete wholes – in other words, they tend to perceive entities as being single items. A linear step-by-step hypertext would facilitate this conception of the architecture as a complete whole. Conversely, analysts tend to process information in discrete parts, and therefore a hierarchical architecture, which allowed for freedom of movement between pages, would be most suitable them and facilitate their recall. What is more perplexing is why the relational architecture was more facilitative to intermediates. The usability data suggest that participants found the relational condition most difficult to work with. It is theoretically possible that intermediates possess the characteristics of both analysts and intuitives and were therefore more effective at working in the relational architecture where the qualities of both styles were needed.

This finding provides support for the cognitive styles matching hypothesis, which suggests that when the cognitive styles of the system and the user are matched, then recall is facilitated. Hypertext appears to offer promise to such a matching hypothesis, as the architecture may be designed with consideration given to the cognitive style of the user.

Concept Mapping

Participants in the hierarchical architecture condition produced the least dense maps; there was little difference between the density of maps produced of the linear and relational architectures? This finding is partly consistent with what was predicted, although the higher density scores obtained by participants in the linear condition may be accounted for by the fact that participants found the linear architecture easier to work with than the hierarchical architecture. Accordingly, this allowed them to process the information from this architecture more easily and therefore produce maps of greater density. The higher density scores produced by participants in the relational architecture can, as predicted, be explained by the fact that the intricate relational architecture encouraged participants to produce dense maps purely because of the impression that this architecture gave them. This finding
differs from that of Shapiro (1998), who found no difference in density scores between participants performing in different architectures. However, it is feasible that differences in the layout of the hypertext between this study and that of Shapiro may account for this difference in findings.

No significant effects were observed for cognitive style. However, it is interesting to note that the greatest variation in density scores between conditions occurred for the intermediates, with little variation for the analysts and intuitives. Why this is the case is worthy of further investigation.

Assessments of complexity revealed that participants performing in the relational architecture produced the most complex maps, followed by those in the linear condition, with those in the hierarchical condition producing the least complex maps. The complexity measurement seeks to reveal a user’s impression of the extent of the hypertext. As noted above, the intricate relational architecture used in this study may have created the impression that the hypertext was more extensive than the impression given by the other two architectures, accounting for the higher complexity scores in this condition.

A slightly different finding to Shapiro was noted by McNamara, Hardy, and Hirtle (1989), who observed that when producing maps of the environments in which they had worked, individuals’ representations tended to be hierarchical in form even when the environment had no predefined hierarchy. It was reasoned that certain types of information are naturally mentally organised and stored in a hierarchical manner.

### Hypertext Usability

In order to clarify the findings further, participants were asked five questions regarding how they perceived the usability of the hypertext. Differences were found between participants in each architecture condition, although no differences were found between cognitive style types within each architecture condition. First, for Question 1, differences were noted in how easy participants found it to work with the hypertext document. Participants in the linear condition reported that they found it easiest, followed by participants in the hierarchical condition, with participants in the relational condition reporting it as the most difficult to use.

For Question 2, which asked how easy participants found it to locate specific information, those in the hierarchical condition found it most difficult, with little difference between the linear and relational conditions, which is consistent with the low density and complexity scores attained by participants using these architectures.

Question 3 asked about feelings of disorientation, and revealed that participants in the hierarchical and relational conditions felt most disoriented. This finding is consistent with that of McDonald and Stevenson (1996), who suggested that perceived disorientation was dependent upon the form of the hypertext architecture with which participants were working, suggesting that hierarchically and relationally structured hypertext contributed more to feelings of disorientation than linear hypertext. This is explained by the fact that in the linear condition, participants were
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aware that the information they need could only be further back or further forward in the hypertext.

No differences were observed for Question 4, about whether participants had made a complete search of the whole document. This result is not consistent with the findings of either McDonald and Stevenson (1996) or McKnight, Dillon, and Richardson (1990), who reported that participants in a linear condition reported more accurate estimates of the document size than those using non-linear hypertext. These differences may be accounted for by differences in the time allowed for participants to search the hypertext between this study and the studies of McDonald and Stevenson (1996) and McKnight et al. (1990). In this study the limited time allowed may have influenced participants’ estimation of the size of the hypertext document.

Finally, Question 5 revealed that participants in the linear condition found the tasks easiest to perform, followed by participants in the hierarchical condition, with participants in the relational condition reporting the tasks as being most difficult to perform. This finding is again consistent with McDonald and Stevenson (1996), who reported that the participants in their study who had used a linear hypertext stated that they had learnt more about the knowledge domain, and expressed greater confidence in their ability to use the hypertext, than participants in the hierarchical and non-linear hypertext conditions.

The results in the present study indicate that no differences were evident in self-reported feelings of disorientation or ease of use between analytics, intermediates, and intuitives. This is not consistent with the reasoning that intuitives should report a greater degree of disorientation than analysts in hierarchical and relational hypertext architectures because they would be attempting to form an overall impression of the hypertext, which would not be the case for the analysts. However, disorientation in this study was only assessed by one question, and therefore the issue clearly requires further and more detailed examination.

Conclusion

It is suggested that the findings of this study may be applied in the context of matching hypertext architecture to the cognitive style of the user in order to facilitate more effective recall of information from hypertext. This therefore has important implications for e-learning, as it is possible that individuals may benefit from using web-based learning structures designed to match their particular cognitive style. Web-based hypertext would appear to offer great promise to such a matching, as the interface may be designed with consideration of the cognitive style of the user in order to facilitate learning. However, although differences were noted between concept mapping and usability scores between participants in each architecture condition, cognitive style, contrary to the initial hypothesis, had no effect. Accordingly, the evidence presented here would seem to suggest that concept mapping scores and usability assessments are unlikely to explain differences in performance between individuals possessing different cognitive styles.
References


