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The effects of graphical overviews on knowledge acquisition in hypertext

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Abstract A central aspect of designing hypertext for learning concerns the structure of the information in the hypertext and the view the learner is offered of this structure. In this study, a hypertext environment was enhanced with a graphical overview that represented the basic, inherent, structure of the domain and the layout was designed in such a way that learners were unobtrusively encouraged to follow a sequence of exploration that followed the domain structure. This so-called 'visual' lay-out was compared with two lay-outs that presented randomly positioned nodes. One of these two lay-outs contained hints (using 'highlighting') to stimulate learners to follow a domain related exploration similar to the one incorporated in the visual lay-out. The other ('control') lay-out did not provide such hints. Results showed that participants from both the 'visual' and the 'hints' conditions demonstrated a more domain-related exploration pattern than participants from the 'control' condition. Participants in the 'visual' lay-out did not show a better recall of the content of the nodes as such, but showed a significantly better acquisition of knowledge of structure than participants from the other two conditions. These data indicate that a visual display conveys knowledge in its own right and that knowledge gained does not depend on the exploration route followed in the hypertext material.

Keywords: Control group; Hypermedia; Motivation; Navigation; Self-directed; Undergraduate; Visual representation.

Introduction

Exploratory learning environments, such as hypertext or hypermedia-based learning environments, are expected to engage learners in an active, self directed, learning process. Many authors claim that this should lead to better motivation, comprehension, and transfer (Dillon & Gabbard, 1998; Jacobson & Archodidou, 2000). Review studies, however, assessing the effect on learning from hypermedia have shown no overall effects compared to linear presentation formats (see e.g. Chen & Rada, 1996; Tergan, 1997; Dillon & Gabbard, 1998) and some studies even show detrimental effects of the use of hypertext or hypermedia (see e.g. McKnight *et al.*, 1990; Rada & Murphy, 1992). A major barrier for fruitful exploration learning in hypertexts as signalled by several authors (e.g. Conklin, 1987; Marchionni, 1988;

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Rouet, 1990) is that people easily '*get lost in hyperspace*' while exploring. Hypertext offers a large degree of freedom and users seem to have trouble handling this freedom. Disorientation, or 'losing context', according to Conklin (1987), is a problem that is endemic to the use of hypertext. With traditional, linear, instructional text the situation is different. This type of text is generally specifically organised for learning. The learner does not have to decide about the sequence in which to learn the nodes, and usually overviews are provided in the form of abstracts and summaries. In contrast, effective exploration of a hypertext document does require the learner to perform complex cognitive actions such as *planning* and *monitoring.* It is likely that the observed ineffectiveness of learning in exploratory environments arises from an inability to meet the cognitive demands made by the exploratory environment. Learner activity is assumed desirable, but in plain exploratory environments, particularly in the more extensive ones, too much seems to be left to the learner.

Various types of solutions have been proposed to help learners to overcome the complexity of exploration. Quite restrictive support measures are the "guided tours" as used by Allison & Hammond (1989) and Arents & Bogaerts (1993). More freedom is given by support that helps to monitor the history of the exploration, e.g. by leaving 'footprints' (McAleese, 1989) sometimes combined with means to mark important sections (Rouet, 1990) and annotating the material studied (Monk, 1990). Graphical overviews have taken a lead in helping users overcoming disorientation (see e.g. Conklin, 1987; McAleese, 1989; de Young, 1990; Tan, 2000). Several studies have found that graphical overviews, and even the specific layout of the graphical interface, influences the effectivity and efficiency of information retrieval from the hypertext both under general conditions (Mogaheg, 1992; McDonald & Stevenson, 1998) and in performing a specific (design) task (de Vries & de Jong, 1997, 1999). In a meta-analysis of 23 studies, Chen & Rada (1996) concluded that the most significant result concerned the effect of graphical overviews on results gained. Norman (1988) argues that one of the main principles for interface design should be 'visibility' (i.e. the internal functional structure of a system must be visible at the outside to allow the user to make deliberate decisions on how to handle the system). In line with Norman, this study assumed that the need for visibility also holds for an internal structure of a domain that is to be learned from a hypertext.

