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Effect of high-level content organizers on hypertext learning

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ABSTRACT

This study investigates the cognitive abilities involved in hypertext learning and design approaches that can help users. We examined the effects of two types of high-level content organizers – a graphic spatial map and an alphabetical list – on readers' memory for hypertext structure. In the control condition, a simple "home" page with no navigational aid was offered. Subjects were asked to read the hypertext with the purpose of learning the content, but in the post test phase they also had to recall the layout of nodes and links. Memory for links and page places varied as a function of condition. When a spatial map was available participants reconstructed more accurate formal structure then in the two other conditions. Participants' memory about page places was the least accurate in the list condition. Results also indicate that participants use the content organizer when it is available in order to orientate during learning from hypertext documents.

Our results prove that a content organizer showing the formal structure can facilitate the spatial mapping process. However, an organizer exposing a different structure than the real one would generate a conflict.

1. Introduction

For about two decades, people have been increasingly reading and interacting with electronic texts. New technologies and electronic devices make it possible for more and more readers and learners to easily reach millions of multimedia documents. In developed economies, electronic multimedia files are gradually replacing printed books, newspapers and documents. The digitalization of texts changes not only the way we access to them, but their inherent structure. The well known linear printed representations of information are progressively substituted by documents organized in non-linear virtual networks.

Researchers have been producing more and more empirical evidence proving that reading practices of electronic documents rely on capacities that are not involved in the same way in printed text comprehension. The challenges that readers face using electronic displays was hallmarked by the phenomena of disorientation and cognitive overload in the early literature (Conklin, 1997; Foss, 1988; Kim & Hirtle, 1995). Recent studies demonstrate the cognitive surcharge of hypertextual learning activity (Amadieu & Tricot, 2006; DeStefano & LeFevre, 2007; Rouet, 2006; Zumbach & Mohraz, 2008). Several explanations were proposed by these studies for the surcharge phenomenon – e.g.: small letters, handling the peripherals, missing markers, no superstructure, frequent loss of context. One more possible explanation is that readers of digital texts have to keep memories of the arrangement of informational units in the electronic environment in order to efficiently plan their trajectories.

For Kintsch (1998), text comprehension is defined as the construction of a mental representation of semantic content, and the surface features of the texts are quickly eliminated. Meanwhile, hypertext theorists assume the intervention of mental mapping of the formal structure in hypertext learning (Edwards & Hardman, 1989; Juvina & Van Oostendorp, 2008; Nilsson & Mayer, 2002; Padovani & Lansdale, 2003; Pazzaglia, Toso, & Cacciamani, 2008; van Hooijdonk, Maes, & Ummelen, 2006; Vörös, Rouet, & Pléh, 2009).

Research evidence suggest that both individual and design factors are influencing the mental mapping process of nonlinear textual arrangements (Amadieu, van Gog, Paas, Tricot, & Mariné, 2009; Padovani & Lansdale, 2003; Pazzaglia et al., 2008; Vörös et al., 2009). The purpose of this study is to provide additional evidence concerning the effect of different high-level organizers on the mental representation of hypertextual structures.

2. Navigation during hypertext reading

Since hypertext pages appear on the user interface only at the time of viewing, in contrast to printed book, magazines and other

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materials, hypertexts are never entirely visible to the users. Moreover, unlike single linear texts, hypertexts present several paths between the pages, allowing for each reader to construct individual pathways. For these reasons, a hypertextual network of pages can be defined at two levels: the informational content level and the layout level. The informational content level corresponds to the semantic contents at the local and global levels within the network. At the local level, semantic information is conveyed in words, phrases, lists and text passages (together with other kinds of information such as graphics and pictures). At a more global level, information is conveyed through the topic of pages and page groups, such as in the ‘‘sports’’ section of a news web site. The informational content level is similar to the micro- and macrostructural content of a printed text (van Dijk & Kintsch, 1983).

The layout level corresponds to the linking of pages within the hypertext through menus and embedded links. The configuration of link defines a topological space (Kim & Hirtle, 1995; Padovani & Lansdale, 2003) which may, but does not necessarily overlap with the global semantic content of the hypertext. In some hypertexts, the structure of links closely mirrors the global organization of topics and contents. For instance, the online catalog of a music store may contain links to subcategories as ‘‘classical’’, ‘‘pop’’ and so forth. However, most web sites contain sets of information pages that may be accessed, read, and understood separately. Examples include electronic newspapers, public service or touristic sites. For instance, the home page of a newspaper may contain links to the sports, weather forecast and politics pages, which have little in common except that they may be of interest to the news reader. Thus, in most cases, the structure of links within a hypertext is not totally determined by the semantic structure of the contents, and vice versa.

As a consequence, knowing the semantic structure of the content is not sufficient to navigate efficiently. Even in cases where the semantic structure affects the formal structure, the lack of knowledge on the topic can prevent users from perceiving it (Rezende & Barros, 2008). Therefore, understanding the global structure of hypertexts requires the user to identify both the semantic and topological components.

