

## Factors influencing hypertext reading comprehension Factores que influyen en la comprensión lectora de hipertexto

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**Abstract**

This paper revises some of the most significant studies about hypertext reading. With the aim of determining the main factors and variables that influence reading comprehension of such textual format, some definitions of hypertext are provided, and the aspects that affect the characteristics of each hypertext document such as the node granularity, the number and type of links, its overall structure, and navigation aids, are analyzed in detail. In addition, specific tasks and processes associated with reading comprehension of hyperlink text are revised, with particular emphasis on the selection of reading order, which is the process that differentiates the multilinear reading of hypertext and the linear reading of printed text. According to the analysis, it can be concluded that these factors will have different effects in terms of the cognitive load of the readers according to their domain knowledge. In this regard, it is noted that the textual cohesion is an element of great importance to understand hypertext for those readers with low knowledge domain.

**Resumen**

Este artículo revisa algunas de las investigaciones más destacadas el ámbito de la lectura de hipertexto. Al objeto de identificar los factores y variables que influyen en la comprensión lectora de este tipo de formato textual, se revisan y analizan diferentes definiciones de hipertexto, así como los aspectos que inciden en las características de cada documento hipertextual, entre los que se encuentran la granularidad de sus nodos, el número y el tipo de enlaces, su estructura global, y las ayudas a la navegación. Además, se abordan las tareas y procesos específicos asociados a la comprensión lectora de textos hipervinculados, haciendo especial hincapié en la selección del orden de lectura, que es el principal proceso que diferencia la lectura multilineal de hipertexto de la lectura lineal de texto impreso. A tenor del análisis realizado, se puede concluir que dichos factores tendrán efectos diferentes en términos de carga cognitiva de los lectores dependiendo del conocimiento de dominio que estos posean. Sobre este particular, se observa que la cohesión textual es un elemento de gran importancia para la comprensión del hipertexto en lectores con bajo conocimiento de dominio.

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## Introduction

For decades, both teachers and researchers have tried to define those aspects that have an impact on reading literacy (Flores-Carrasco, Díaz-Mújica & Lagos-Herrera, 2017), understood as the simultaneous process of transactional extraction and construction between the reader's experiences and knowledge and a text in an activity context (Gutiérrez-Braojos y Salmerón-Pérez, 2012). The progressive integration of Information and Communication Technologies (ICTs) in different spheres, including education, has been accompanied by an increasing number of studies on hypertexts reading literacy, which may broaden the traditional definition of reading literacy by taking into account those specific variables that are not present when reading printed materials. As a sample of the growing interest in this issue, it should be noted that since 2009, the PISA tests include specific tests to analyse reading literacy in digital texts (Pérez-Abril & Roa-Casas, 2014).

The main outcome of digital hypertexts, regarding non-linear reading, is that their technology format makes access to information much easier, because the reader may switch from one node to another by clicking on the links. This way, thanks to the rapidity when switching from one node to another, hypertexts allow for leveraging the non-linearity principle in its entirety. From a global point of view, Salmerón (2006, p. 6) assures that "hypertexts can be used generically as a batch of documents that are linked together". On his part, Landow (2006) gives a more holistic definition whereby hypertext documents are digital texts comprising text blocks (*lexies*) joined together using links that foster a non-linear reading experience (also known as multi-linear or multiple-sequence reading). Nielsen (1996) pursues this concept and assures hypertexts are documents that do not have any pre-set order determining the sequence that must be followed by the reader when he/she reads the text. In this sense, hypertexts are defined as "...systems made up of blocks or pieces of texts that are joined

together through links, thus offering the reader different reading paths" (Madrid, 2010, p. 23). Therefore, according to Amadiou & Salmerón (2014), a significant portion of such hypertext comprehension tasks requires readers to follow their own reading sequences and integrate the information from different nodes by establishing semantic relationships between them.

## Tasks involved in hypertext reading

Hypertext reading involves accessing a certain number of nodes (intratextual reading) by "jumping" from one node to another in a specific order (intertextual reading). This implies that, in order to achieve reading literacy, the reader must manage successfully two tasks that are performed simultaneously: navigation tasks and reading tasks.

Navigation tasks require to set a navigation course through the hypertext's spatial (topological) structure, which involves identifying which words or sentences of each node represent a link and selecting/triggering the links that are to be read on the basis of certain reading objectives, in addition to identifying and mentally representing the hypertext's topological structure. In view of the foregoing, the spatial layout of linear hypertexts will involve a reduced cognitive workload compared to the structure of hierarchical hypertexts (where readers can choose different links inside each node that in turn take to subordinated nodes); and the latter will in turn involve a reduced cognitive workload compared to networked hypertexts (where nodes communicate to one another without following any hierarchical criterion whatsoever). In fact, several studies show that navigation courses affect hypertext reading comprehension (Jáñez & Rosales, 2016).