The effects of a visual display of the domain structure may come in two ways. First, providing learners with a systematic visual overview of the domain is expected to induce a systematic route through the domain and may thus lead to a better acquisition of the structure of the domain. This latter claim is supported by studies on the effects on learning of the sequence in which written material is presented. Many of those (older) studies compared randomly generated sequences with sequences that are based on the logical structure of the domain. Although several early studies did not report any differences (Vlachouli-Roe *et al.*, 1962; Levin & Baker, 1963), a number of later studies reported a significantly better acquisition of knowledge when following domain structure-related sequences (Brown, 1970; Tobias, 1973; Kintsch *et al.*, 1977). Dee-Lucas & Larkin (1995) state that, compared to traditional text, hypertext systems make it more difficult for learners to build an integrated representation of the information because they move between units, missing the continuous line of reading that is characteristic of traditional text. Second, visual overviews are supposed to enhance acquisition of domain structure because they display the structure of the domain directly. Whereas in traditional text learners have to extract the overall structure (relations between higher and lower level ideas) from the running text, visual overviews display these structures directly in the titles of nodes and their interrelations. Dee-Lucas & Larkin (1995) compared learning from a hypertext with a visual overview with learning from the same hypertext with names of nodes presented as an unstructured list. They found that learners with the unstructured list produced less coherent representations than learners with the graphical, structured overview. In another study, however, Jonassen (1993) found that students who were provided with a graphical overview did not acquire better 'structural knowledge' than students who learned with unstructured nodes or with an interface that lead them on a node-by-node basis through the hypertext. Jonassen (1993) even found on a recall test that the group learning with the unstructured interface outperformed the groups working with the structured interfaces.

The visual display that is used in the current study was comparable to the visual or graphical displays from the Jonassen (1993) and Dee-Lucas & Larkin (1995) studies. These two studies were extended in two ways. First, the learning results were measured in three different ways: knowledge of the overall structure of the domain (configural knowledge), knowledge of the relations between two specific nodes (propositional knowledge), and knowledge of the content of the nodes (definitional knowledge). Second, an analysis was made of the exploration behaviour of learners that went beyond measuring nodes visited and time spent at each node and that tried to capture their exploration pattern. These extensions made it possible to assess the effects of presenting a visual display of the domain structure in a hypertext system on learning behaviour and knowledge acquisition.

Method

The domain

In the selection of the subject matter for this experiment, the prior knowledge of the learners was a crucial factor. It was assumed that the effectiveness of the interface manipulation depends on the amount and nature of the learner's prior knowledge with the structure of the interfaces most likely having more effect with subject matter material that is relatively unfamiliar to the learners. Studies by Mohageg (1992), McDonald & Stevenson (1998), and Dee-Lucas (1999) showed that experts rely on their prior knowledge when interacting with a hypertext system, whereas novices rely more on cues in the interface. Following this, a domain was chosen that was largely unfamiliar to participants in this study. The hypertext system consisted of 26 fragments in the domain of fuel supply systems of a Dutch car. The fragments contained descriptions of the various aspects of process control in a modern fuel injection system. In such systems, several factors are measured (e.g. external temperature) to supply an optimal amount of fuel for a combustion engine to run properly. For example, in cold weather conditions, the system needs to supply relatively more fuel as more will condense in the engine and is therefore not available for combustion. The hypertext was organised in a hierarchical way. At the highest level, it contained general introductions to measure and control processes. At the subsequent level, it provided descriptions of the particular processes in a fuel supply system. Finally, at the lowest level, it gave examples of measuring or control under specific circumstances.

Experimental design

A hypertext system was developed with three different interfaces.

In Condition 1, the 'visual' condition, the overview was organised using a *'visual'* layout. That is, the hypertext environment (on 'fuel supply systems') was enhanced with a graphical overview that represented the basic structure of the domain and the layout was designed so that learners were unobtrusively encouraged to choose a sequence that followed the domain structure. This lay-out followed a vertical hierarchical structure of nodes with is_a relations (e.g. a motor temperature measurement is_a measurement), the top two horizontal levels indicated sequential, temporal relations (e.g. a motor temperature measurement is_followed_by a determination of default signal), and the lower three horizontal levels indicated causal relations (e.g. measurement of a high motor temperature causes relatively low signal correction). An impression of the interface of the 'visual' condition is given in Fig. 1, but only a limited number of the nodes and relations are presented.