Navigation on the web may have a specific purpose, such as finding an answer to a question or buy a product from an online store, but in other cases, it consists in browsing through several pages and sites on one or more related topics by following links. Link-based navigation is the activity by which readers can understand the semantic content and the topological architecture of the partially visible hypertextual network. As the reading order of the textual fragments is not formerly defined, according to the existing navigational models, users make decisions about their itineraries in a stepwise fashion, following their interest or choosing the semantically most appropriate option (Juvina & Van Oostendorp, 2008; Pirolli & Fu, 2003; Salmerón, Kintsch, & Cañas, 2006). More precisely, during navigation, hypertext users face several tasks which can result in different layers of mental representations, including a perceptual one, representing the navigation experience in terms of time and space (van Hooijdonk et al., 2006). For Padovani and Lansdale (2003) hypertext navigation involves both moving from one point to another and learning the structure of the informational space.

Therefore, navigation can involve tasks relating to the understanding of semantic information and those in connection with orientation activity in space. In addition, navigation is achieved by manipulating computer peripherals (keyboard, mouse), which still adds supplementary treatments compared to reading a printed text.

3. Effect of high-level organizers on navigation

Since hypertext is not linear, its formal structure is often represented in form of high-level graphic organizers. On the text comprehension level, a graphic organizer is supposed to act as concept map. At the same time, for the orientation activity it can function as spatial map. Thus, both components of hypertext navigation – text comprehension and spatial orientation – are expected to be influenced by graphic organizers.

3.1. Concept maps in linear text and hypertext comprehension

Novak and Cañas (2006) consider concept maps as effective learning tools that lead to well structured, assimilated new knowledge. Several empirical results demonstrate the beneficial effect of high-level graphical content organizers on linear text learning (Glenberg & Langston, 1992; Nesbit & Adesope, 2006; O’Donnell et al., 2002; Robinson, Robinson, & Katayama, 1999). Evidencing semantic relations between textual units, graphic organizers can effectively contribute to the development of the mental representation of semantic content and reduce the cognitive load of learning (Sweller & Chandler, 1994). On the other hand, the beneficial effect of these organizers is explained by the additional visuo-spatial coding of the text (Robinson et al., 1999).

Hypertexts can be presented as dynamic content organizers where the content of pages is accessible by clicking on the page titles on the content map. Research results concerning the effect of organizers on knowledge acquisition from hypertext demonstrate diverse outcomes. Scott and Schwartz (2007) suggest that an adjunct organizer benefits the comprehension process as far as it is capable of generating germane metacognitive load and integrative model construction. The hierarchical version of hypertext organizers was showed to facilitate the learning of the main ideas (Dee-Lucas & Larkin, 1995) and the comprehension of readers with low prior knowledge on macrostructural (Potelle & Rouet, 2003) or situation model (Shapiro, 1998b) level. A recent study by Salmerón, Baccino, Cañas, Madrid, and Fajardo (2009) revealed that longer processing of hierarchical overviews at the beginning of the reading resulted in higher comprehension for low knowledge students. In contrast, later usage of overviews lowered the comprehension of highly coherent hypertexts (Salmerón, Baccino, & Cañas, 2006; Salmerón et al., 2009).

3.2. Maps in orientation within physical and hypertextual spaces

So far, there is no theory elaborated on the general mechanism to explain how users construct a mental representation of the non-linear document space.

A possible assumption is that readers encode the structure of hypertext by analogy to physical spaces. According to the Landmark, Route, Survey (LRS) model, in physical environments a map-like representation of the spatial arrangement is elaborated gradually through three knowledge steps (Goldin & Thorndyke, 1982). First, landmarks are identified. In the next step landmarks are connected – this is route knowledge. Route knowledge describes temporally ordered sequences of actions carried out during navigation to reach target places (Golledge, 1999). In the last step, the person organizes the whole into a configurational representation producing the cognitive map of the environment.

Although the hypertextual space is a virtual space, where the motor dimension of physical navigation is replaced by the manipulation of computer devices, the Internet vocabulary uses many items expressing movements in space – like “jump” from a page to another, “visit” a site, “open” a page, or “surf” the Internet –

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in order to describe navigational activities and the space in which those activities take place. Studies show that similar spatial knowledge can be obtained through simulated navigation, like in virtual environments or film-based learning (Goldin & Thorndyke, 1982; Hegarty, Montello, Richardson, Ishikawa, & Lovelace, 2006). Recent results on text comprehension also confirm the involvement of spatial processes in hypertext navigation. The concepts of situation model and mental model (Johnson-Laird, 1983; van Dijk & Kintsch, 1983; Zwaan, Radvansky, Hilliard, & Curiel, 1998) together with numerous experimental studies (Avraamides, Loomis, Klatzky, & Golledge, 2004; Brunyé & Taylor, 2008; Gyselinck, De Beni, Pazzaglia, Meneghetti, & Mondoloni, 2007; Péruch, Chabanne, Nesa, Thinus-Blanc, & Denis, 2006) support the idea that representations derived from spatial descriptions contain the structure of the described space. Moreover, recent theories on text comprehension (Barsalou, 1999; Glenberg & Robertson, 1999) emphasize the perceptual character of the situation or mental models.

