# Effects of Hypertext Structure, Navigation Support and Academic Exposure to Contents on Learning From Hypertext

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**Reference**

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**Abstract**

The aim of this study was to examine the effects of structure and navigation aids on students' learning from hypertexts. Participants were 48 undergraduate students. Group 1 ($N$ = 24) read 2 hypertexts (one network, one hierarchical) with high navigation support (a graphical overview, a coherent links list, and use of different colours for visited and unvisited links). Group 2 ($N$ = 24) read the same hypertexts, but with low navigation support. Both groups were assessed at the start of the semester and again at the end on three measures: comprehension, concept-mapping and perceived disorientation. High navigation support had an impact on structure effects, eliminating the negative impact of network structures that are commonly reported for novices. Finally, perceived disorientation was, unexpectedly, higher for hierarchical hypertext in all conditions. Implications for research and education are discussed.

**Keywords**

Hypertext structure; Reading comprehension; Navigation support; Disorientation

# 1. Introduction

Higher education makes increasing use of online information systems as part of their teaching strategies (Hiltz & Turoff, 2005; Sandberg, 2011). For instance, professors can post course outlines, summaries or slide presentations on Web-based platforms for students to look up and work with. The state of the art regarding how best to design these online instructional materials remains inconclusive. Whereas most designers opt for traditional linear types of texts (for instance, pdf versions of lecture summaries), others venture into more innovative formats, such as hierarchical or networked hypertexts. The impact of the different formats on students' comprehension and learning of the materials is an issue of theoretical and practical interest. In addition, electronic texts can be presented with or without a number of navigation aids that will make them more or less easy to use, such as tables of contents or using different colours to differentiate visited and unvisited links. Again, whether the inclusion of such navigation aids actually makes a difference in naturalistic instructional settings is largely an open issue.

The present study first reviews the literature on students' comprehension of hypertext, with a special emphasis on the effect of hypertext structure. Then the effects of navigation support are reviewed. The second part of the paper presents an experiment that sought to investigate the effect of text format and navigation support features on students' comprehension of online instructional materials

# 2. Literature review

## 2.1. Task models and information selection in hypertext reading

Theories of online reading have proposed that specific skills are involved when reading hypertext. For instance, Van Deursen and van Dijk (2009) identified four categories of Internet skills: operational (such as operating an Internet browser), formal (recognising hyperlinks and Internet navigation skills), informational (skills to locate the necessary information) and strategic (making the right decisions to achieve goals). The MD-TRACE model (Rouet, 2006; Rouet & Britt, 2011) proposes that reading tasks involving multiple documents rely on both external resources (task instructions, the available documents, search tools, help potentially available from a tutor or from peers...) and internal resources (including relatively permanent resources, such as prior knowledge, and transitory ones, such as the reader's understanding of task demands or understanding of how the different nodes in the hypertext are related to each other). With these considerations in mind, five processing steps take place:

Step 1: Create/Update a task model: a representation of the expected outcomes for the task. It includes task goals (e.g., the information to be found) and procedures for achieving them (e.g., the type of source that may be tapped).

Step 2: Assess information needs: taking decisions on whether to search for information or start writing draft answers to the task.

Step 3: Interact with information, which consists of three substeps: assessing the relevance of the items in the external resources, process text contents to comprehend or locate relevant information, and finally create/update a mental model of the documents (combining information from different nodes in the hypertext, for example).

Step 4: Create/Update a task product: constructing a response to the activity.

Step 5: Assess whether the product meets the task goals.

The quality of a student's task model (Step 1) depends in part on their prior knowledge of the domain. Additional knowledge may help students set up more relevant task goals through a clearer understanding of the task requirements. In addition, Interaction with information resources (Step 3) may be influenced by the design of the information system, for instance the organization of links within a hypertext.

**2.2. Effects of hypertext structure on performance**

In a hypertext, information is clustered in nodes and the options (links) offered to navigate among those nodes reflect the hypertext structure. The most common types of structures are hierarchical and network structures (Cangoz & Altun, 2012). In a hierarchical hypertext, the links provided to navigate are structured in a hierarchical manner: higher links lead to the most general information and lower links give access to more specific information. In networked structures, each node is connected to either some or every other node (see Figure 1). Following Chien (2010), in complete networks, users can access any node from anywhere in the system, while in incomplete networks not all nodes are connected with each other. It is worth noting that most authors use the broader concept of "network" (Lee & Tedder, 2003) or "non-linear" (McDonald & Stevenson, 1998) structures, not specifying if they are referring to a complete or incomplete network.

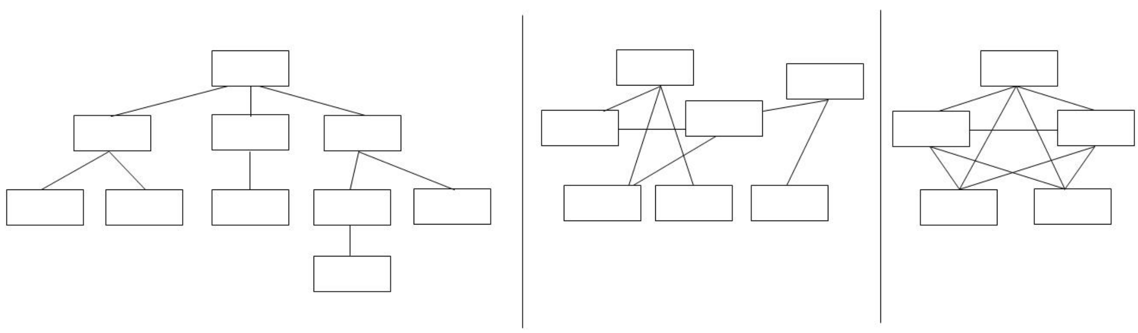

Figure 1. Example of hierarchical structure (left), incomplete network structure (middle), and complete network structure (right). Rectangles represent nodes, and lines represent the connections among them.