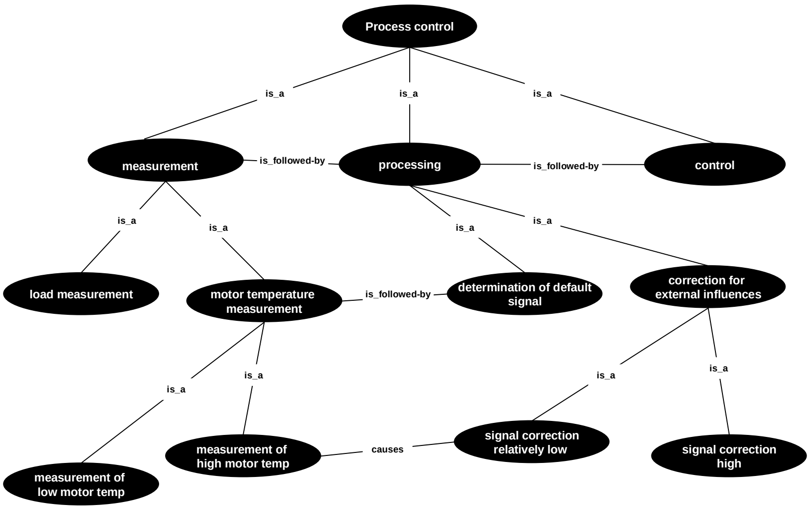

Fig. 1 Part of the interface of the 'visual' condition (Condition1).

In Condition 2, the 'hints' condition, a visual layout was also used to present the same nodes as in Condition 1, but now the nodes were arranged randomly on the screen (without nodes overlapping). In Condition 2, participants were provided with hints on how to traverse the system. These hints were implemented by highlighting nodes in the overview, where the sequence of highlighting reflected the domain-related layout from Condition 1.

Condition 3, the 'control' condition, was created by using the same 'random' overview as in Condition 2. In this case, no hints on the sequence of traversing the system were provided.

Since the aim was to study the influence of the displayed structure of the domain on learning it was decided to provide as little textual information concerning relations as possible. Therefore, great care was taken to avoid explicit references within text fragments to other nodes. Hence, the only information on relations was provided by the visualisation of those relations in the graphical overview. This visualisation was the only access to the hypertext fragments and thus, though unusual, it was not possible to go from within one hypertext fragment directly to another. Finally, in the interface the learners were allowed to move the nodes, primarily because moving usually made relations between nodes more evident. In all conditions participants were free to decide on the sequence of exploration.

Participants

The participants (*n* = 46; 15 in the ‘visual’ condition, 15 in the ‘hints’ condition, and 16 in the ‘control’ condition) were first year undergraduates in Psychology. Participation in the experiment was part of a study requirement, though participants had the right to choose from several experiments. The participants were assigned randomly to the conditions with the exception that both genders were equally distributed over conditions.

Procedure

Prior to working with the hypertext system, the participants were trained on a practice domain consisting of four nodes. Dee-Lucas & Larkin (1995) showed that the influence of the form of the overview of a hypertext on participants’ performance is higher when learners receive global learning goals compared to when they receive specific learning goals. Participants received a global assignment asking them to learn as much as possible from the hypertext. They were also informed that an above moderate performance on the post-test would be (financially) rewarded. The participants had to work for at least 25 minutes with the hypertext and no maximum time limit was set. Participants were told that they should read all text fragments and that each fragment could be read more than once. Differences in efficiency between conditions could emerge since the total time was not limited and participants were allowed to visit text fragments more than once. To get a clear picture of the exploratory route, participants were forced to read only one fragment at a time. Finally, three types of knowledge tests (as described later) were administered prior to and then after the session with the hypertext.

