HYPERTEXTUAL INFORMATION STRUCTURES AND THEIR INFLUENCE ON READING COMPREHENSION: AN EMPIRICAL STUDY

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1. The global structure of hypertexts: reading strategies for locating information

In traditional texts the inner system of logical relations is realised through a linear sequence of text elements. With the appearance of hypertexts and their non-linear structure the mediation of information has changed dramatically. The genre of hypertext offers different paths through the material. This change in the linguistic order of elements has also led to the transition from an *interpretative* to an *explorative reading process* (Aarseth 1997:64) a concept which basically refers to reading to obtain facts by following one's own path. What follows the two main types of linguistic ordering developed by hypertext designers will be described and related to corresponding reading strategies for locating information.

In hypertexts linguistic ordering is realised through the processes of *selection* and *chaining*. On the text level letters are chained to form words, words are chained to form sentences and finally, sentences are chained to form texts. At this level the rules for combining and chaining are the same as for paper-based writing and thus linear reading will meet with success. Textlinguistic requirements, such as continuity and wholeness still apply and are kept in mind by authors of hypertexts. Therefore readers will generally profit from linear reading. Even though they can choose from different paths, the path appearing when a text is read line by line will always be dominant.

However, when you take a closer look at the wide range of structural possibilities of hypertexts, you will soon become aware of the limits of linear linguistic ordering and reading. Due to the special characteristics of hypertexts a linguistic level above the text level is created. When texts are combined into hypertexts this combination of texts need not have the characteristics of chaining (Engebretsen 2000: 210). For this conversion three main types of structural combinations namely *linear, axial* and *networked hypertexts* are used.

The first type of text structure, the so-called *linear structure,* results from a simple conversion of a traditional linear text into hypertext. The second type, the so called *axial structure,* is hierarchical in nature. It is characterised by a sequence of central nodes which serve as a centering axis or 'trunk'. The nodes indicate a recommended reading strategy. The trunk has a number of 'branches' with additional information which readers may choose to click on. Usually the screen in axial hypertexts is divided into frames. The trunk is presented as a static frame and contains a summary of the core facts of the document. Within the trunk links are indicated through colouring and underlining. If the reader clicks on such a link, a supplementary node will appear in a separate frame leaving the main text in the trunk node unaffected. Within axial text structures, readers usually resort to a *systematic reading pattern* as defined by Balcytiene (1999:3), and open the links in the order they appear in the centering axis. In the third type of text structure, the *network structure,* nodes are linked together on the basis of semantic criteria. In *network structures* readers have a greater degree of navigational freedom. They find graphical representations of information elements on the screen which serve as a map. To view the various text files the readers must click on each of the graphical representations in the map. The map remains on the screen when the respective node is opened. The following figure serves to illustrate the three different types of text structures.

If readers want to access information in interconnected *axial* or *networked hypertexts,* they will have to resort to *explorative reading*. It is important for them to realise that the way in which texts are interconnected represents a meaning-creating context in itself. Thus, readers have to come to grips with content, organisational and presentational structures. Usually hypertext designers keep this in mind when selecting the text elements they want to interconnect by electronic links. So they often decide on a global structure for the system of nodes and links. This global structure determines how the hypertext can be read and limits the range of navigational choices for the reader.

In the interconnected axial and network structures, self-regulated learners who are to a higher degree capable of using metacognitive skills are at an advantage. In Balcytiene's terminology (1999:303), their reading strategy can be described as *exploration due to individual preferences.*

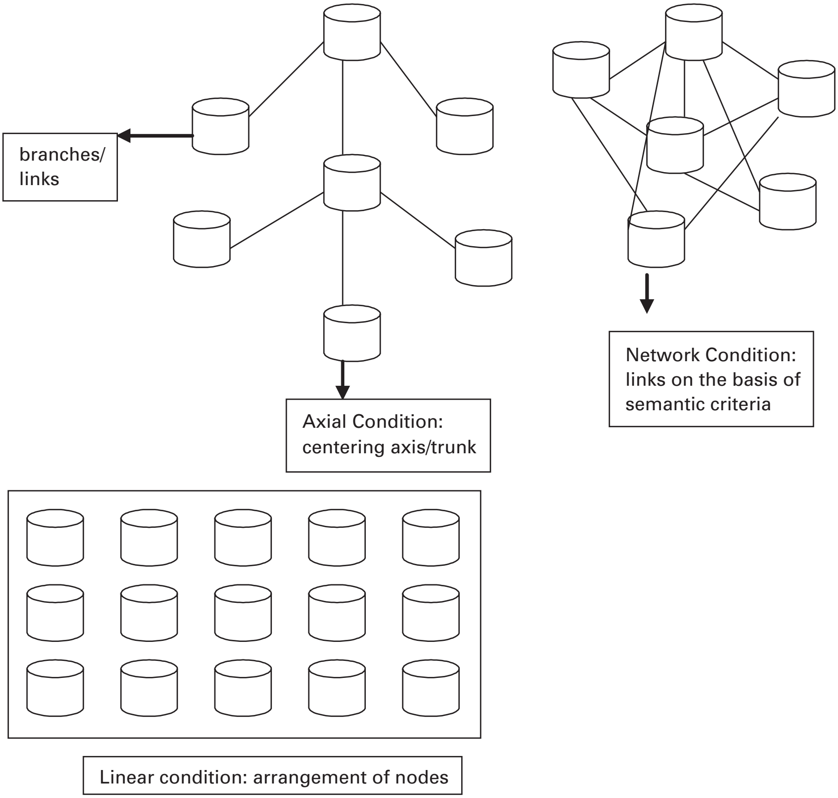

FIGURE 1: Text structures in hypertexts

Since interconnected structures are by nature less coherent, the information they contain can only be decoded if the reader possesses a certain amount of background knowledge. In an interesting study conducted by Salmeron (2005), it was found that low-knowledge participants learned more by following a high coherence order whereas high-knowledge participants learned more by reading hypertexts in a low-coherence order.