Mental maps contain directional and distance distortions (Landau & Jackendoff, 1993; McNamara & Diwadkar, 1997; Tversky, 2002) defining globally a graph-like topological space (Remolina & Kuipers, 2004; Zetzsche, Wolter, Galbraith, & Schill, 2009) like hypertexts. The quality of mental representations and the cognitive load of their development depend on both individual differences in visuo-spatial working memory and abilities (Coluccia, Bosco, & Brandimonte, 2007; Meilinger, Knauff, & Bülthoff, 2008; Miyake, Friedman, Rettinger, Shah, & Hegarty, 2001) and the source of spatial information (Klatzky, Lippa, Loomis, & Golledge, 2002; Péruch et al., 2006; Thorndyke & Hayes-Roth, 1982). Maps displaying a graphical overview of the space can lead directly to a survey representation (Thorndyke & Hayes-Roth, 1982).

Up to now, empirical studies have provided inconsistent evidence on the involvement of cognitive mapping processes in hypertext navigation and the effect of navigational maps. Several classical studies concluded that users seemed to create a map like mental representation of the hypertext formal structure during navigation (Chen & Czerwinski, 1997; Downing, Moore, & Brown, 2005; Otter & Johnson Lost, 2000; Pazzaglia et al., 2008; Potelle & Rouet, 2003; Shapiro, 1998a). Britt, Rouet, and Perfetti (1996) found that hypertext readers use the home page as a landmark, especially when the global organization of the system is confusing. Pazzaglia et al. (2008) and Vörös et al. (2009) found that subjects' visuo-spatial span influenced learning the hypertext layout. On the other hand, research found that navigation results in a representation of the semantic relations of pages and not that of the formal layout of hypertext (Farris, Jones, & Elgin, 2002).

The spatial mapping process can also be supported by the involvement of visuo-spatial abilities and memory capacity in navigational efficiency. Recent studies found that high visualization ability increased navigational performance (Downing et al., 2005; Nilsson & Mayer, 2002; Zhang & Salvendy, 2001).

While examining the effect of maps, prior studies have focused on high level overviews as semantic representations of hypertext contents. For instance, Potelle and Rouet (2003) found that a hierarchical map facilitated low prior knowledge readers' comprehension of the hypertext contents at a macro-level, whereas the type of map (i.e., list, hierarchical or network) did not impact high prior knowledge readers' comprehension. They concluded that maps should offer the reader a structuring scheme that is consistent with their prior knowledge (or lack thereof). They suggested that links in networked pages require inferences as to the semantic relationships between nodes that are beyond the ability of low prior knowledge readers. Latest research examines the effect of navigational maps which reflect the formal structure of the hypertext. The result of Morozov (2009) implies that a hierarchical navigational map would decrease the cognitive charge of the orientation process during hypertext learning and Danielson (2002) showed that with a continuously visible map, participants navigate more efficiently. Scott and Schwartz (2007) suggest that maps decrease the cognitive load of navigation caused by disorientation. Naumann, Richter, Flender, Christmann, and Groeben (2007) revealed that hypertext specific guides, such as hyperlinks and navigational maps, have a doubly beneficial impact: they increase navigational efficiency while they also improve low skill learners text comprehension. Vörös et al. (2009) found that a map was more beneficial to low visuo-spatial memory capacity readers than to their peers in building the mental representation of hypertext structures.

4. Experiment

In the present study, we investigate the effect of different organizers on the encoding of the link structure and semantic content during an exploratory navigation of a hypertext. More specifically, we examine the effects of two content organizers – a hierarchical graphical map defining the formal layout of hypertext pages and an alphabetical list of page titles – compared to a situation where no navigational aid is provided.

We suppose that in order to navigate efficiently, hypertext readers elaborate the mental representation of the text layout. Therefore, we investigate the assumption that content maps reflecting the hypertext architecture may be helpful for readers. They would serve as an adjunct organizer, reducing the cognitive complexity of mentally representing and remembering the link structure of hypertext. In contrast, an organizer imposing a structure, which differs from the real layout, will infer the mental representation. We chose to symbolize the structure by a linear list, because this form of overview is widely used by web pages and it is similar to the well-known organization of table of contents and printed text architecture. The damaging effect of the list can be due to the contradictions between the linear presentation of the content on the organizer and the real hypertext structure. Another possibility is that, to ease their cognitive load, users will navigate by using the organizer and not the links on the pages, so they will not discover at all the formal structure of the text.

4.1. Participants

Fifty-four volunteers (12 males and 42 females) with diverse academic backgrounds, between 19 and 39 years of age ($M = 22,96$; $SD = 3,29$), participated in the experiment. All participants were native French speakers. They were tested individually in a single session of up to an hour.

4.2. Procedure

The experiment started by two working memory tests. As we supposed that hypertext learning consist of the subtasks of text comprehension and spatial orientation, both verbal and visuo-spatial working memory capacities were assessed. A computerized version of a Corsi Blocs-like test (see Pickering, Gathercole, Hall, & Lloyd, 2001) was used to measure the participants' visuo-spatial (or VS) capacity. The participants had to retain and repeat on a touch-screen the order of appearance of black boxes on a matrix. We measured the subjects' phonological loop (or PL) capacity using a test based on Jacobs' studies (see Racsmány, Lukács, Németh, & Pléh, 2005).