On the other side, reading tasks imply integrating the content from the nodes to create a coherent mental representation (an intertextual representation) that, using the MD-TRACE model (Rouet & Britt, 2011), translates into three strongly interlinked processes that allow

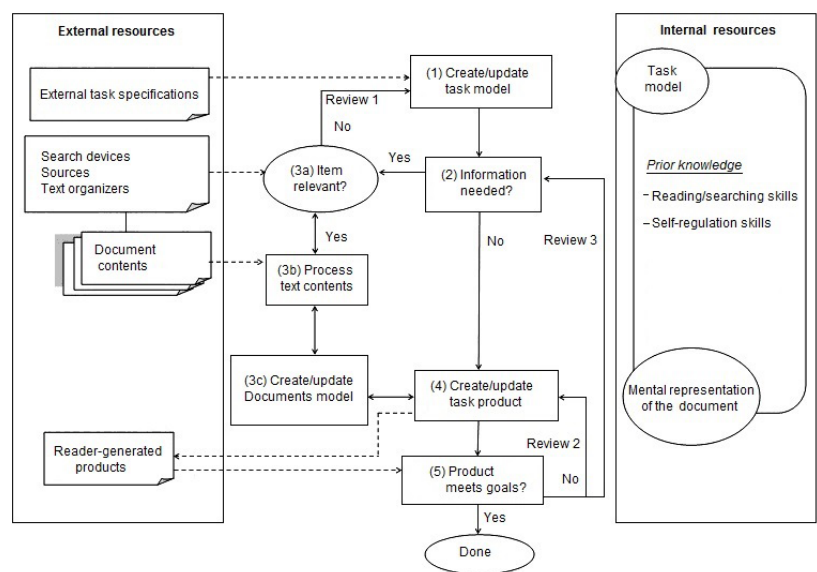
to access, process and integrate intertextual information (graph 1). In first place, the reader evaluates the relevance of each node for the task that is to be performed (3a); the content of the nodes selected is then processed in depth, reading them in a specific order (3b); and, in last place, a mental representation of the content of the hypertext is created, which becomes an internal resource for the reader and will be updated as the reading process progresses (3c). These processes, notably process 3b, will make the reader to, on the one hand, identify what cohesive elements of the hypertext enable to identify the explicit semantic relationships between nodes and, on the other, use his/her previous knowledge to make inferences that fill in the information gaps that exist between nodes.

### Aspects that affect the specific features of hypertext systems

All hypertext systems have two basic elements that are responsible for their non-linear structure: nodes and links. Additionally, each hypertext has specific features that are linked to the following aspects: the granularity or size of its nodes; the number and type of links used; its global structure; and the navigational assistance it provides.

#### Node granularity or size

Several studies suggest that those hypertexts containing a greater number of nodes and a greater amount of information per node mislead readers while they are navigating and increase ineffective cognitive workload in the reader's working memory. Therefore, in these cases, those readers having working memories with greater capacity will attain a better text comprehension (Burin, Barreyro, Saux & Irrazábal, 2015). In this sense, it is advised that the design of hypertexts include nodes that are neither too



Graph 1: MD-TRACE model (adaptation of Rouet & Britt, 2011)

thin nor too thick (Codina, 2001; Iriarte, 2004; Nielsen, 2012). Iriarte (2004, p. 54) thus states that “.....reading a hypertext with nodes that are too small may be frustrating for the reader. If the nodes are too large, the genuine advantage of hypertexts is not leveraged: the establishment of associative relationships between significant parts of a document”. Similarly, Codina (2001, p. 40) assures that “the nodes should not be either too large or too small, but suitable for the purpose, content and target audience of the hypertext”.

#### Link type and number

As far as the number of links is concerned, most studies show that the greater the number of hyperlinks is, the greater the cognitive workload borne by the reader's working memory is (Parush, Shwartz, Shtub & Chandra, 2005). Nevertheless, other empirical studies qualify these results, whether because when they take the number of links into account no significant differences in the cognitive workload are found or because they show that readers navigate more slowly through hypertexts having fewer links (Lin, 2003). These different outcomes seem to be solved in studies such as that of Madrid & Cañas (2009) and Madrid, Van Oostendorp &

Puerta (2009), who conclude that what actually affects cognitive workload is the order texts are read and thus, regardless of the number of links found in the hypertext, those readers who read in a more coherent order bear less cognitive workload than those who do it in a less coherent order. More specifically, Madrid & Cañas (2009) point out that reading in a low-coherence order involves ineffective cognitive workload for those readers who have poor domain knowledge.