1.1. Supporting understanding: choosing the appropriate global structure

We can assume that the author's choice of global structure is influenced by his/her intention to support readers' understanding and memory of the content. Authors aim at choosing appropriate mechanisms to make the collection of interconnected texts a logical unit. In hypertextual environments these mechanisms comprising implicit and explicit connective elements generally referred to as *coherence* can no longer be treated as a text-immanent feature only. It is impossible to assume that a text type which invites individual reading strategies has coherence as strong as it would have in a linear text.

But how can a hypertext author —who regards coherence as a result of mental work done by the reader— ensure that a reader actually assigns coherence to his/her text? This can only be done if s/he focuses on the inner activity of the readers as participants in the communication process. When they read his/her hypertext, they participate in the communicative process and search for *relevance*. According to *relevance theory* (Sperber and Wilson 1986), *relevance* is defined as a logical relation between the unit of meaning activated at the moment of reading and those units activated earlier in discourse. This entails that the relationship between the individual node being read and the global structure of the whole document has to be clearly indicated for the reader. Moreover, each individual node has to be a coherent unit in itself because the author does not know which units of the text the reader has read before or will read after having read the individual node. This kind of *internodal coherence* can be achieved through thematic homogeneity.

The author of a hypertext assigns certain tasks to the reader, such as deciding on the path. Consequently, it is necessary for him/her to view coherence as an interplay between textual and cognitive factors. Textual factors, such as the actual sequence of sentences within a node (cf. *cohesion* Halliday and Hasan 1978), can be realized within the framework of text grammar. In this area s/he can choose between three different forms of couplings. *Referent couplings,* that is, individual words with identical or related references in two subsequent sentences are very frequently used within nodes. In addition there are *sentence couplings* in which conjunction or adverbs show temporal or other relations between sentences. A third form of cohesive devices used are so-called *mixed couplings* in which individual words such as 'this' or 'that' summarize the content of a previous sentence in order to relate it to new information.

Cognitive factors start to play a role when the author works on coherence at a higher text level. Hypertext authors create large and small text units and arrange them in a global structure that constitutes a unit of meaning in itself. The logical relatedness between the text units must be made explicit to the reader. This can be done on the text surface by providing readers with maps or graphical representations of the text structure or it can be left to the reader's ability to make inferences where necessary. If the author provides a global superstructure, s/he might aid the decoding of *global* *coherence* which according to Engebretsen (2002: 216) defines the place of individual nodes in the hierarchical structure of main themes and subthemes.

We have seen that hypertext authors do a lot to make the complex linguistic structure of hypertexts more accessible to readers and to ensure that they assign coherence to their texts. In most analyses, coherence occurs at three different levels. First, at the node level where it corresponds to the traditional textlinguistic notion of coherence. This is referred to as *intratextual coherence*. Next, we have to consider the relationship between two text nodes read in a sequence. This relationship is referred to as *intertextual coherence*. The third level, *hypertextual coherence,* denotes the logic that is reflected through the structure that governs the whole system of links and nodes (Engebretsen 2002: 217).

The three levels of coherence in hypertexts have led to the use of textual macro- and superstructures in hypertext design. These are semantic representations provided in the form of graphs or flow charts. They are meant to facilitate the integration of new information into the readers' interpretative framework or mental schemata. Textual macrostructures visualise the hierarchical system of propositions at various text levels. The macropropositions found in the graphical representations of texts are the result of the cognitive activity of reducing. Authors apply what van Dijk calls *macrorules* (1980: 32) to filter out the most important information. These macrorules are called *deletion*, *generalization*, and *construction*.

In addition to information about the semantic categories, readers need some information about structural relations at the syntactic level. For this purpose, it is necessary to include *superstructures* that indicate *how* the different types of macropropositions are arranged in the hyper document. Superstructures enable the reader to distinguish between themes and subthemes. They outline the propositions of the text at the various levels in the semantic hierarchy. According to Kintsch and van Dijk (1983), superstructures facilitate the comprehension of material because they enable readers to predict the likely ordering and grouping of elements in a text. In the following definition van Dijk (1980:108) refers to functional categories which, in my opinion, bridge the gap between semantic and syntactical information:

> [...] a superstructure is the schematic form that organises the global meaning of a text. We assume that such a superstructure consists of functional categories [...] and rules that specify which category may follow to combine with what other categories.

So far we have discussed the realization of coherence at different text levels and the author's means of visualising semantic and syntactic relations. The following section will show that these visualisations draw heavily on schema theory as an explanatory framework because they are meant to function as reproductions of cognitive maps.

2. Navigation and cognitive maps: the framework of schema theory

Navigation has become a subject of great interest in hypertext research. The so-called navigation problem also known as 'getting lost in hyperspace" (see e.g. Conklin 1987) has become a dominant theme in reading research. However, this problem is very difficult to address. The difficulties result from the traditional methodological problem of measuring the reading process as opposed to the reading outcome. Due to the lack of suitable measures of process activities, the impact of information structure on reading comprehension is often explained in terms of process difficulties such as navigation. This study also starts from this assumption.