Data collection

Process measures All actions of the participants were logged with a time stamp. This provided information on the overall activity in the environment, time spent, and nodes visited. The logfiles were also used to extract the exploration pattern of the participants. First, the ‘connectivity’ of the participants’ exploration was examined. More specifically, this concerned the number of ‘jumps’ made by participants. That is, did they follow links in the interface or did they traverse between unrelated nodes? Second, the ‘consistency’ of traversing was assessed. That is, did the exploration pattern follow the hierarchy, temporal, and causal parts of the domain structure? In this case logfiles were used since these data could be gathered unobtrusively with no interference in the learning process.

Product measures It was expected that differences in the sequence of exploration would mainly influence the acquisition of knowledge of structure and not the learning of the content of the nodes. Content of the nodes was measured by a *definitional knowledge* test. Knowledge of structure was first measured with a test of knowledge of direct relations between concepts (the *propositional knowledge* test). Second, knowledge of the overall structure of the domain was measured by a so-called *‘configural’ knowledge* test (cf. Goldsmith *et al.* 1991).

Definitional knowledge. Definitional knowledge was considered as knowledge of facts acquired from the text fragments. This type of knowledge was tested by means of a multiple choice test that required recognition of facts as given in the text fragments. An example item from the definitional knowledge test is: '*The position of the throttle switch provides information on: (1) the amount of oxygen supplied; (2) the amount of fuel supplied; (3) both 1 and 2 are correct; (4) both 1 and 2 are incorrect; (5) no idea'*. The final answer option was in all cases 'no idea', this option was added since little knowledge of the subject matter was anticipated, especially in the pre-test. By telling the participants not to guess but to use this option it was hoped to avoid too large a bias due to guessing. The pre-test and post-test both consisted of a total of 20 items with 5 possible answers.

Propositional knowledge. For measuring propositional knowledge, several types of items were developed. Hierarchical (i.e. generalisation-specification) relations, categorisation or identification of subclasses were tested. Temporal relations were tested by asking for ordering in time or by asking for the missing parts of a procedure. Causal relations were tested by asking for predictions. All relations that were present in the hypertext system (except for the absolutely trivial ones) were tested. An example item asking for a temporal relation is: '*The process of correction for external influences is amongst other things preceded by measuring: (1) the motor temperature; (2) the r.p.m. (rotations per minute); (3) the air pressure in the inlet; (4) none of the above options is correct; (5) no idea*'. An example item asking for a causal relation is: '*A malfunction in the motor temperature sensor during cold start causes the blocks of the basic supply signal to be: (1) too short; (1) too long; (3) irregular; (4) none of the above options is correct; (5) no idea'*. The pre-test and post-test both consisted of a total of 20 items, each with 5 answer alternatives, where again one of the options was the 'no idea' option.

Configural knowledge. Configural knowledge was tested by means of a card sorting task (see Shavelson & Stanton, 1975). In this card sorting task, the participants were instructed to cluster the 26 nodes of the hypertext. For this task, a tool was created with an interface identical to that of the hypertext system, except that it did not allow access to the hypertext fragments. Participants were instructed to move the nodes to form stacks that were clusters of related nodes. Neither clustering criteria nor limit on cluster-size were given. To obtain a measure for knowledge of the overall structure, the results of each participants' card sorting task were compared with a norm model. This norm model was chosen so that it resembled the original domain organisation as much as possible. To calculate the correspondence to the norm clustering, a proximity matrix was generated from both the participant and the norm clustering. A cell of the proximity matrix is filled with a 1 if row and column concepts belonged to the same cluster, and with 0 if they belonged to different clusters. The correspondence of the participants' proximity matrix to the norm matrix was calculated using a measure for correspondence by de Jong & Ferguson-Hessler (1986). This measure accepts matrices composed of dichotomous data as input.

Results

This study assessed the effects of presenting a visual lay-out of domain structure on the acquisition of knowledge. To determine the effect of the visual display *per se* and the effect of a more structured route through the hypertext system induced by the visual lay-out, two conditions were added in which learners worked with a hypertext system that lacked the domain structure in the lay-out. In one condition ('hints' condition) students were stimulated to follow a structured, domain oriented sequence. In the final ('control') condition no domain-related visual lay-out was present and also no hints on the route through the system were given. In the results section, first the way students went through the hypertext ('process measures') will be compared between conditions. Second, the effects of conditions on several knowledge tests ('product measures') will be examined.