Therefore, from our perspective, hierarchical structures constrain navigation, offering a limited amount of links using a general-to-specific rationale. Network structures, on the other hand, allow for more navigation freedom. According to this definition, network structures involve a larger link density compared to hierarchical structures, especially when complete networks are used (Shin, Schallert & Savenye, 1994; Chien, 2010). Even studies using incomplete networks often use higher link densities on those structures compared to hierarchical ones (McDonald & Stevenson, 1998). Therefore, differences in link density may be seen as a consequence of structure manipulations rather than an accidental confound.

Empirical studies have generally found that hierarchical hypertexts are more beneficial for low prior knowledge readers than networked hypertexts (Chen, Fan, Macredie, 2006; Amadieu, Gog, Paas, Tricot & Mariné, 2009). For example, Potelle and Rouet (2003) showed how low prior knowledge students benefited more from a hierarchical-linking structure than from a network-linking structure, while high prior knowledge readers performed equally well in both conditions. Beneficial effects of hierarchical structures for novices, and lower performance on network structures have been reported by many other authors (Shin, Schallert & Savenye, 1994; Amadieu *et al.*, 2009; Burin, Barreyro, Saux & Irrazábal, 2015).

A few studies have found contrasting results. For example, Lee and Tedder (2003) found higher recall scores in a network structure, and Chien (2010) showed how participants navigated more efficiently using a network structure compared to a hierarchical one. These inconsistent findings might be explained by prior knowledge (a variable not controlled in those studies): participants might have been knowledgeable of the topic, which could explain the lack of effect of a hierarchical hypertext. Also, these studies did not mention navigational aids implemented, which may also have had an impact.

### 2.3. The role of navigation support on hypertext comprehension

Hypertext environments are considered to be more appropriate for experts, since novices often suffer from disorientation problems; therefore, the inclusion of navigation support is of key importance to design effective learning materials in this format (Chen, Fan & Macredie, 2006). Two navigation aids that have a great impact on hypertext performance are concept maps and hyperlink design (Salmerón, Strømsø, Kammerer, Stadtler & van den Broek, 2018) as evidenced in a growing number of studies.

A concept map is a graphic organizer that uses labelled nodes designating concepts and links representing relationships among those concepts (Nesbit & Adescope, 2006). Previous findings show that hypertext performance, both in learning and navigation, is enhanced when hypertexts have a concept map compared to hypertexts with no concept map (Puntambekar, Stylianou & Hübscher, 2003; Blom, Segers, Knoors, Hermans & Verhoeven, 2018) especially in novices (Fesel, Segers & Verhoeven, 2017), suggesting that concept maps facilitate the creation of an organized mental representation of texts (see Amadieu & Salmerón, 2014, for a review). It is important to highlight that the mere presence of a concept map does not necessarily improve performance (Müller-Kalthoff & Möller, 2003; Vörös, Rouet & Pléh, 2011). In order to be most useful, they should be familiar and simple (DeStefano & LeFevre, 2007; Urakami, 2019), they should be used at the beginning of the reading session (Salmerón, Baccino, Cañas, Madrid & Fajardo, 2009), and they should be structured hierarchically to facilitate novices' performance (Amadieu *et al.*, 2009).

It is worth noting that graphical overviews can be dynamic, if nodes can only be accessed through the hyperlinks embedded in the overview, or static, if they do not contain hyperlinks. According to Bezdan, Kester and Kirschner (2013) dynamic overviews need to be opened after every node, since it is the main way of navigation, and this continuous and forced use of the graphical overview might be potentially redundant, which in turn may hinder learning. Static overviews do not impose this continuous use.

Hyperlinks have been widely studied due to the key role they have on hypertext performance. According to DeStefano and LeFevre (2007), hypertext reading may overload working memory capacity because of the need to make decisions on which links to follow, a task that consumes cognitive resources. In fact, recent experiments showed how the different working demands of the strategies implemented to read hypertexts have an influence on performance (Naumann & Goldhammer, 2017; Salmerón, Naumann, García & Fajardo, 2017). Also, manipulating the amount and size of hyperlinks has different impacts on reading comprehension (Arias-Robles & García-Avilés, 2016): linear formats with no links yielded better comprehension results than using several or a lot of links, and the shorter these links were the better for comprehension. Also, to facilitate this task of choosing which links to follow, it is necessary to know the actual link selection strategies readers use in hypertext. Salmerón, Kintsch and Cañas (2006) and Protopsaltis (2008) agree on that readers use mainly three hyperlink selection strategies: *coherence* (choosing the link that is most related to the latest read node), *top link* (picking the first mentioned node), and *interest* (selecting the most interesting node). The coherence strategy leads to better comprehension than the other strategies, especially in novices (Salmerón, Kintsch & Cañas, 2006), improving achievement (Britt, Rouet & Perfetti, 1996). Therefore, how hyperlinks are positioned plays an important role in readers' performance. Other hyperlink characteristics that researchers suggest to be beneficial are using a list of links rather than inserting links in the text (Su & Klein, 2006), or changing the colour to differentiate visited from unvisited links (Nielsen, 2000). Also, Web page conventions, such as using blue links (Gagl, 2016), or positioning menus on the left or right, must be followed, since changing them can hinder performance (Pearson & van Schaik, 2003). Thus, it is expected to find an effect of navigation support on the relationship hypertext structure – prior domain knowledge, eliminating the disadvantages that network structures are supposed to exert on novices.

## 3. Purpose and hypotheses

The present study aimed to analyse how the amount of navigation support (low vs high) interacts with hypertext structure (network vs hierarchy) on students' performance at two different points in time. Studies manipulating these variables in the same experiment are scarce, and to the best of our knowledge no previous research has analysed this topic using a within-participants design. As previously explained, hypertext structure and prior knowledge have effects on different levels of hypertext performance such as comprehension and disorientation, therefore three hypotheses will be tested to analyse these effects on the different levels:

H1: A network structure will hinder comprehension only when navigation support is low.