In the present paper 'navigation difficulty' is used according to the definition of Elm and Woods (1985), who use the expression to speak about users not knowing how the information is organised or how to find the information they seek. Many studies such as that of Hammond and Allison (1989) point to the difficulties readers have with navigation in hypertext:

> Experience with using hypertext systems has revealed a number of problems for users [...]. First, users get lost [...]. Second, users may find it difficult to gain an overview of the material [...]. Third, even if users know specific information is present they may have difficulty finding it. (294)

Psychological models of navigation draw on the concept of cognitive maps. In Tolman's (1948) paper, frequently cited as seminal, he claims the existence of a cognitive map internalised in the human mind, which is more or less similar to the physical layout of the environment. According to Tolman (1948:192), information that is to be processed by the brain is: "worked over and elaborated [...] into a tentative cognitive-like map of the environment indicating routes and paths and environmental relationships." Empirical studies conducted ever since have taken the notion of some form of mental representation for granted. When navigation is conceptionalised in psychological terms, we find four levels of representation: *schemata*, *landmarks*, *routes* and *surveys*.

It is quite obvious that we must possess schemata of the physical environment we find ourselves in. Otherwise we would be swamped with every new sensory perception we encounter. We possess frames of references (see e.g. Downs and Stea 1977) or as Brewer (1987) calls them *global schemata*. They provide us with a basic orienting frame of reference and form the basic or raw knowledge structures. We produce *instantiated schemata* as soon as we add specific details to the schema. If we orient ourselves in new environments, we first call on global schemata like e.g. the schema for city and we then proceed by relating specific details of our new environment to this schema. Thus, in the first stage we create schemata that are sufficiently complete to be models or maps for the situation we find ourselves in. Transferred to hypertexts this means that we approach the text type with our global schema of traditional linear text and add information provided by links and overview maps when we build our cognitive hypertext map.

While engaging in the activity of navigation, we build *instantiated schemata* by going through progressive stages. The second of these stages is closely related to our knowledge of *landmarks* which provides us with the skeletal framework on which we build our cognitive maps. The term *landmark* is used to describe features of the environment which are stable. We often identify our position in terms relative to *landmarks*, such as buildings, statues and so forth within hypertexts *landmarks* could be introductory nodes that remain stable on the screen while we are opening additional documents in separate frames.

In the third stage *route knowledge*, that is, the ability to navigate from point A to point B gains importance. Landmark knowledge that has been acquired is used to make decisions about when to turn left or right. *Route knowledge* helps us to find our way round and to provide others with effective route guidance. This ability is not necessarily advantageous because a person may possess *route knowledge* without knowing much about their environment. This implies that *route knowledge* may be non-optimal or even totally wasteful.

In the fourth and final stage of schema instantiation we apply *survey* or *map knowledge*. This kind of knowledge is based on our world frame of reference. It refers to our ability to give directions or plan journeys along routes which we have not directly travelled. Moreover, it enables us to describe relative locations of landmarks within an environment without actually being there. Transferred to the context of hypertexts, this means that we can draw on our knowledge about intertextuality derived from our experience with similar electronic documents and suggest useful paths to readers.

It may seem questionable to cut a complex process, such as navigation, into distinctive levels of representation. Current research is dominated by the view that development of knowledge structures happens on a continuum. Also the assumption that each stage represents a developmental progress is certainly subject to legitimate criticism. However, so far no satisfying alternative has been provided by researchers and thus I propose that a model based on schema theory describing instantiations of basic knowledge is of some utility both for hypertext authors and reading research since its findings can be applied in the design of electronic information spaces and in reading strategy programs.

3. Outline of the empirical study

3.1. Method

In this empirical study on the cognitive processing of hypertexts, a brief speed reading test developed by www.readingsoft.com was adapted and transformed into three different hypertext structures. ReadingSoft.com is a provider of software solutions for enhanced reading. The company was founded in 1998 by Charles Cousin and Michel C. Vinckenbosch. It applies recent discoveries in the field of neural and cognitive sciences to respond to information overload and to improve global literacy with an innovative computer based speed reading method to develop efficient reading.

The purpose was to find out if and how the three different structures would facilitate text comprehension. A text consisting of 597 words and a follow-up multiple choice test were presented to 60 subjects. First, in its original linear version, then in the adapted axial structure and finally, in the form of a network structure. The participants were randomly assigned to one of the three groups. The 20 participants in each group were instructed to read the text as quickly as possible with the intention of taking the comprehension test afterwards. The same follow-up multiple choice test comprising 11 comprehension questions was used in all three conditions. Two one-way analyses of variance were conducted to compare the different text types with reading time and comprehension level as the 2 dependent variables.

The subjects were 60 university students of English philology in their second year of study. They had all passed two language courses which according to the European framework of reference correspond to level C1. They took the test in my presence. As the investigator I observed scrolling behaviour and also interviewed each subject. In the oral interviews after the comprehension test three items were controlled for: reading strategies, that is, the path readers had taken through the document, problematic text passages and the presentation format itself. First, subjects were provided with screen dumps on which they had to draw the path and to number the links in the order they had opened them. They then had to comment on how they performed four tasks namely specifying target information, making a decision on which structural features would be relevant, extracting the appropriate details and integrating these details. Third, they had to circle difficult text passages and to evaluate the presentation format naming advantages and drawbacks.

In order to get a clear picture of the test design some screen dumps depicting the three conditions will be included in the following section. The first figure illustrates the linear condition in which the subjects had to read the text more or less as they would on paper. There were no links and after pressing the start button they simply had to scroll down, read the text in the traditional narrative structure and finally press a stop button. After that their reading time was displayed.