Process measures

Time on task and overall activity There were no differences between conditions in average time students spent in the hypertext system ($F_{2,43} = 2.49$, ns). The mean duration in the hypertext system for the 'visual' group was 1691 seconds ($sd = 253$), the 'hints' group spent 1990 seconds in the hypertext ($sd = 439$), and the 'control' group 1833 seconds ($sd = 482$). Activity in terms of the number of traverses also showed no differences ($F_{2,43} = 0.85$ (ns). The mean number of traverses in the 'visual' group was 41.60 ($sd = 12.62$), in the 'hints' group 35.13 ($sd = 16.03$) and in the 'control' group 43.56 ($sd = 24.76$). No correlation was found between time on task and the dependent variables propositional knowledge ($r = – 0.03$) or configural knowledge ($r = 0.02$).

Connectivity The first measure of the participants' exploration pattern in the hypertext was called *connectivity*. Connectivity expresses how much students followed the links in the interface. To assess connectivity, for each participant the *average distance covered* in visiting two nodes that were related was calculated (in calculating this distance a correction for 'necessary' traverses was made).

A main effect for connectivity was found ($F_{2,43} = 11,32$, $p < 0.001$), and a *posthoc* analysis (Scheffé) revealed that connectivity scores were significantly higher for both the 'visual' ($m = 0.90$; $sd = 0.04$) and 'hints' group ($m = 0.87$; $sd = 0.10$) when compared to those of the 'control' group ($m = 0.75$; $sd = 0.13$). This means that in their exploration patterns participants in the 'visual' and 'hints' groups more closely followed the links from the interface than participants in the 'control' group.

During a qualitative analysis of the traverses of 12 participants from the 'visual' and 'control' group (the three best and three worst performers from both groups), differences between the groups in the initial exploration phase could be observed. The route of the 'visual' group was found to be highly connective from the beginning. Large 'jumps' were only observed in a later stage of exploration. In contrast, within the 'control' group 'jumping' was certainly seen in the initial stage. A possible explanation might be that participants in the 'control' group started browsing the material but that the 'visual' group skipped this phase. To investigate this, each route was split up into an 'initial phase', incorporating the first 10 traverses and a "final phase" incorporating the traverses 11 and on. The connectivity results for both phases can be found in Table 1.

Table 1. Scores for connectivity for two phases in the learning process

	Initial phase		**Final phase**	
	m	***(sd)***	***m***	***(sd)***
Visual	0.95	(0.08)	0.90	(0.18)
Hints	0.92	(0.16)	0.86	(0.09)
Control	0.63	(0.04)	0.81	(0.11)

The connectivity scores for the 'control' group were significantly lower in the initial phase ($t = – 5.17$, d.f. = 15, $p < 0.001$) compared to the final phase. In addition, the connectivity scores of the ‘visual’ group were significantly higher in the initial phase ($t = 2.37$, d.f. = 14, $p < 0.02$) compared to the final phase, while the same holds (marginally) for the ‘hints’ group ($t = 1.64$, d.f. = 14, $p < 0.06$).

Consistency In addition to whether participants followed links in the hypertext, it was measured if they followed the overall domain structures. As indicated above, the hypertext system basically consisted of a number of structures, one (vertical) hierarchical structure, two (horizontal) temporal structures, and three (horizontal) causal structures. For each of these structures, a measure of *consistency* was determined. For each exploration of a separate structure, it was determined whether it followed the links in the structure or not. Table 2 presents the average consistency scores for the separate structures in the different experimental groups.

Table 2. Scores for consistency

	Conditions					
Primitive	**Visual**		**Hints**		**Control**	
structure	***m***	***sd***	***m***	***sd***	***m***	***sd***
Hierarchy	0.93	(0.26)	0.88	(0.34)	0.06	(0.25)
Temporal-1	0.80	(0.41)	0.88	(0.34)	0.44	(0.51)
Temporal-2	0.87	(0.35)	0.88	(0.34)	0.25	(0.45)
Causal-1	0.73	(0.46)	0.69	(0.48)	0.43	(0.50)
Causal-2	0.67	(0.49)	0.81	(0.40)	0.06	(0.25)
Causal-3	0.67	(0.49)	0.56	(0.51)	0.00	(0.00)

The data on consistency (see Table 2) showed an overall effect for condition, except for the first causal structure. Post hoc analysis revealed that level of consistency in the ‘visual’ and ‘hints’ conditions is for all primitive structures significantly higher than in the ‘control’ condition, again with the exception of the first causal structure.