The participants had to repeat series of digits. For both span tests, five trials were performed on each level. After successfully accomplishing a level, the series in the next level were one item longer. The final score corresponded to the number of items of the last series produced with less than four erroneous trials.

In the study phase, participants studied a website about Iceland with or without a high-level organizer. In the first condition subjects could use a graphical navigational map (Map condition (M)), in the second condition a list of page titles helped participants (List condition (L)) and in the control condition, there was no navigational aid (Title condition (T)).

Participants were randomly assigned to one of the three conditions. Subjects' visuo-spatial ($F(2, 51) = .08$, $p > .05$; M $M = 5, 56$; M $SD = .92$; L $M = 5, 61$; L $SD = .78$; T $M = 5, 5$; T $SD = .86$) and verbal ($F(2, 51) = .27$, $p > .05$; M $M = 6, 39$; M $SD = 1, 1$; L $M = 6, 39$; L $SD = 1, 29$; T $M = 6, 28$; T $SD = .75$) memory capacities were equivalent in the navigation conditions.

The maximum time for navigation was fourteen minutes, but participants were free to stop navigation before if they considered that they had finished their task.

Participants were informed that they had to visit all the pages and to retain semantic information. To establish a situation approaching real navigation activity, the participants did not know in advance that they would have to memorize the hypertext layout during the open navigational task.

After completing the navigation, participants had to reassemble the layout of the hypertext using a toolkit of page printouts and to draw arrows in order to represent the links between the pages. In the toolkit, nineteen cards were reproductions of real sites, and in order to test the participants' landmark knowledge, there were twelve distracter cards.

Finally, content comprehension was measured with a multiple-choice test. The questionnaire included 16 questions in four categories, as proposed by Hofman and Van Oostendorp (1999). The four categories were derived from the combination of structural (microstructural and macrostructural) and representational (text-base and situation model) dimensions of Kintsch's theory (1998).

4.3. Material

The hypertext about Iceland had a mixed structure. It was composed of 19 nodes organized in 5 hierarchical levels. The basic hierarchical architecture of the hypertext was defined by 18 bidirectional links. Six semantic links embedded in the text corps completed the formal configuration (Fig. 1).

The pages included short texts on Iceland. Each text had one or two images attached to it. The global semantic structure of the site did not correspond to its spatial layout and vice versa (for example: the page "Today" was under the page "History", "Nature" was under "Culture"). Consequently, the link structure could not be inferred from a semantic representation of the content.

Hierarchical links were organized in alphabetical order, out of text, thus starting from the position of a link users could not deduct the layout of the pages. The number of links connecting each node was not constant. Content pages also included a "Home" icon that returned to the opening page.

According to the condition, the hypertext Iceland was presented with a high-level content map, with a list of page titles or without any navigational aid. In the Map condition, a map represented the basic hierarchical structure of the site by explicitly showing the hierarchical ordering of page titles with the embedded and navigational links between them (Fig. 1). In the list condition, a vertical list presented the page titles in alphabetical order (Fig. 2). The