It is expected that students would perform better on a hierarchical structure than on a network structure, since hierarchical structures offer access only to high related nodes (*e. g.* Potelle & Rouet, 2003). However, including extra navigation support may eliminate the difficulties posed by network structures. These structures offer access to both related and unrelated information, and since background knowledge is not available (or sufficient) to make appropriate navigation decisions, offering a graphical overview of the contents and helping to decide which links to follow (through a coherent order of the links list offered, and colour changes of the visited links), may facilitate navigation and performance.

H2: A network structure will hinder students' concept map construction only when navigation support is low.

For the same reasons as in hypothesis 1, it is expected that including extra navigation support facilitates the construction of a conceptual map of the hypertext. Therefore, only students using a low support design should have problems with this task. And since hierarchical structures limit navigation to highly related nodes (facilitating the creation of a coherent mental model), only a network structure should pose higher demands, causing lower achievement as a consequence.

H3: Perceived disorientation will be higher for students in network structures only when navigation support is low.

Novices are usually more disoriented navigating a network structure than a hierarchical structure, while experts show no differential effects (*e. g.*, Amadieu et al., 2009). Any link readers choose to follow in a hierarchical structure will be coherent with the contents they are reading, so they would not feel lost easily. However, in the network hypertext, they are faced with a lot of links that will take them to incoherent contents if they do not choose carefully. Trying to find a coherent reading order in an unknown topic may cause readers to feel disoriented, not knowing where to go. It is expected that navigation support help students to overcome these difficulties, so previous findings will be replicated only with low support hypertexts.

# 4. Method

## 4.1. Design and participants

Participants were 48 undergraduates from the Faculty of Education in a large Spanish university. They participated voluntarily as part of their course in Educational Psychology in a two-part experiment: first, all participants were assessed at the beginning of the semester, while they are novices on the topics (Testing phase 1; all participants self-reported a lack of prior domain knowledge), and second, all participants were assessed again at the end of the semester, after attending their lectures on the topics (Testing phase 2). Informed consent was obtained for all participants and the research protocols met the university ethical guidelines for that kind of study.

Two groups were formed randomly (24 participants in each group): Group 1 used high support hypertexts and Group 2 used low support hypertexts (see section 4.2.1 for more information). Both groups read two hypertexts in each Testing phase: one with a hierarchical structure and the other one with a network structure.

## 4.2. Materials

### 4.2.1. Hypertexts

Two expository texts were used as materials. One dealt with the topic of information processing (Topic 1), and the other one with memory (Topic 2). In order to balance both order of presentation of the topics, and order of presentation of the hypertext structures, two hypertexts (coded as Web pages using HTML and CSS) were created for each topic (one with a hierarchical structure and the other one with a network structure). Hypertexts about Topic 1 were 1,962 words in length, distributed in

13 nodes. Hypertexts about Topic 2 were 1,953 words in length, distributed in 13 nodes. The conceptual structure of both topics was similar. All hypertexts included a list of links in the left margin that participants used to navigate. In hierarchical hypertexts, this list offered links only to parent, child and sibling nodes, while network hypertexts offered links to all nodes in the hypertext. This means that hierarchical hypertexts offer restricted access to nodes, allowing only coherent transitions among nodes. The network structure did not impose any restrictions, and the list of links offered access to every other node in the hypertext, irrespective of their coherence or relatedness.

Both groups used the same materials, manipulating only the amount of navigation support implemented in the Web page (specifically, the presence or absence of a graphical overview, and the links design and order):

***Graphical overview***

Hypertexts from Group 1 (high navigation support) included a concept map while hypertexts in Group 2 (low navigation support) did not. The concept map was static, included as an individual node in the hypertext (see Figure 2), so participants could access them at any moment they wanted (or not use them at all). Therefore, navigation among nodes was done through the list of links on the left margin. This way, it emulated common web resources, where graphical overviews are not usually implemented as dynamic, being a menu with a list of links the most common design.

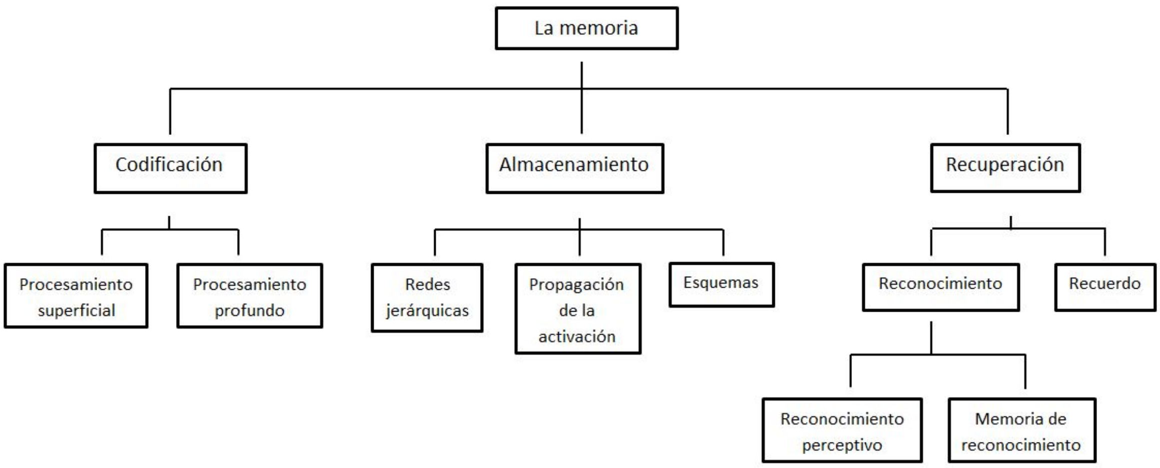


Figure 2. Sample graphical overview for one of the topics. Boxes represent the 13 text nodes and lines represent which nodes are connected through hyperlinks in the hypertext. The graphical overviews were static (non-navigable), so no hyperlinks were included in the boxes nor lines. Navigation was only possible through the list of links (see Figure 3).