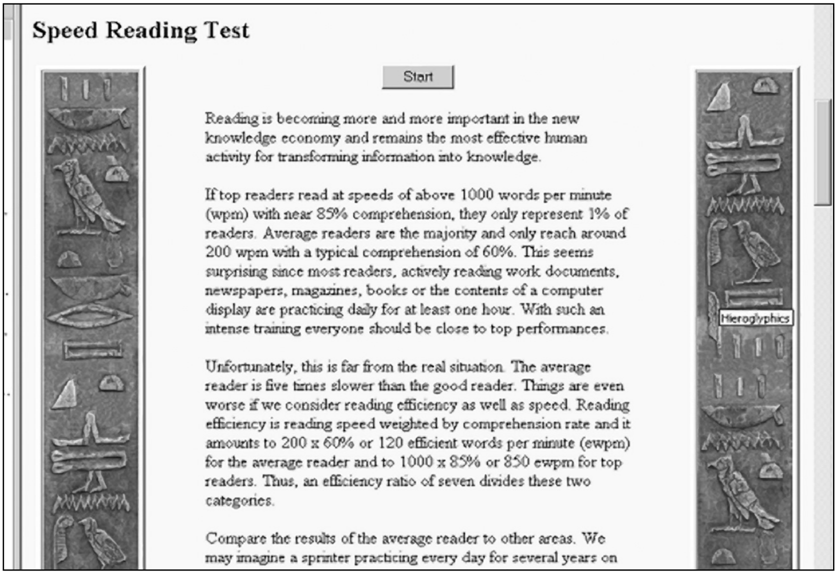

FIGURE 2: Linear condition

In the axial condition students were provided with a text with a trunk or main node. There three links were inserted by means of text-internal markings which take the subject to the branches with additional information. If you click on a link (as can be seen in figure 3), the trunk node remains on the page and the branch node appears on the right hand side. The colour of the link changes as soon as it has been activated.

In the network condition (see Fig.4) nodes were linked together criss-cross on the basis of semantic criteria. There is no apparent hierarchical structure. In fact, this is the most open presentational structure and gives the reader a greater degree of navigational control. As far as the organisational structure is concerned, the text is divided into smaller chunks which are represented by squares in the map on the left hand side. When students activate these text-external markings the introductory node giving general information about the speed reading, the test remains on the page at the top of the right hand side. The colours of the links do not change once

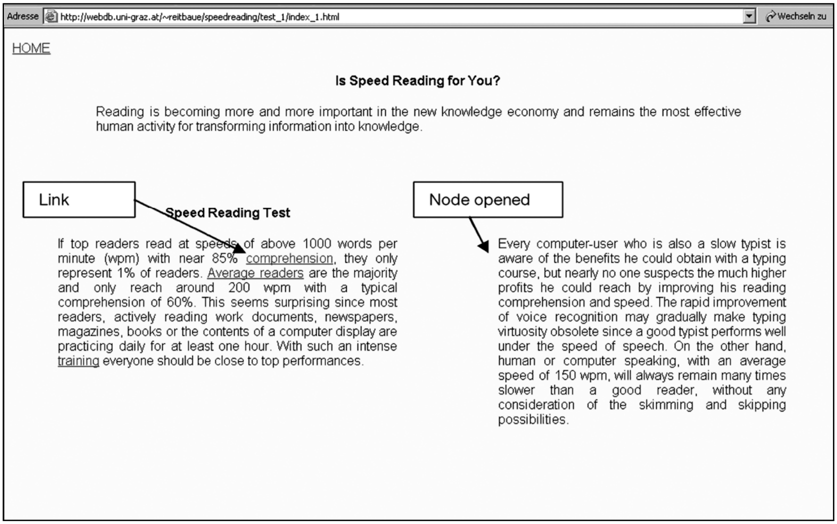

FIGURE 3: Axial condition

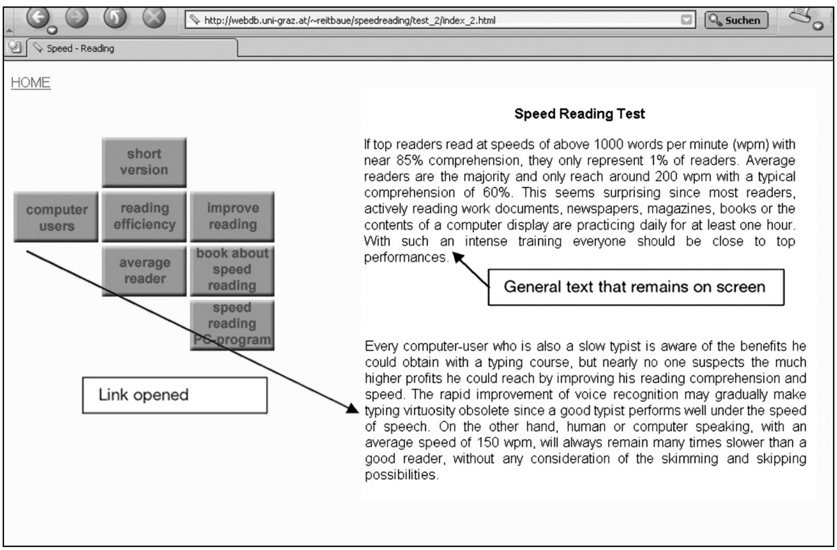

FIGURE 4: Network condition

they have been activated. Since these links are text-external they can be categorized as implicit. This also implies that they suggest co-ordinating and additive relations rather than subordinating ones.