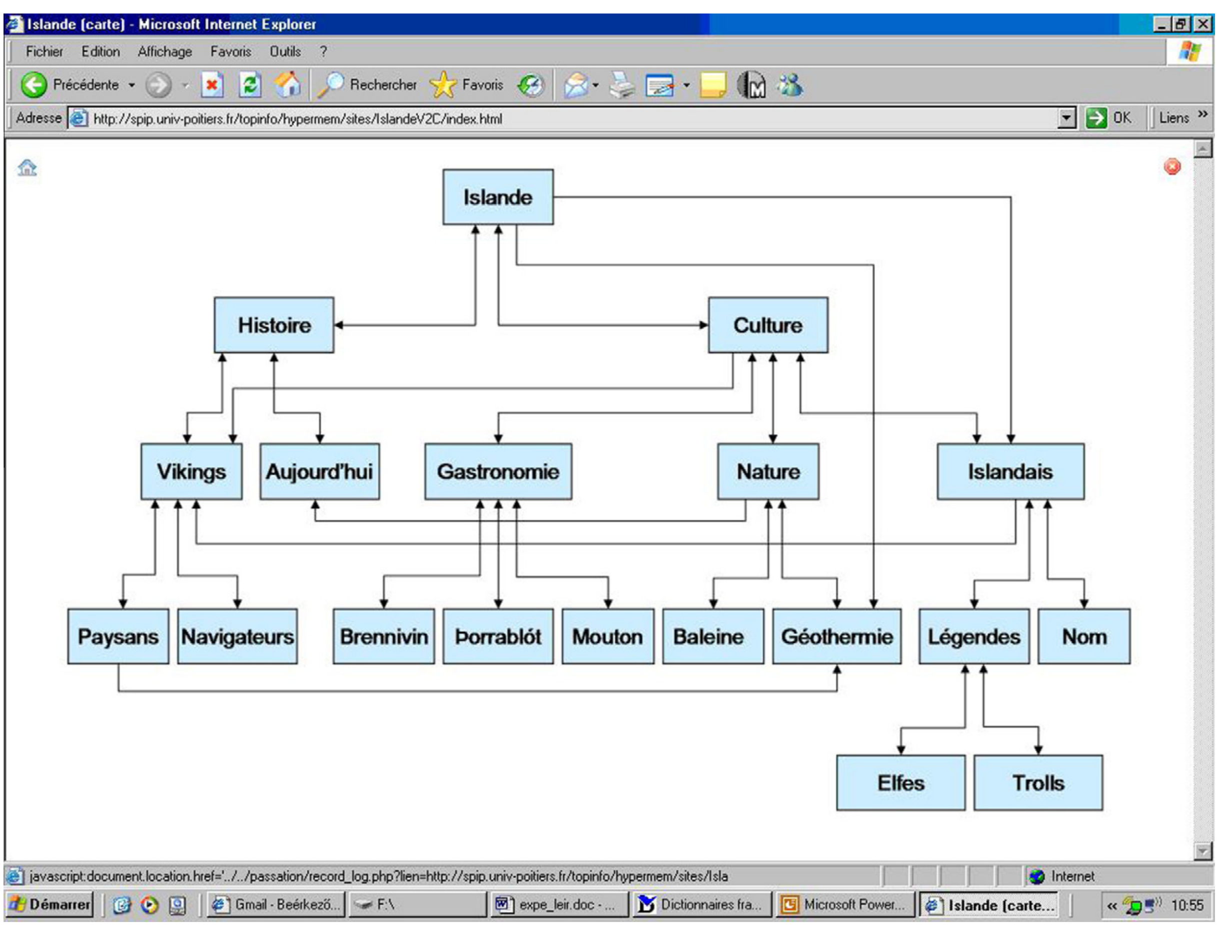

Fig. 1. The structure of the website on Iceland. The Figure shows the content map that was displayed on the opening page in the "map" condition.

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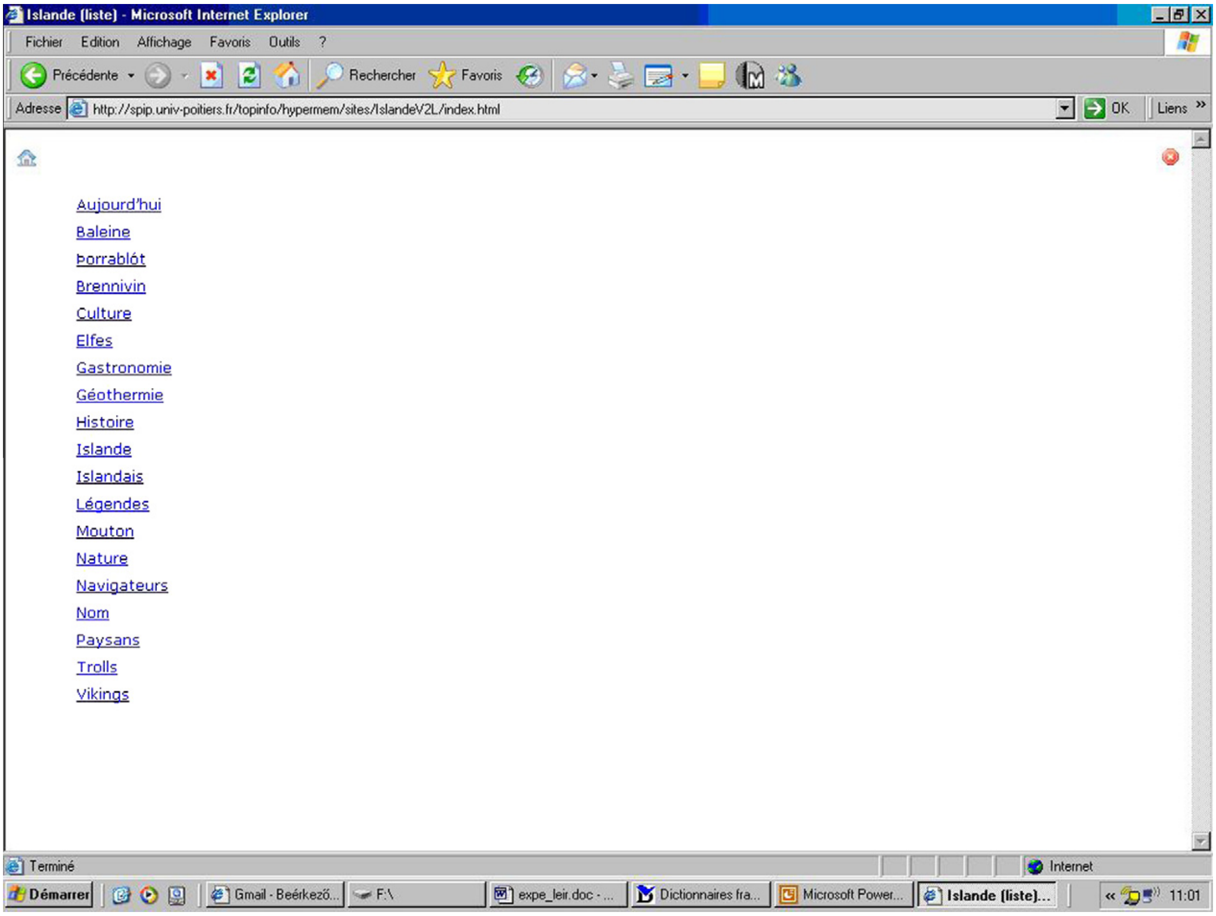

Fig. 2. List of page titles. The figure exhibits the content organizer in the "list" condition.

content map and the list were displayed on the opening page and linked to all other pages. Clicking on the title of page on the organizer resulted in the display of the respective page.