Product measures

The results of the test for definitional and propositional knowledge are expressed in terms of the number of items correct (out of 20), whereas configural knowledge is expressed in terms of the correspondence to the norm model. For the data on configural knowledge, due to lack of activity in the card sorting task, the results of one participant from the ‘visual’ condition and that of one participant from the ‘hints’ condition had to be removed from the data set ($N = 44$). Table 3 and Fig. 2 present an overview of the results.

Table 3 Scores on the knowledge tests

Condition		**Definitional**			**Propositional**			**Configural**		
		Pre	**Post**	**Gain**	**Pre**	**Post**	**Gain**	**Pre**	**Post**	**Gain**
Visual	*mean*	2.67	10.00	7.28	1.53	10.33	8.08	–0.01	0.49	0.50
	sd	(2.72)	(3.49)	(3.85)	(1.89)	(3.16)	(3.59)	(0.08)	(0.32)	(0.35)
Hints	*mean*	2.20	10.33	8.13	2.87	8.47	5.60	–0.02	0.27	0.28
	sd	(2.14)	(2.29)	(2.95)	(3.42)	(2.00)	(3.85)	(0.10)	(0.30)	(0.41)
Control	*mean*	3.13	9.56	6.44	2.06	6.81	4.75	–0.02	0.08	0.10
	sd	(3.05)	(4.12)	(4.53)	(2.27)	(3.19)	(2.65)	(0.07)	(0.23)	(0.22)

As can be seen in Table 3, no large differences in prior knowledge were found. One way multivariate analysis of variance did not reveal a difference between conditions ($F_{6,80} = 1.20$, ns.) for the pre-test results. Although the pre-test differences were small, disregarding these may lead to inappropriate conclusions. Hence, from here on ‘knowledge gain’ scores that reflect the differences between pre-test and post-test scores are used. These knowledge gain scores, when subjected to a multivariate analysis, showed an overall constant effect, indicating that the participants indeed learned from working with the hypertext environment ($F_{3,41} = 64.87$, $p < 0.001$). This learning effect was significant for definitional ($F_{1,43} = 167.25$, $p < 0.001$), propositional ($F_{1,43} = 122.30$, $p < 0.001$) and configural knowledge gain ($F_{1,43} = 31.56$, $p < 0.001$). The different treatments were found to affect learning since the gain scores showed a main effect of condition ($F_{6,78} = 3.76$, $p < 0.001$). Using a univariate analysis, this main effect can be ascribed to effects on propositional and configural knowledge. For these types of knowledge gain, the results revealed significant differences between the conditions ($F_{2,41} = 7.46$, $p < 0.001$) and ($F_{2,41} = 6.81$, $p < 0.001$), respectively. Univariate analysis revealed no differences for definitional knowledge ($F_{2,41} = 0.59$). Post hoc analysis (Scheffé) revealed that differences between the 'visual' condition and the 'hints' condition and differences between 'visual' condition and 'control' condition were significant (at $\alpha = 0.05$) for both the propositional knowledge and the configural knowledge test. Differences between the 'hints' and the 'control' conditions were not significant for propositional knowledge. Differences between the 'hints' and the 'control' conditions were only marginally significant ($t = 1.67$, d.f. = 28, $p < 0.06$) for configural knowledge. For definitional knowledge, there were no significant differences between conditions.