The following section on findings will try to illuminate how axial and networked structures strengthened or weakened textual coherence and were thus beneficial or harmful to the mental work required for establishing relevance between certain units of meaning.

3.2. Results

There were substantial differences in reading achievement across the three different conditions. Consistent evidence for the advantage of the axial and networked over the linear presentation format was found. In the following section I will first describe the differences in reading comprehension rate and the average reading time required from a statistical point of view, then I will analyse the results of the individual comprehension questions in more detail and finally, I will relate them to the presentation format.

3.2.1. Statistical analysis of the data

The results of the one-way analysis of variance show that there is a highly significant effect of the independent variable condition (axial, linear, network) on the dependent variable comprehension score (p= ,005 as established by the Duncan Post Hoc tests). This significance is mainly due to the higher scores for condition axial. There is, however, no significant effect of the independent variable condition on the dependent variable time (p=,125). From a purely descriptive point of view we do find differences in reading time when we compare the mean values. In the axial condition, the average reading time required was 6.2 minutes, in the linear condition 6.9 minutes while in the network condition it was 7.1 minutes.

3.2.2. Analysis and discussion of results

In the linear condition the percentage of correct answers was the lowest. As can be seen in Fig. 5, students performed rather poorly with 63.8% of correct answers compared to the two other conditions (79.9 in condition axial and 68.6 in condition network). The interviews revealed that although students had more experience with reading linear text, they felt that in the electronic medium this text was lacking some kind of orientation guide. The text was considered too long to be read in a linear mode and scrolling was experienced as being tedious. Especially when subjects wanted to go back to certain passages in order to revise the main propositions, they complained about the time they had to spend searching for key terminology. They also argued that cohesion between the topic sentences of the individual paragraphs was more difficult to establish because of the spatial limitations imposed by the screen. Nevertheless, the average reading time needed was only 6:09 minutes. This was less than the time it took students to read the networked version, 7:01 minutes.

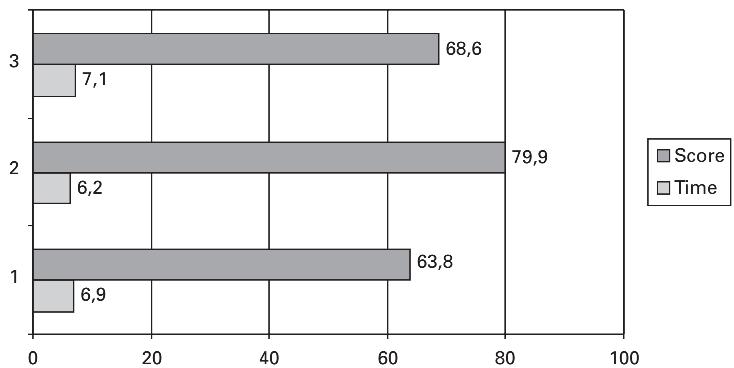

FIGURE 5: Results: comparison of different text types

In the axial condition students performed best. With 79.9% of correct answers the comprehension rate was the highest. The average reading time required was 6:02 minutes and thus lower than in the other two conditions (see Fig. 5).

In the follow up interviews students argued that they favour this text-internal linking system within the main node because it indicates the hierarchical information structure of the text. The links in axial hypertexts serve as an implicit form of hierarchical clustering. Students felt able to obtain a controlled view of the content of the document and saw the links as a list of concepts that would be discussed in the text.

None of the students diverted from the original order of the links in condition axial. The recognition of lexical cohesion was facilitated by the links denoting key terms and this in turn eased requirements for the identification of inter- and intranodal coherence. This phenomenon can be traced back to the fact that the connections between the links and their corresponding nodes is mainly established through the use of lexical repetition of key terms. Moreover, students argued that the textual discourse markers signalling sequence in the node 'training' were very helpful as far as memorising the information is concerned. Students claimed that '*There are three possible ways*', '*one*', '*second*', and '*finally*' which occurred in this node served as *frame markers*. According to Hyland (1999: 7), frame markers refer to metadiscoursive elements that explicitly refer to discourse shifts or stages and are mainly used in three different functions: first, to sequence material (*first, next, 1,2,3,..)*, second, to label text stages (*to conclude, in sum*) and third, to indicate topic changes (*well, now*). The first two functions were identified by participants, however, only in the axial and networked condition. Its seems as if the effect of *frame markers* is also dependent on the topographical layout and is weakened if the limitations of the screen force the user to scroll in order to see all of them.

In the network condition the comprehension rate was 68.6%, which means that students performed significantly better than in the linear condition (63.18%). However, compared to the axial condition with a rate of 79.9% this is still a considerably low performance. The average reading time needed for this document structure was 7:01 minutes and exceeded those in the other two conditions (cf. Fig. 5).

We may find a lucid explanation for the highest score in reading time in this type of document structure itself which forces the reader to flick backwards and forwards between small sub-sections of text. This is likely to disrupt concentration and expository flow. The paragraphs which were the natural units of text in the original, linear version were used to create natural section breaks. By splitting the text up into short independent sections without altering a single word of the original text, part of coherence and reinforcement created through the flow of arguments between the paragraphs might have been lost. Whalley (1993:11) expresses his concerns about serving up linear, cohesive texts as small chunks and argues that "the fragmentation effect in hypertext [...] is likely to make it more difficult for the learner to perceive the author's intended argument structure."