### *Links order and design*

Links in hypertexts from Group 1 used different colours for visited and unvisited links, while links in hypertexts from Group 2 did not change colour. Also, hypertexts in Group 1 ordered the links list keeping in mind the strategies used by readers that were reviewed earlier. Specifically, links were listed following a coherent reading order, so selecting the top unvisited link would always lead to the most related node in the hypertext. Hyperlinks in Group 2 were listed alphabetically.

Figure 3 offers a screen capture of one node from the webpage comparing the differences between both hypertext structures, and in Figure 4 another screen capture is offered to visualize the differences between high and low navigation support implemented in the hypertexts used.

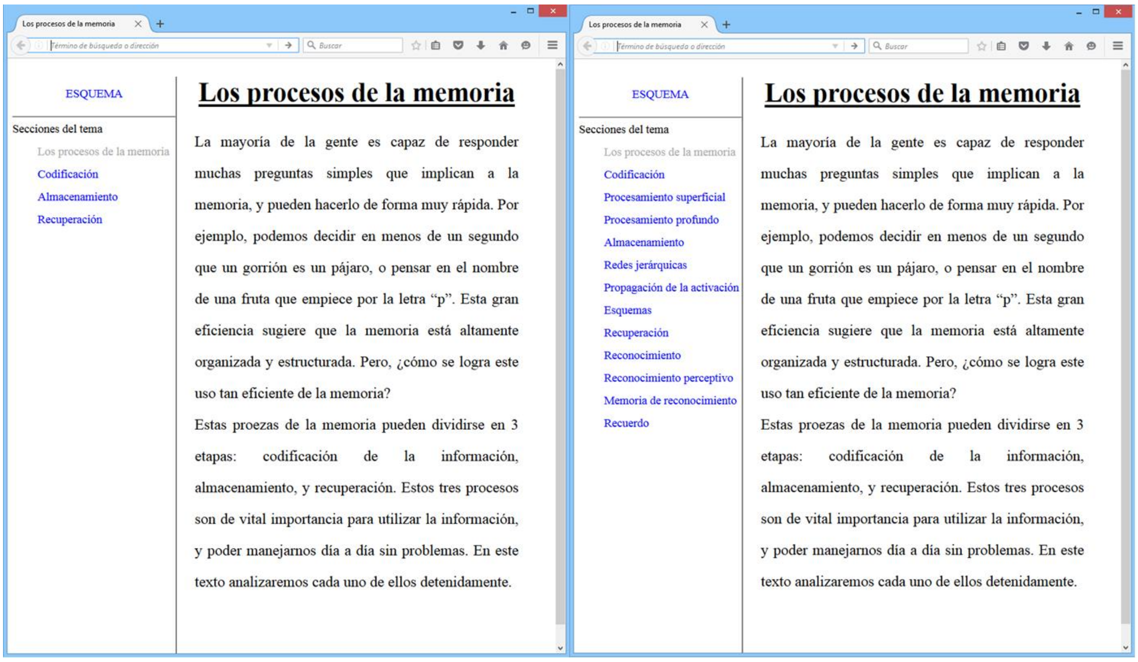


Figure 3. Hypertext with a hierarchical structure (left): Links offer access only to parent, sibling and child nodes of the current page that is being read and, therefore, different links will be offered once you enter any other section. To the right, the network structure offers links giving access to all nodes in the hypertext, irrespective of the node you are reading.

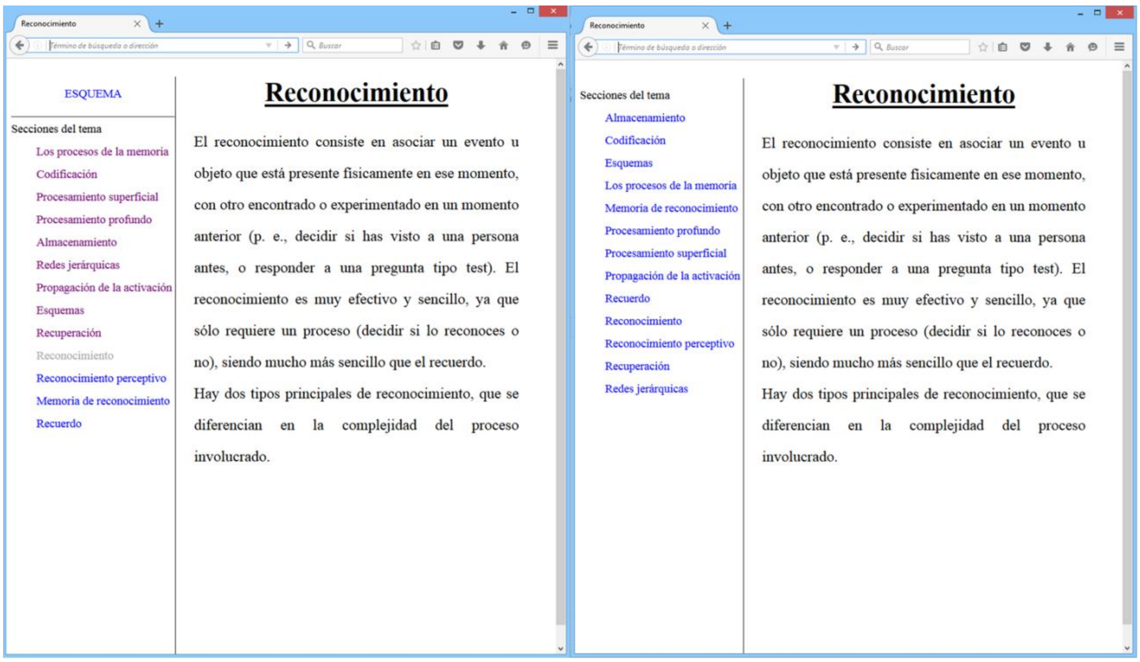


Figure 4. To the left, a high navigation support hypertext page: Links are ordered coherently from top to bottom, different colours are used for visited (purple) and unvisited links (blue) and the current node is shadowed (grey) in the links list; also, an individual node is added at the top to access a graphical overview. On the right, the same node without all these features (low support design): links ordered alphabetically, same colour for all links, and no graphical overview (see section 2.2. to understand the importance of these manipulations). Both pages correspond to the network structured hypertext.