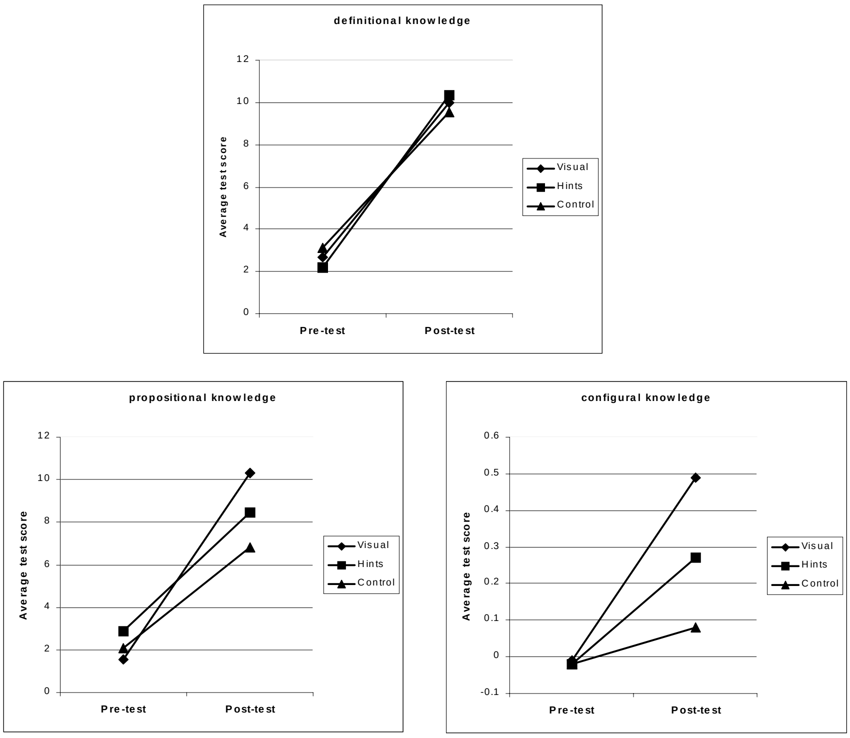

Fig. 2 Graphical display of the results on the different knowledge tests

Conclusions and discussion

In the present study, the impact of different interfaces on learning from a hypertext system was assessed. The study was designed in such a way that effects from the graphical interface and the learning route induced by the interface could be separately assessed. Following critical comments from review studies (Tergan, 1997; Dillon & Gabbard, 1998), a set of knowledge measures directly tapping types of knowledge relevant for the stated theoretical hypotheses was used. By means of the logfiles, it was possible to assess the learning process in a deeper manner than has been done in previous studies.

The first hypothesis tested was that the interface may influence the exploration route that students follow in a hypertext system. The related prediction in the study was that in presenting a visual overview of the domain (Condition 1, the 'visual' condition) and giving learners hints to follow a domain related route (Condition 2, the 'hints' condition) would encourage participants to follow a more domain related sequence of traversing the domain than participants in a condition that lacked these features (Condition 3, the 'control' condition). Data showed that participants in the 'visual' and 'hints' conditions indeed followed the links in the interface (displaying the domain structure) more closely than participants in the 'control' condition. A further comparison of the 'visual' with the 'control' condition showed that in the 'control' condition jumping through the nodes was especially dominant at the start of the learning process. Process data further showed that, overall, participants from the 'visual' and 'hints' conditions were more consistent in following the separate 'substructures' in the hypertext than participants from the 'control' condition. In summary, it was found that participants in the 'visual' condition, in which the structure of the domain was visually displayed, and participants in 'hints' condition, in which the structure of the domain was suggested by highlighting relations, showed a more domain-related exploration pattern than participants in the 'control' condition. This finding supports the general idea that interface aspects can influence learners' exploration routes.

The second hypothesis tested concerned the idea that a more structured exploration pattern would positively influence knowledge of individual relations between concepts. The related prediction states that participants in the two conditions that guided the exploration route ('visual' and 'hints' conditions) would show higher gains on the propositional test than participants in the 'control' condition. The basic idea was that propositional knowledge test assessed the relations between separate concepts and that in the 'visual' and 'hints' conditions this would be positively affected by the domain related route that was followed. Data partly followed this prediction. Only participants in the 'visual' condition had higher gains on propositional knowledge than participants in the 'control' condition. There was no significant difference in gain between participants from 'hints' and 'control' condition. As was tested under the first prediction, no differences in the *exploration route* between participants in the 'visual' and 'hints' conditions were found. Thus, the conclusion here can be that it is not the exploration route per se that leads to the acquisition of propositional knowledge.