Conversely, if you look at comprehension results it appears that the splitting of the page into seven small nodes had no such detrimental effects. The varying performance data are initially puzzling but the follow-up interviews on difficulties encountered when navigating through this networked hypertext revealed possible explanations. First, most students argued that the link system lacks some indication of hierarchy. Although it appealed to them that the arrangement of links in the form of a network allowed them to choose their path freely and to follow their interests, they would have preferred annotated links that indicate whether they lead to a note with additional information or to a node containing key propositions. Second, all subjects stated that the pre-chunking into smaller units acted as a mnemonic device and had a beneficial effect for those questions in the comprehension test that dealt with key propositions labelled by corresponding links. Finally, participants claimed that they repeatedly reread the main node because they wanted to take it as a kind of starting point for planning their path through the text. Since it did not contain any hints in this regard, this venture only increased reading time.

Moreover, follow-up interviews showed that successful readers with a high comprehension score were more efficient as far as node traversal is concerned. They focused on nodes they considered important and re-inspected their responses. Gillingham (1993), who conducted a study on reader strategies and adults' hypertext comprehension, also found out that readers who used this kind of depth-first search strategy were more successful.

These results clearly show that that the structure of a hypertext does have an effect on reading time and the amount of information comprehended by the reader. It is now necessary to take a closer look at textual features which make it difficult for the reader to perceive the author's message. For this purpose a detailed analysis of the eleven multiple choice questions of the comprehension test used will be included. As can be seen in Fig. 6, which gives a survey of wrongly answered questions, the scores for the three document types differ widely. While in the axial condition only 46 out of 220 questions were answered wrongly, the score in the network condition is 69 and in the linear condition 81. There is evidence to suggest that document structure affected the comprehension rate.

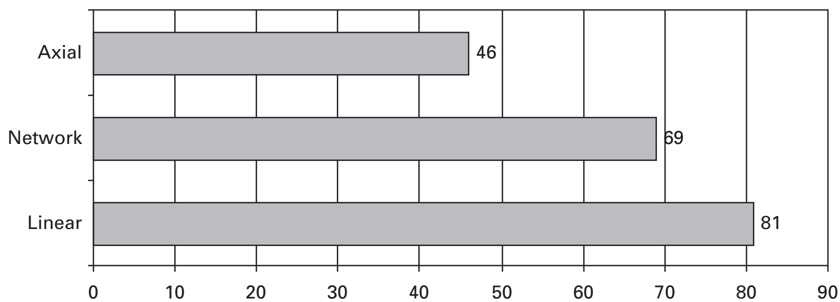

FIGURE 6: Wrongly answered questions (out of 220 in each condition)

In the evaluation of the individual questions of the comprehension test I will try to take location of the information in question and linking system into account. Since the text was copied verbatim in all three conditions, the differences found may be related to the fragmentation effect produced by the textual presentation. Isolation of adjacent topics and subsections modify the context and the interpretation of cohesive devices both on the inter- and intranodal level of coherence. By means of the five most problematic questions it will be illustrated how this fragmentation effect affected reading comprehension.

Question number 1 (see below) refers to the first two sentences of the main node which remained on the screen in all three conditions. As can be seen in Fig. 7 it was the second most difficult question in the test.

Q1. Compared to average reader, the accomplished reader reads with?

A ○ higher speed and worse reading comprehension

B ○ higher speed and better reading comprehension

C ○ higher speed and same reading comprehension

B, well done!

The answer to this question is embedded in a paragraph in which a lot of figures are given. In the linear condition and in the axial condition, the answer is preceded by a general topic sentence. However, 15 students of group linear, 12 of group network and 8 of group axial could not answer question 1. There were two links in condition axial highlighting *comprehension* and *average reader* on the left hand side of the page which obviously helped subjects to recall the propositions of this paragraph better than in the other two conditions. The two links marked two hotspots in the paragraph indicating that there are differences between average and accomplished readers. However, the follow up interviews revealed that the difficulties with this question were not only a consequence of missing links but mainly induced by the lexical problems, since many test takers were not familiar with the meaning of the adjective *accomplished*.

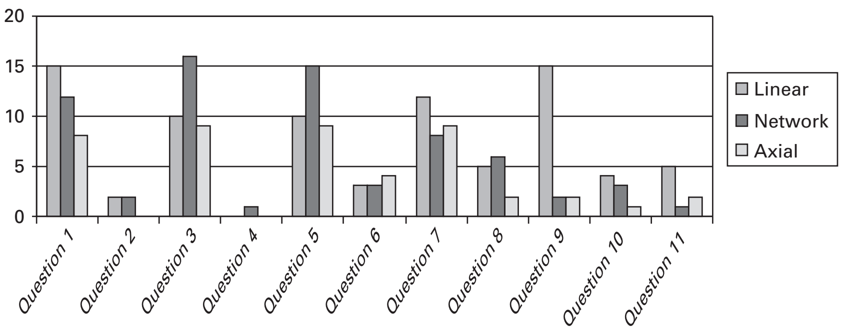

FIGURE 7: Wrongly answered questions: comparison

Question 3 proved to be the most difficult question especially for subjects of group network. Like question 1 it also referred to the main node and asked for the average reading speed.(see below)

Q3. The average reading speed is around?

A ○ 120 wpm

B ○ 150 wpm

C ○ 200 wpm

C, well done!