When no map was available (Titke condition), the home page was a blank page containing only a "Click here to continue" link. Users could navigate by using the links included on each content page, or by returning to the opening page through the "Home" button. As a global content representation was not available the hypertext structure had to be inferred from navigation.

4.4. Empirical predictions

A hypertext with a high-level content organizer that reflects its formal structure, would promote a more accurate spatial representation of the page places and links, relative to the situations where there is no navigational aid or the navigational aid imposes a different structure. As we foresee an incidental mental mapping process, this positive effect of the map was expected even if the posttest recall of the structure was not part of the experimental instructions. The organizer would have greater effect on the survey knowledge, which is the highest level of spatial knowledge, than on the route knowledge. Since the landmark knowledge does not require the retention of spatial relations, we did not anticipate an effect of the organizers.

If the content organizer does not reflect the hypertext formal structure, as in the List condition, it may disrupt its spatial mental representation, since the structure perceived during the navigation and the structure transmitted by the organizer are not identical. We assumed that participants in the List condition would realize the contradiction between the two structures, and develop a mental representation of the structure by means of the list than built it up step by step by a link following navigation (see also the result of Britt et al. (1996).

We also hypothesized that any navigational aid is widely used in order to decrease the cognitive load of the orientation processes of hypertext navigation.

Finally, as the semantic relationships between pages were not too strong, the pages could be understood separately and the high-level organizers (and the hypertext structure) did not reflect a semantic relationship of contents across pages, we expected no effect of the organizers on the comprehension of page contents.

4.5. Results

Following the literature on spatial cognition, we evaluated spatial knowledge at landmark, route and survey levels. Based on similar measures published in the literature (e.g. Otter & Johnson Lost, 2000; Padovani & Lansdale, 2003; Vörös et al., 2009) the following formulas were used:

- Landmark knowledge was measured by the percentage of pages correctly recalled: (correct pages/ total pages used for the reconstruction + correct pages/total number of hypertext pages)/2
- Route knowledge was characterized by the proportion of correct links:(correct links/total links drawn + correct links/total possible links)/2
- Survey knowledge was assessed by the mean of the proportion of correctly placed pages and correctly recalled structural units: average of (correctly placed pages/total pages used + correctly

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placed pages/total number of pages)/2 and (correct hierarchical units/ total hierarchical units used + correct hierarchical units/ total number of hierarchical units)/2

A page was considered correctly placed if there was a hierarchical link directing toward it from the page above. A page and the pages connected by hierarchical links were considered as a structural unit. A unit was considered as correctly recalled if it contained all the pages belonging to the unit out of the pages used for the reconstruction of the structure. We think that this measure can reflect the accuracy of a mental overview of a hypertext topology.

The metrics gave a result between 0 (poor representation) and 1 (only in case of totally accurate representation).

We also compared the frequency of correct placement of each page during the reconstruction after navigation in the different conditions.

We analyzed the map usage based on two online navigation data:

- time spent on the homepage where a content organizer was or was not presented according to the condition;
- number of returns to the homepage.

For the comprehension text, participants received one point for every correct answer. Thus the maximum score was 16 (i.e., 4 in each category of questions).

4.5.1. Spatial knowledge

The recall of pages (i.e., landmark knowledge), was almost perfect in all three conditions (Fig. 3 and Table 1) and there was no effect of the condition for landmark knowledge, F (2, 51) = .64, $p > .05$.

The recall of links (i.e., route knowledge) varied as a function of the condition F (2, 51) = 3, 39, $p < .05$. Planned comparisons revealed higher accuracy in the Map condition relative to the List condition, t (34) = 2, 67, $p < .05$, but not to the Title condition, t (34) = 1, 88, $p = .68$.

There was a main effect of the condition for the survey knowledge, F (2, 51) = 5, 39, $p < .01$. Supporting our predictions, the planned comparison revealed higher performance in the Map condition relative to both the Title, t (34) = 2, .05, $p < .05$ and List conditions, t(34) = .3, 36, $p < .01$. The frequency of correct placement of the pages "Paysans", $X2$ (1, N = 36) = 4.05, $p < .05$, "Moutons", $X2$ (1, N = 36) = 8.86, $p = .00$, "Légendes", $X2$ (1, N = 36) = 4.43, $p < .05$, "Trolls", $X2$ (1, N = 36) = 4.43, $p < .05$, and "Brennivin", $X2$ (1, N = 36) = 5.79, $p < .05$, was significantly higher in the Map condition than in the Title condition. All those pages were on the two lowest – forth and fifth – levels of the hierarchy. Compared to the List condition, navigation with a map resulted in significantly higher amount of properly placed "Islande", $X2$ (1, N = 36) = 4.5, $p < .05$, "Histoire", $X2$ (1, N = 36) = 4.05, $p < .05$, "Gastronomie", $X2$ (1, N = 36) = 9.03, $p = .00$, "Mouton", $X2$ (1, N = 36) = 7.26, $p < .01$, "Borrablot", $X2$ (1, N = 36) = 5.79, $p = <.05$, "Légendes", $X2$ (1, N = 36) = 4.43, $p = <.05$, and "Brennevine", $X2$ (1, N = 36) = 8.86, $p = .00$, pages. Thus, pages on the first, second and third levels of hierarchy were also recalled in significantly less cases after navigating with a list overview.