It is worth highlighting that hypertext structure can be considered as navigation support (restricting navigation to high coherent nodes, or allowing more freedom on which nodes to visit). However, hypertext structure is often studied in isolation, and authors assume a great impact of this variable on its own, recommending hierarchical structures in general (e. g., Calisir & Gurel, 2003), regardless of any other navigation support that may be implemented. This is why structure effects are being analysed separated from the other features of navigation support implemented, to better test if those structure effects are affected by other features of navigation support. Also, this is why the "low" navigation support term is used where only structure is manipulated, instead of "no" navigation support, because such structures are already offering some level of navigation aid.

#### 4.2.2. Assessment materials

Comprehension scores were assessed with 10 short answer questions, asking for information that could be found on a single node (text base comprehension). A scoring rubric was created by two experts on the topics. Also, the professor in charge of the subject scored a third of the assessments (extracted randomly from the whole sample) using the same scoring rubric. Inter-rater reliability using Intraclass Correlations (ICC(3, 1)) was .97. Reliability was assessed using Cronbach's alpha: reliability of the test used to assess comprehension in Topic 1 was $\alpha$=.728 and for the test used to assess comprehension in Topic 2 was $\alpha$=.693.

Also, students were asked to create a concept map (a blank space was given, with no concepts list, skeleton of the structure, or similar). The specific instruction they received was to "create a concept map including the main concepts and ideas from the text you have just read, and how they are related to each other". A simple scoring rubric based on Koul, Clariana and Salehi (2005) and Oliver (2008) was employed to compare students' concept maps to the concept map created by their professor: one point was given for every concept and for every link between concepts in students' maps that were also in the instructor's map. Final scores were transformed into a 0-100 scale.

Finally, participants were asked to self-report their perceived disorientation while navigating, on a 0-10 scale (being 0 no disorientation problems and 10 heavy disorientation problems). A definition of disorientation was included ("feelings of not knowing where you were in the system, not knowing where to go, or not knowing how to get where you wanted to go"), to make sure participants had the same construct in mind before self-reporting. Perceived disorientation has been successfully assessed through a single item in previous research (Graff, 2005).

**4.3. Procedure**

Participants were randomly divided into two groups (Group 1 used high support hypertexts, and Group 2 used low support hypertexts) and both groups were assessed at the beginning of the semester, before starting the lectures (Testing phase 1). Participants were given 15 minutes to read the first hypertext (this time proved to be enough to read all the materials in a pilot study with 30 different students). They accessed the materials trough a common web browser (Mozilla Firefox). They were instructed not to access other web pages different from the experimental ones, but they could use any tools from the web browser (markers, back/forward buttons...). Right after that time, 25 minutes were given to complete the assessment tasks (comprehension questions, concept map, and perceived disorientation) related to that hypertext (again, this time proved to be enough to complete all tasks without rushing in the pilot study). After a 5 minutes break, 15 minutes were given to read the second hypertext (with a different structure than the first one) and another 25 minutes to complete the assessment tasks related to it. Order of presentation of the topics and order of presentation of the hypertext structures were counterbalanced.

After this initial assessment, students attended their lectures for the subject as part of the normal curriculum with their usual professor. The researchers had no influence or participation in the lectures.

At the end of the semester (Testing phase 2), all participants were assessed again, in the exact same way as before and using the same materials (participants were not informed of the characteristics of this final assessment). All assessments were performed on pencil and paper materials. In an effort to run the experiments in a naturalistic instructional setting, all participants were drawn from the same class group, the tasks were performed in their usual computer lab mimicking their workshops (where they are given the materials and have to hand in a report before the bell rings, therefore, in a limited time), the topics to be learnt were part of their curriculum for that module, and the lectures on those topics were given by their usual professor.

## 5. Results

### 5.1. Comparability of the groups

All participants initially reported a lack of background on Educational Psychology or similar topics. Also, participants in both groups had similar hypertext experience, as assessed by the mean number of hours per week they reported to spend surfing the Internet ($F$ (1, 46) = 1.175, $p > .05$).

### 5.2. Comprehension scores

Since the design involved a large temporal interval between the two testing phases, with the students reading the same materials and questions twice, and because potentially confounded chronological factors could not be totally controlled, both testing phases will subject to separate statistical analyses. Performance on the two phases will be compared in the discussion.

### 5.2.1. Testing phase 1

A mixed ANOVA using subgroups (the subgroups created for balancing presentation order) as a between-participants variable and hypertext structure as a within-participants variable, showed no significant effects on reading comprehension scores (Group 1: ($F$ (3, 20) = 0.685, $p > .05$; Group 2: ($F$ (3, 20) = 1.055, $p > .05$), indicating that there were no order of presentation effects, and that topics did not prime each other.