With this question the fragmentation effect became operative. In both condition network and condition axial, there was a separate link saying *average reader* but in condition network this link was outside the main node. In addition, the expository flow was interrupted by an inserted paragraph and this had a detrimental effect on information retrieval. Participants argued that a link outside the main node distracted their attention from the figure that was asked for and given in the main node. They interpreted the separate link as a sign of elaboration on the topic. The reading of the inserted paragraph increased their cognitive effort and somehow drew their attention away from the main node. As can be seen in Fig. 7, subjects of the group axial in which the link *average reader* was in the immediate vicinity of the reply in demand achieved the best results. The figures in the linear condition were also better than those in the network condition. Here readers argued that the follow-up paragraph dealing with reading efficiency contained a formula which repeated the figure for average reading speed and thus enhanced recall. Internodal coherence established through repetition seems to have had a positive effect on recall.

Question 5 (see below) turned out to be very problematic in the network condition. Fifteen out of twenty students did not answer it correctly. In the axial condition only 9 were not able to answer question 5 correctly and in the network condition 10 students answered this question wrongly.

Q5. A sprinter running as the average reader reads, runs 100m in?

A ○ 10 seconds (near record time)

B ○ 35 seconds (jogging)

C ○ 70 seconds (walking speed)

C, well done!

If you take a closer look at the corresponding links and the topographical presentation format, you might come to the conclusion that again a lack of internodal coherence in condition network is responsible for the differences in performance. In both the axial condition and the linear condition the node containing the answer is preceded by an introductory node which further elaborates the huge differences that exist in reading efficiency between average and poor readers. Readers do expect a type of local coherence between two nodes that are linked together or otherwise allowed by the system to be read in a sequence. In addition, the separate link *average reader* in the axial condition functioned as an ostensive signal of mutual relevance (Engebretsen 2000). Statements given by subjects in the follow-up interviews corroborate this. Students argued that the second sentence of the preceding note was helpful in answering question 5.

The results of Question 9 (see below) show the most striking variations in performance. With this question the clearest evidence for the advantage of the axial and networked over the linear presentation format was found. While in condition linear 15 out of 20 students did not answer it correctly, only 2 students in the axial condition and 2 students in the network condition failed to answer the question correctly.

Q9. What will lessen the importance of fast typing?

A ○ Spelling-checkers

B ○ More ergonomic keyboards

C ○ Progress in voice recognition

C, well done!

In the linked conditions axial and network the links *comprehension* and *computer users* provided an additional associative context. Especially in condition network participants stated that the link *computer users* enhanced navigation. The new node which was opened through the link established a coherence and semantic relationship which in turn seemed to have been helpful in building a mental representation. There is some corroboration for Horney's (1993) view that links in hypermedia mainly serve two purposes namely to indicate that a relationship exists between two nodes and to provide a path between them. Obviously in this case the links had also helped to reduce the fragmentation effect caused by the division of the content into hypertext nodes.

3.2.3. Conclusions

Summing up, it has been demonstrated that comprehension can be aided by the use of links. One and the same text presented in three different forms —two of them supported by links— produced different comprehension results. Readers benefited from the two conditions in which the large text was parsed into self-contained paragraphs. In the axial condition hierarchical links signalled by highlighted text, which took up the basic structure of the text were used. In the network condition links functioned as cross references and were signalled by buttons outside the main node. In both cases the positive effect on information retrieval has been evidenced by the comprehension results.

In addition, the analysis of reading strategies in the follow-up interviews attempted to reveal the strategies people use when confronted with different hypertext systems. The answers showed that readers engage in a variety of subtasks when trying to comprehend and memorize textual information. Parallels to Guthrie's model (1988: 178-199), which specifies five tasks readers engage in when retrieving information from a text, were found.

The first task of *specifying the target information* was performed by all subjects in all three conditions. Students of the linear condition suggested that drawbacks resulted from the presentation format which made scrolling necessary and failed to provide marked hotspots within the text. Thus, the specifying of key terminology which students named as being most important when reading for information was difficult. In the axial condition and the network condition target information was equated with the links provided in the document.

The second task *deciding which structural features e.g. sections of the text will be relevant as search destinations* for the target information was carried out differently. In the linear condition in which the only structural device used was the division into paragraphs, students' decisions were influenced by their expectations concerning questions that might be asked in the follow-up multiple choice test. Two thirds of the subjects in this group stated that they only skimmed through the sections containing figures since they were convinced that they would not be able to store them in their short-term memory and they also believed that they would be of minor importance. The topic sentences of the individual paragraphs were named as being decisive, helpful features when making decisions about relevant chunks of information. Moreover, students in the linear condition attached special importance to discourse markers and summarising statements.

Subjects of the linked conditions used the links as their main frame of reference when initiating their search for target information. This was possible because links create signification themselves and are not simply a medium of passing from one point to another (Burbules 1996). Links were considered key elements and also seen as "associative relations that change, redefine and enhance or restrict access to the information they comprise" (Burbules 1998:103). Subjects argued that the pinning down of information was enhanced in the linked conditions, particularly when they were able to detect lexical cohesion relations. Lexical cohesion, which can take the form of synonymy, hyponymy and metaphor, is used in the main node and also appears in the links that take readers to different subtexts. Participants stated that through the recognition of synonyms, repetition and hyponyms it became easier for them to make rapid judgements about whether it was desirable to read a certain block of text or not. In addition, links were regarded as a kind of summary of the relevant propositions of the text. Since participants expected to find questions concerning each link in the test they considered all of the corresponding nodes equally relevant search destinations. In the network condition they followed their interests when deciding on the sequence in which they opened the links while almost 90% of the subjects in the axial condition opened the links in the order given in the main node.