We did not find any significant difference between the spatial knowledge assessed by complex measures in the List and Title conditions. However, the means of the knowledge about spatial relations (i.e. route and survey knowledge) were the lowest in the list condition (see Table 1 and Fig. 3) and the place of pages "Islande", $X2$ (1, N = 36) = 4.5, $p < .05$, "Culture", $X2$ (1, N = 36) = 5.6, $p < .05$, and "Gastronomie", $X2$ (1, N = 36) = 7.111, $p < .01$, was significantly less often correctly recalled after navigating in presence of a list. Those pages located on the three highest level of the hierarchy.

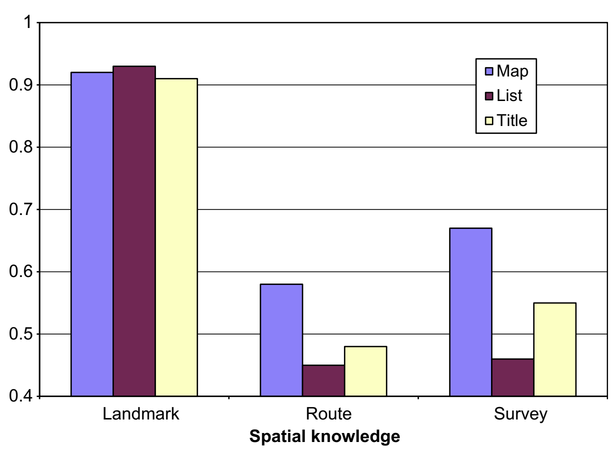

Fig. 3. Mean of spatial knowledge in the divers conditions.

4.5.2. Use of navigational aid

We analyzed the use of the content organizers during navigation (Table 2).

Taking into account all three conditions, there was no main effect of condition for the number of visits to the home page, F (2, 51) = 2, 89, $p = .07$. However, the planned comparison showed that there was a difference between the Map and Title conditions, t (34) = 2, 24, $p < .05$, as well as between the List and Title conditions, t (34) = 2, 38, $p < .05$. Therefore, supporting our hypothesis, the number of return to the homepage varied as a function of presence or absence of an organizer. When an organizer was present, either it was a map or a list, subjects returned more frequently than in case of an empty homepage.

There was a main effect of the condition for the total time spent on the homepage, F(2, 51) = 28, 40, $p < .01$. The planned comparison revealed that the time spent on the opening page in the Map condition was higher compared to both the List, t (34) = 2, 49, $p < .05$ and the Title, t (34) = −10, 11, $p < .01$ conditions. The time spent on the list was also significantly higher that the time on an empty opening page (i.e.: Title condition), t (34) = −6, 4, $p < .01$. The time spent on the homepage varied according to the quantity of information it contained.

Table 1
Average score and standard deviation on spatial knowledge.

Condition	Landmark		Route		Survey	
	M	St	M	St	M	St
Map	0.92	0.08	0.58	0.13	0.67	0.16
List	0.93	0.08	0.45	0.17	0.46	0.22
Title	0.91	0.07	0.48	0.18	0.55	0.21

Table 2
Average and standard deviation of the online measures.

		Condition		
		Map	List	Title
Number of returns to the opening page	M	8.94	9.00	5.50
	St	5.99	5.73	2.50
Total time on the opening page (s)	M	58.33	40.11	12.78
	St	25.92	17.06	6.07

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Table 3
Average and standard deviation of the comprehension scores.

		Condition		
		Map	List	Title
Microstructure	M	6.06	6.28	6.06
	St	1.43	1.49	1.55
Macrostructure	M	5.72	4.89	4.78
	St	1.36	1.28	1.77
Text base	M	5.78	5.17	5.56
	St	1.44	1.25	1.58
Situation model	M	6.00	6.00	5.28
	St	1.64	1.46	1.74

4.5.3. Content comprehension

There was no effect of navigation condition either on the total comprehension scores, $F(2, 51) = .33$, $p = .72$, or on microstructural, $F\ (2, 51) = .13$, $p > .05$, macrostructural $F\ (2, 51) = 2.17$, $p \geqslant .05$, textbase, $F\ (2, 51) = 1.72$, $p > .05$, and situation model, $F\ (2, 51) = 1.20$, $p > .05$ levels (see Table 3).