A mixed ANOVA with hypertext structure (hierarchical vs. network) as a within-participants factor, and navigation support (high vs. low) as a between participants factor was performed (square root transformation needed). Structure had no significant effects on comprehension ($F$ (1, 46) = 0.097, $p > .05$), and navigation support had no effects either ($F$ (1, 46) = 0.358, $p > .05$). However, an interaction effect of structure × support was found ($F$ (1, 46) = 6.279, $p = .016$), indicating a combined effect of both variables (see Figure 5). A compromise power analysis for a repeated measures ANOVA, within-between interaction, and an obtained effect size of $f = 0.3695$ indicates a very high statistical power (0.97), indicating that the sample size was adequate for the design used and the results obtained (Faul, Erdfelder, Lang & Buchner, 2007).

Simple effects of this interaction showed how participants performed better using a hierarchically structured hypertext than a network structured hypertext when navigation support was low ($F$ (1, 46) = 3.968, $p$ = .052; marginally significant), but no significant effects where found when support was high ($F$ (1, 46)= 2.408, $p$ > .05). Having no graphical overview, a list of links ordered alphabetically (instead of ordered coherently) and not implementing colour changes in hyperlinks to facilitate tracking which sections have already been visited seemed to have a negative impact on the readers working with the networked hypertext.

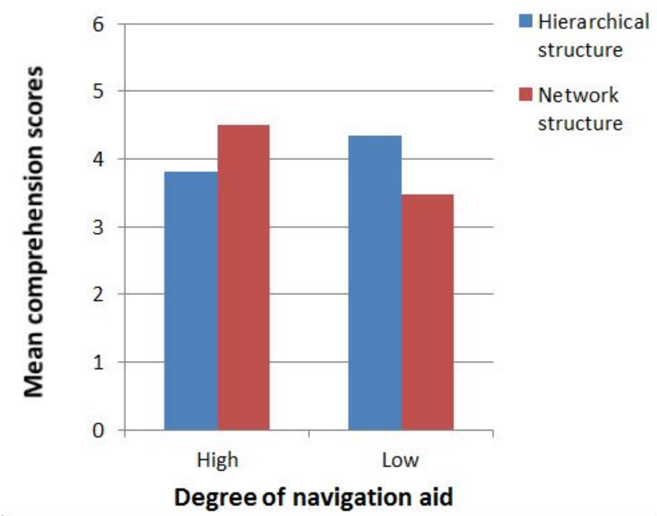


Figure 5. Mean comprehension scores in Testing phase 1 (0-10 scale). Please, notice that neither structure nor navigation support had significant effects, so the higher performance of hierarchical hypertext in Group 2 does not imply a significant difference compared to hierarchical hypertext in Group 1. It is the interaction of both variables what causes the significant differences.

Previous findings (higher benefits of hierarchical hypertexts or lower performance using network hypertexts) are only replicated with low support hypertexts.

When navigation support is high, the opposite result can be observed: a network structure leads to higher comprehension scores, although significance is not reached.

#### 5.2.2. Testing phase 2 and comparison across phases

As in Testing phase 1, a mixed ANOVA with hypertext structure (hierarchical vs. network) as a within-participants factor, and navigation support (high vs. low) as a between participants factor was performed (square root transformation needed). No significant effects were found.

Figure 6 shows that results are very different in this Testing phase 2: both groups had similar results irrespective of the hypertext structure they were using. Despite there is a visible advantage of Group 1 (high support) over Group 2 (low support), differences did not reach significance ($F$ (1, 46)= 2.316, $p$ = .135).

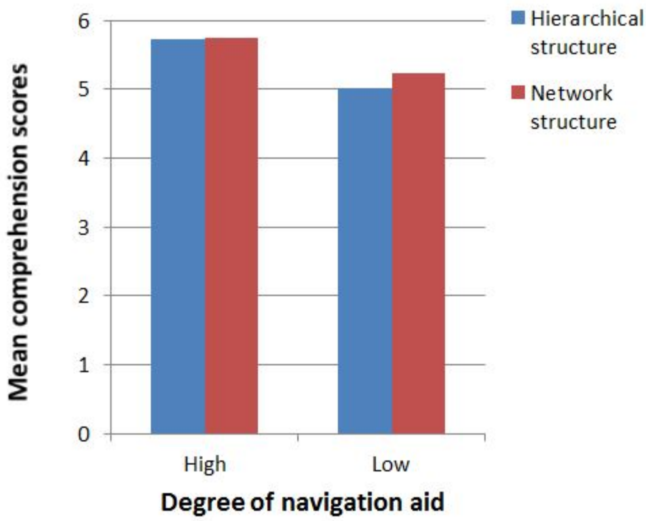


Figure 6. Mean comprehension scores in Testing phase 2 (0-10 scale).

Also, results were significantly higher in this Testing phase 2, as indicated by a mixed ANOVA including Testing phase as a within-participants variable ($F$ (1, 46) = 52.035, $p$ < .001).

### 5.3. Concept map scores

Data from concept map scores were not normally distributed, so non-parametric tests were performed.

### 5.3.1. Testing phase 1

First, within-participants comparisons were made using Wilcoxon signed-rank test. Significant differences were found only in Group 2 ($z = -3.359$, $p < .001$). Therefore, as it can be seen in Table 1, participants at the beginning of the semester in Group 2 (low support) constructed richer concept maps when they used the hierarchical hypertexts (mean scores of 58) than when they used the network hypertexts (mean scores of 40). Effect size was medium to large ($r = -0.48$, the minus sign can be ignored). However, the network hypertext did not hinder performance compared to the hierarchical hypertext in the high support condition.