A third hypothesis was based on the idea that following a domain related exploration route (as was expected in both the 'visual' and 'hints' condition) would provide learners with the opportunity to experience the overall configuration of the domain. This overall structure was, of course, also displayed directly in the visual overview. The related prediction states that participants in the 'visual' condition would gain higher configural knowledge than participants in 'hints' condition, who in turn would show a higher gain in configural knowledge than participants in the ‘control’ condition. This prediction was partly corroborated by the data. The difference between the ‘visual’ and ‘control’ conditions was significant. The difference between the ‘hints’ and the ‘control’ conditions almost reached significance.

A final hypothesis that conditions would show no differences in knowledge of the content of nodes was supported by the data. This confirmed the idea that what students learned within a node was independent of the route that brought them there or the context in which it was embedded.

The outcomes of the present study provide a better understanding of results from previous studies and it underscores the value of recommendations made in several review studies. From the results also lessons may be learned about the theoretical underpinnings of learning from hypertext and find inspiration for the design of hypertext environments.

One of the main outcomes of this study is that different results can be found for different types of knowledge measures. This explains the seemingly contradictory results of the Jonassen (1993) and Dee-Lucas & Larkin (1995) studies. Using dependent measures that resembled the definitional and propositional test, Jonassen found no advantage in providing students with graphical overviews or node-by-node guidance. When Dee-Lucas and Larkin used a dependent measure similar to the configural test, they found positive effects for a graphical overview compared to a textual unstructured overview. A study by Chou & Lin (1998) showed comparable results. Students who were offered an overall map of the underlying structure of a hypertext system scored better on a concept mapping task than those students who received only partial maps. The results from these studies are in line with the results of the present study. In a more general sense, this touches upon the conclusion drawn in several review studies on learning from hypermedia (Chen & Rada, 1996; Tergan, 1997; Dillon & Gabbard, 1998) that the results of studies reviewed are equivocal. The results of the present study support the notion that learning from hypertext may occur, though it was not compared to more linear types of learning material. Dillon & Gabbard (1998) concluded from their review of studies comparing learning from hypermedia and other media that hypermedia is most useful when learning complex and extensive domains where searching for information is relevant and when data manipulation and comparison of data is important. In this study, the domain was not an extensive domain, but due to the different types of relationships involved and the nature of the domain it could be seen as not an easy topic for the participants. Of course, one can only speculate about effects when a more extensive domain is involved but it could be expected, following Dillon & Gabbard (1998) that the effect of a graphical interface would then even be more distinctive.

A second characteristic of the current study that might limit the value of the results of the current study is the limited study time that was given to students. They were asked to study for a minimum of 25 minutes and in reality spent around 30 minutes in the hypertext system. This short study time was, of course, related to the relatively limited size of the domain, as explained above. Again, one might speculate about the results if a longer study time (and more extensive domain) had been used. One position could be that differences between conditions might then disappear. However, studies like this one in which no differential effects are found often state that the limited study time might be the cause for this and would lead to the expectation that a longer study time would even sharpen these findings.

One of the most cited theoretical notions used in the context of learning from hypertext is cognitive flexibility theory (e.g. Spiro & Jehng, 1990; *Spiro et al.*, 1992). Basic to this notion is the idea that approaching a domain from different angles enables learners to make multiple comparisons and relations and this leads to a ‘flexible’ cognitive structure. Niederhauser *et al.* (2000), however, found a negative correlation between ‘criss-crossing’ a hypertext and learning results. Though the idea of cognitive flexibility was not tested directly, the implicit assumption in cognitive flexibility theory that knowledge gained is influenced by the route followed is not supported in this study. The overall conclusion is that the most significance influence on learning results comes from the graphical overview and that the effect of this interface is due to the direct display of the domain structure. Designing hypermedia environments should therefore not only look at the overall exploration pattern of learners but present the learner with graphical overviews and link these to deep representations of the domain. Recent and detailed approaches towards designing hypermedia environments (Jacobson & Archodidou, 2000) take this into account.

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