5. Discussion and conclusion

The main objective of this study was to investigate the effects of high-level content organizers on the mental representation of hypertext structure. The participants were divided into three balanced groups according to their visuo-spatial and verbal memory capacity. Participants had to read and memorize the content of a touristic website. Navigation was helped by a spatial map, a list of page titles or there was not available navigational aid during the reading. In the post test phase the incidental learning of the formal structure was examined by analyzing its mental representation on the three level of spatial knowledge.

We made the general assumption that by using the list, subjects could not discover the actual structure of hypertext, or that the list would generate a conflict, as the linear list formation shown on the home page and the real structure of the hypertext differ. Meanwhile, the map showing directly the formal configuration in its entirety as a graph would result in a more accurate mental representation compared to the two other navigational situations.

The landmark knowledge was not assumed to be facilitated by the map or inferred by the list, because it is the knowledge of pages and therefore, does not depend on the memory of spatial relations. As we expected, there was no differences between the conditions on the level of landmark knowledge.

The performance tendency was the same in case of the route and survey knowledge, i.e. encoding of links and page places: by using the list, the performance was the lowest; the map generated the highest result; and when no navigational aid was available, the performance was between the two other conditions. On the survey level – which is the highest, map-like knowledge of a space – the map resulted in a significantly more precise mental representation relative to both the list and control conditions (Table 4).

We did not find significant difference between the List and Title condition on the level of survey and route knowledge (Table 4). Even though some pages on the highest levels of hierarchy were less often placed correctly after navigating with the help of a list. We recognized the same pattern of difference of appropriately placed pages between the List and Map conditions. In contrast, compared to the Map condition, readers with no navigational aid less often properly recalled the position of a few pages only on the two lowest levels of hierarchy. Rouet, Voros, and Pleh (in press) also found that deeper links impose a higher load on visuo-spatial memory, possibly due to the need for users to memorize their itinerary from the starting point. We believe that the List condition

Table 4
Effect of navigational condition on spatial representation of the structure.

	Three conditions	Map vs. list	Map vs. title	Title vs. list
Landmark				
Route	*	*		
Survey	*	*	*	

resulted in distortions on the high level of the hierarchy, because readers provided with a list tended to place some pages as a function of list order rather than link structure. That result indicates that the content representations can be harmful if they do not match the actual link structure.

We think that the lack of significativity in some cases may due to the semantic reconstruction of the layout (see Vörös et al., 2009). Even if the global semantic structure of the site did not determine its spatial layout, the formal place of some pages could be inferred from the semantic relationships (for example: Navigators under Vikings or Elfes under Legends).

The participants had to return to the empty opening page or to the content organizers to support their orientation while navigating. Participants used the map or the list more frequently than the empty opening page for orientation purposes. When no map was available, returning to the home page was sometimes used as an alternative. Britt et al. (1996) also showed that the opening page is used as landmark.

Subjects also spent more time on the opening page when they received more information supporting their navigation. Demonstrating that a map is a useful navigational tool showing important information, participants spent the most time on the homepage in the Map condition. Subjects spent less time on studying the list than examining the map, but more time compared to an empty page. We believe that our results indicate that participants made use of the list organizer to learn the structure but failed to get the information they needed.

The outcomes support our prediction that a high-level content representation reflecting the hypertextual layout would act as scaffolds. Moreover, our results support the findings showing the facilitating effect of maps during navigation (Conklin, 1997; Morozov, 2009; Naumann et al., 2007; Scott & Schwartz, 2007) and are consistent with studies demonstrating the involvement of spatial mapping processes in hypertext learning (Downing et al., 2005; Nilsson & Mayer, 2002; Pazzaglia et al., 2008; Zhang & Salvendy, 2001).

As we wanted to avoid the semantic reconstruction of the layout, the semantic relationship between the pages was not always respected by their formal relations. Overviews should directly enhance the comprehension as far as they display the semantic relationships between text units (Robinson et al., 1999; Sweller & Chandler, 1994). We think that the contradictions between the semantic and formal structure reflected by the map caused the lack of effect of the graphic organizer on the comprehension. Other studies showed that organizers augment the comprehension only on a macrostructural (Potelle & Rouet, 2003) or situation model level (Shapiro, 1998b). The hypertext used in the present experiment did not have a strict global semantic structure. Pages in general were understandable separately and some informational units did not refer to any other. That could also contribute to the ineffectiveness of the map on high level comprehension. Another explanation is that the text was too easy to show a difference. Indeed, the participants obtained rather high scores at each level of the comprehension test.

A high-level content organizer can reflect the semantic relationship between pages, the formal layout of the hypertext, but can impose a totally new or a mixed structure. Our experiment shows the

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importance of the harmonization of the semantic and formal structures. Moreover, our study proves that participants need external high-level content organizers to orientate during hypertext reading and that a map can reduce the amount of processing needed to build up a mental representation of the hypertext layout.

Based on the literature review, one can also think that if the formal and semantic structures coincide, and the relationships of pages are evidenced on a graphic map, the map would facilitate both the comprehension and the navigation. How spatial processes relate to the comprehension of the hypertext semantics remains to be investigated. Indeed, from the point of view of the user, hypertext is above all a semantic space. It would be interesting to further investigate the interactions between spatial and semantic structures and the effect of maps on the comprehension.

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