*Table 1. Mean comprehension scores (from 0 to 100) in the concept map task.*

| | | Testing phase 1 | | Testing phase 2* | |
|---|---|---|---|---|---|
| **Group** | Structure | Mean | SD | Mean | SD |
| **1 High support** | Hierarchical | 59.85 | 24.83 | 92.45 | 10.56 |
| | Network | 61.91 | 20.48 | 92.63 | 11.49 |
| **2 Low support** | Hierarchical | 58.11 | 22.41 | 70.39 | 22.77 |
| | Network | 40.07 | 15.04 | 63.30 | 24.15 |

* All means were significantly higher than in Testing phase 1 at $p<.05$

Then, between-participants comparisons were made using Kruskal-Wallis. Group 1 (high support) outperformed Group 2 (low support) using the network structure ($\chi^2(1) = 13.461$, $p < .001$), but both groups obtained similar results using the hierarchical structure ($\chi^2(1) = 0.227$, $p > .05$).

### 5.3.2. Testing phase 2 and comparison across phases

Again, within-participants comparisons were made using Wilcoxon signed-rank test. No significant differences were found. So, contrary to Testing phase 1, hypertext structure did not enhance nor hinder concept map construction now. However, participants showed an overall significant increment in performance in this Testing phase 2 compared to their results in Testing phase 1 in all conditions: using a hierarchical structure with high ($z$ = -3.810, $p$ < .001) and low ($z$ = -2.275, $p$ = .021) support, and using a network structure with high ($z$ = -3.704, $p$ < .001) and low ($z$ = -3.945, $p$ < .001) support.

Between-participants comparisons were made using Kruskal-Wallis. In this occasion, Group 1 (high support) outperformed participants in Group 2 (low support) in both structures: hierarchical ($\chi^2(1)$ = 12.532, $p$ < .001) and network ($\chi^2(1)$ = 21.392, $p$ < .001), and not only in the network structure as in Testing phase 1.

It is worth noting that the concept maps created by participants did not tend to reproduce the graphical overview offered in the high support condition.

**5.4. Perceived disorientation**

Self-reports on perceived disorientation (see descriptives in Table 2) were also analysed using Wilcoxon signed-rank test. Results showed how participants felt more disoriented in hierarchical structures than in network structures in all conditions: Testing phase 1 × low support ($z$ = -2.366; $p$ = .016, $r$ = -0.34), Testing phase 1 × high support ($z$ = -3.023; $p$ = .001, $r$ = -0.44), Testing phase 2 × low support (only marginally significant, $z$ = -1.734; $p$ = .083, $r$ = -0.25) and Testing phase 2 × high support ($z$ = -2.431; $p$ = .013, $r$ = -0.35).

*Table 2. Mean disorientation scores (from 0 to 10) while navigating, as reported by participants.*

| | | Testing phase 1 | | Testing phase 2 | |
|---|---|---|---|---|---|
| **Group** | Structure | Mean | SD | Mean | SD |
| **1 High support** | Hierarchical | 3.17 | 2.08 | 2.79 | 2.96 |
| | Network | 1.33 | 1.83 | 1.33 | 1.58 |
| **2 Low support** | Hierarchical | 3.29 | 2.40 | 3.21 | 2.84 |
| | Network | 1.83 | 1.74 | 2.50 | 2.48 |

Some navigation data that may be related to disorientation will be offered next, using Wilcoxon signed-rank test. In Testing phase 1, participants made more visits to the graphical overview while using the hierarchical hypertext ($z$ = -2.081; $p$ = .016) compared to the network hypertext, and they also needed more time to access all nodes at least once in the hierarchical structure ($z$ = -3.286; $p$ < .001).

In Testing phase 2, no significant differences between both structures were found in time needed to access all nodes at least once, in number of visits made to the graphical overview, or the total time devoted to the graphical overview.

Comparing both Testing phases, total time devoted to the graphical overview increased for both structures in Testing phase 2 (hierarchical: $z$ = -2.629; $p$ = .004; network: $z$ = -2.886; $p$ = .001).

Regarding missed nodes (nodes that were not accessed at all during the reading session), participants missed more nodes overall while using hierarchical structures, though differences only reached significance for low support design at Testing phase 1 ($z$ = -2.831; $p$ = .002). This is congruent with participants feeling more disoriented in the hierarchical hypertext.

Inspection of reading orders shows, at Testing phase 1, how 91% of participants using high support designs followed the provided link order, while only 66% of participants using low support designs did. This means that the majority of participants in the low support condition followed the given order (using a “top link” strategy) despite that order being incoherent (links were ordered alphabetically). At Testing phase 2, participants using the low support design presumably devoted more effort to read coherently (or they had better knowledge on the topic to feel confident to attempt), since only 37% did follow the given incoherent order now. However, participants were not interviewed, so these assumptions must be taken cautiously.

## 6. Discussion

The goal of the present study was to analyse the interactions between navigation support (low vs. high) and hypertext structure (hierarchical vs. network) using a within-participants design. We now review our empirical predictions and whether they were supported by the data.

H1: A network structure will hinder students’ comprehension only when navigation support is low.

The data provided some support for this hypothesis. As illustrated in Figure 5 previous results regarding the detrimental effects of network structures for novice readers (see Potelle & Rouet, 2003) were replicated. However, our data suggest that this conclusion is valid only for low support materials, and only at Testing phase 1. This might be explained assuming a lower prior knowledge at this point in time, before students attended their lessons, implying that a high support design could eliminate (or reduce significantly) the difficulties posed by network structures to novices. It is also interesting how participants performed better using a high support design even in Testing phase 2. This data suggests that navigation support has a beneficial effect irrespective of hypertext structure and, possibly, prior knowledge. No differences were found at Testing phase 2, which may indicate that readers were more prepared after the lessons, acquiring some prior knowledge on the topic. This would support previous findings of knowledgeable readers not being affected by hypertext structure (Shin, Schallert & Savenye, 1994). Also, the common result of knowledgeable readers outperforming low knowledgeable ones was replicated (e.g. McDonald & Stevenson, 1998).

H2: A network structure will hinder students' concept map construction only when navigation support is low.