The third task *extracting the appropriate details from each relevant destination* was also considered easier in the linked conditions. In the linear condition it is difficult to differentiate relevant facts from unimportant details because no means of accentuation are used. In the axial condition look-up time for details can be minimized because the online document design provides a definite text-based outline of nodes which enables the user to build up a mental map of the document quickly. In terms of schema theory you could see the links in the main node as a set of related place-holders or slots which can be filled in by details provided in the corresponding node. Links in the network condition also function as elemental structures but in this arrangement they represent the hypertext as a semic web of meaningful relations. These links define a fixed set of relations among which the reader can choose. Extracting details in a system with even more links and short corresponding nodes turned out to be easier.

The fourth task *the integration of details* was also more difficult in condition linear in which no links were used. In contrast, linked conditions which show a similarity to the internal mental models we build up when processing information, made this task easier. If we assume that readers use their schematic representations of text to help them interpret the information in the text and if we further consider schema theory as a valid explanation for how learners process information, we might arrive at an explanation for the better performance of subjects in the linked conditions. According to schema theory, readers posses a network of context-specific bodies of knowledge which they apply to specific situations. Hypertext structures can be regarded as such bodies. Schemata are used for interpreting textual information but are also important in decoding how that information is presented. Readers possess schematic representations of linked texts as well as traditional linear text such as narrative, compare/contrast, cause/effect, etc. (Driscoll, 1994; Halliday & Hasan, 1989). It is easier to integrate information into schematic representations in linked hypertexts if links are typed, that is, make their attribute clear to the user. When readers can make use of referential or associative links, or semantically or argumentatively specified link types reasoning processes and the integration of details are facilitated (Kuhlen 1991: 34).

The fifth task *recycling* if the information provided in the node does not meet the target specification set earlier in the first task can also be addressed more easily with the help of links. In the linked conditions of this test series recycling mainly involves going back to the main node that remains on the screen while in condition linear readers have to scroll up and down due to the lack of any kind of orientation guide. In the ensembles with links the structure of the network of nodes is laid down and arranged in either hierarchical or multi-thematical structures. In the hierarchical condition axial the path readers choose is usually a route that never crosses any node twice, even if the node does not fulfil the reading expectations raised by a link. In condition network readers often move in cycles that bring them back to the exact point of departure when they are not satisfied with the content of the node. The network is seen as a modular structure which encourages recycling and navigating by following free associations.

In concluding, we can say that the results of this test series have shown that non-linear hypertext is obviously a good way to package information and to enhance reading comprehension. Logically several instructional strategies should follow from these results. They will be discussed in the following section.

4. Implications for language teaching

The development of literacy skills in new online media is crucial to success in almost all areas of life. Teachers can help students to develop computer-based literacy skills by focussing on reading strategies as well as on searching and evaluation skills. In their approaches to the enhancement of literacy they must start from the assumption that critical evaluation is central to hyperreading. Their teaching materials should be based on an interactive learning paradigm with an emphasis on autonomous learning (Lemke 1998). To promote autonomous learning students need to be taught how to use search engines effectively, how to skim and scan and how to make judgements about the validity, reliability and accuracy of electronic sources. Moreover, they have to be trained to make judgements about whether to continue reading a Web page, go to other links from the same page or go back to the search engine.

All these goals can be achieved by activating the learners' hypertextual schemata. This will enable them to process the information that they are reading better. Thus, we should advocate the teaching of meta-cognitive strategies for hyperreading. Learners who are provided with teaching materials facilitating the recognition of the type of network structure will be able to make predictions based on their textual analysis. The use of graphical representations of hypertext patterns, of semantic concept maps depicting the relationship between links and corresponding nodes and exercises focusing on the recognition of lexical cohesion might stimulate the recall of valuable prior knowledge and encourage the use of analogies and comparisons.

When designing reading comprehension materials, two additional cognitive processing mechanisms need to be taken into consideration for the efficient decoding of hypertexts: *bricolage* and *juxtaposition*. *Bricolage* (Burbules 1998: 107) is the ability to assemble texts from pieces that are represented in multiple relations to one another. It can be practiced through exercises in which the sequence of nodes and links has been jumbled. *Juxtaposition* (Burbules 1998: 107) is the skill of noticing how the various pieces of a Web page are related to each other through their position on the screen. It can be taught by using screen dumps with blanks that have to be matched with nodes or images.

We have seen that the teaching of hyperreading skills draws on a set of distinctive processing mechanisms which are closely related to those used for linear printed texts, but extend beyond them. Suggestions for further research on these mechanisms that supplement linear processing will be discussed in the final section of this paper.

5. Suggestions for further research

Further research will rely on what is gleaned from research into understanding reader and system variables that impact reading online. A close cooperation between linguists and designers of Web sites would be desirable. We need approaches that take into account the findings of usability studies, research on eye tracking and think-aloud protocols. With regard to the present study it would be interesting to clarify if and how the path a reader takes is related to the comprehension rate. The protocols of the oral interviews that were conducted after the comprehension test suggest that the network structure frequently overwhelms the user and can became a source of disorientation. Sites with complex networks of links mostly lack elementary categorization attempts and cause the user to visit many nodes twice. They do not indicate hierarchies and are therefore difficult to process.

These findings have important implications for the design of Web pages. Displays that combine a record of the user's path through the document with a map of currently available links may be the key to successful navigation. Many designers of Web pages have already started to include scope lines that summarize the number of documents and links in the network and thus provide valuable orientation guides for readers. Future research will show whether they are on the right path.

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