This hypothesis was also confirmed, but only in Testing phase 1. Participants at Testing phase 1 benefited from the hierarchical structure (constructing richer concept maps), but only when navigation support was low. In the high support condition (Group 1), structure effects disappeared. Again, these results indicate that a high support design may eliminate the difficulties posed by network structures, not only on text base comprehension scores (as previously shown), but also in concept map construction, which is considered a more complex learning, related to the 'structural knowledge' (Jonassen, Beissner & Yacci, 1993). The lack of effect at Testing phase 2 might be explained, again, assuming a higher prior knowledge at this point.

H3: Perceived disorientation will be higher for students in network structures only when navigation support is low.

Our results did not support this hypothesis. Previous findings (Amadieu *et al.*, 2009) show how hierarchical structures are beneficial in reducing disorientation in novices. However, the opposite results were obtained in all conditions, that is, higher perceived disorientation in hierarchical hypertexts in both low and high prior knowledge participants. One potential explanation is related to hypertext design. Both high and low support hypertexts had a list of links to navigate. Since network structures offered all potential links in that list, this may have acted as an index or overview of the material. On the other hand, hierarchical structures offered a limited amount of links. This restriction avoids readers to perform incoherent transitions among nodes (which can facilitate learning in certain conditions, as shown in the previous hypotheses), but it can make participants feel more disoriented, since some sections are only available from specific nodes, so some searching is needed to find a specific node. On the contrary, in the network structure participants just need to read the complete list of links to find the section they are looking for. Also, since hierarchical hypertexts offer access to parent, child and sibling nodes, the links offered keep changing depending on the specific node they are reading, while in the network hypertexts all links are available and in the same position irrespective of the section the user is reading.

Previous studies (Jáñez & Rosales, 2016; Rouet & Le Bigot, 2007) may offer some insights to explain this result. These studies suggest that readers, especially novices, perform an exploration of hypertext materials before focusing on a reading task. This exploration phase, in our study, is much easier to perform in network hypertexts, since they offer the complete list of links. However, participants navigating in the hierarchical hypertext do not know the complete extent of the materials until they explore for some time and, as reported in the results, they have more difficulties in making sure they visited all nodes (missing a single link can imply missing several nodes, since that link may be the only one giving access to them).

## 7. Conclusions

The aim was to examine potential interactions between navigation support and hypertext structure. Our results suggest that these variables interact, causing different hypertext performances depending on the specific combinations manipulated. More specifically, it has been shown how readers perform significantly better on hierarchical structures when navigation support of the materials is low, but if this support is high performance is enhanced using network structures. It is interesting that the only significant effect appears through the interaction of both variables (structure and navigation support) when analysed together. In addition, the interaction was no longer apparent at Testing-phase 2, which can be explained assuming a higher prior knowledge in participants at this point. This result might prove useful to explain the contradictory data on previous research: Studies reporting higher performance of hierarchical over network hypertexts may have combined low prior knowledge and low support designs (as shown in Figure 5, Group 2). On the contrary, a higher performance with network over hierarchical structures could mean that prior knowledge was low and navigation support was high (as in Figure 5, Group 1); also, this pattern could even hold true when prior knowledge is high and support is low, as shown in Figure 6 (Group 2). Anyway, these results are a strong indicator that all three variables (prior knowledge, hypertext structure and navigation support) should be controlled in experiments using hypertext materials for learning purposes.

Commenting now on disorientation, readers seem to prefer network structures to navigate, since they report lower disorientation feelings compared to hierarchical structures, irrespective of navigation support and the time of assessment (before or after attending the lessons). It is important to highlight that the network structure used offered access to all nodes from any other node (a complete network structure), so these results may be radically different if other conceptualizations of network structure (like the incomplete network) are used. Future studies should focus on potential relationships between link density and link structure. Also, it is worth noting that navigation support can be further manipulated: the ‘high support design’ used can be further enhanced, for example, using animations (Berney & Bétrancourt, 2016). Of course, the ‘low support design’ used can also be weakened further, using inserted links rather than a list of links (Su & Klein, 2006). Therefore, the results reported here could be even more extreme with more radical manipulations of navigation support.

The present study has some limitations. First, it has been assumed that participants had higher prior knowledge in Testing phase 2 (at the end of the semester) than in Testing phase 1 (at the beginning of the semester) when discussing some of the results. Data also suggest that prior knowledge was significantly higher in Testing phase 2, but there is no data regarding which type of prior knowledge was the one that increased: domain knowledge (participants may have learnt a lot of the contents during the lectures), system knowledge (participants may have had a better knowledge of the specific hypertext materials used), task familiarity (participants may have been more familiar with testing materials), or a combination of all of them. Even other variables may have had an effect. So differences between Testing phase 1 and Testing phase 2 might be explained by other variables different from prior knowledge.

A second limitation is that several features of navigation support were studied in combination. Specifically, high support hypertexts included three features: a graphical overview, different colours for visited and unvisited links, and coherent order of the links list. Therefore, the different outcomes and behaviours of readers using high support hypertexts might have been caused just by one of those elements, or even different outcomes might be more associated to specific support features. Future research might be able to control for these issues, offering clear data on the specific effects of each type of prior knowledge and each type of navigation support.

Finally, another limitation is the small sample. Despite statistical power is high for the main effect, there are some marginal effects that must be interpreted with extra caution considering the sample size they are based on. Replications of the study are desirable to confirm the results reported here.

As regards educational implications, our study offers new evidence that navigation support is a key element in creating adaptive study materials. Both low- and high-prior knowledge participants benefitted from high support designs, especially with network structures: lower prior knowledge readers had a list of links ordered coherently, helping them read all the material in a coherent order without spending cognitive resources in decision making. At the same time, higher prior knowledge readers could navigate non-linearly and create more complex relations among concepts. The challenge of creating materials that adapt to the necessities of students with different knowledge backgrounds or skill levels may be met through navigation support features, while more complex tools that learn from users to adapt to their individual needs are developed.

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