As far as the link type is concerned, they are determined by their different features that cover, among others, the eight features stated below on the basis of the typology proposed by Codina (2001) and the contributions made by some authors such as Iriarte (2004) and Jáñez (2014):

- Direction: one-way links link node A and B and not vice versa, while two-way links link node A and B and vice versa.
- Sequence: sequential links do not allow going from node A to node D without first going to nodes B and C, while non-sequential links allow going directly from node A to node D.
- Navigation model: overlapped links work as a menu and link meta-information and information from the nodes (these links are normally located in a content map, a table on contents, a summary, etc.), while implied links are embedded in the information of the nodes.
- Logic: structural links conform a meta-text that makes navigation through the nodes easier (provide the hypertext with global cohesion), while semantic links establish semantic relationships between the content of the nodes (such relationships can be of concept-definition, of cause-and-effect, of similarity between ideas, etc.).
- Degree: 1:1 links allow going from one node to another, 1:N links allow going from one node to different nodes, and N:1 links allow going from different nodes to one node.
- Creation: the links defined by the author of the hypertext are those established when the document is generated, while the links defined by the reader are those attached by

him/her to a document that has already been generated, such as the wikis.

- Commutation: switch links allow to replace the start node with the target node (when you click on the link, a new link appears in the window), while overlap links overlap the target link on the start node (when you click on the link, a new window that contains the target node appears, which overlaps the window that contains the start node).
- Anchoring: each link between two nodes has a start point and a target point, known as anchors. Such anchors can link one node to another generally, or a node with any specific part of another node.

### *The global structure of hypertexts*

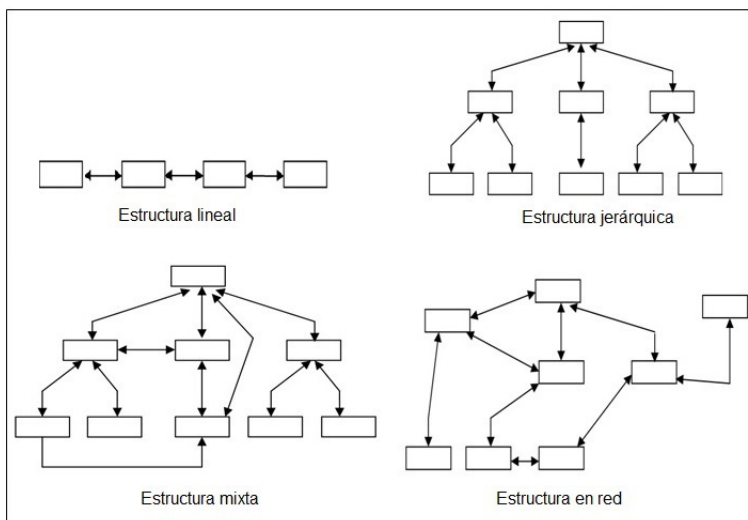
Hypertexts have a global structure that reflects the specific way whereby their nodes are spatially and conceptually organised through their connections. In this sense, according to different studies, it is essential that the structure of the hypertext is suitable both for the reader and the subject addressed (Bezdan, Kester & Kirschner, 2013; Sullivan & Puntambekar, 2015). On this basis, according to Vörös, Rouet & Pléh (2011), all hypertexts are structured at a conceptual or content-level (local and global relationships that exist between the semantic content of the nodes) and at a topological or spatial-organisation-level (connections that exist between the nodes through embedded menus and links). This way, we can identify four hypertext basic structures (graph 2, where rectangles represent the nodes and the arrows represent the links):

- Linear hypertexts have a topological structure (spatial layout) that determines the reading sequence of the nodes (the first node allows accessing a second node that, in turn, allows accessing a third node, and so on). Therefore, the only decision made by the reader in terms of navigation is going backwards or forwards within such sequence.
- Hierarchical hypertexts have a topological structure that despite not being linear fosters semantic cohesion to a greater extent

than the conceptual structure. Each node (excepting those located on the highest hierarchical level and those located on the lowest level) are connected with other nodes that contain subordinated information or with the node it is subordinated to, but it is not linked to other nodes located on the same hierarchical level.

- Networked hypertexts have a topological structure that promotes non-sequential reading; therefore, cohesion between nodes will depend essentially on the reader's navigational behaviour (which is reflected in the nodes selected by him/her and the order he/she follows). As with the preceding structures, each node is linked to different nodes and you can go back to the previous node from those nodes but, unlike such structures, there is not any predetermined reading sequence (as is the case of linear hypertexts), or any global hierarchical criterion when it comes to link the nodes (as is the case of hierarchical hypertexts) and conversely the links between the nodes follow a mainly local criterion leaving different types of semantic links within such hypertexts (for example: links of cause-and-effect, category-example, concept-definition).
- The structure of mixed hypertexts is normally similar to the hierarchical structure, with the unique feature that it links nodes that are on a same hierarchical level and allows going directly from the node on the highest supra-ordination level to that on the highest subordination level. The greater the number of connections is, the more similar to the networked structure it will be and it will thus be less structured.

Several studies on the interaction between hypertext structure and other variables, such as domain knowledge and reading skills/strategies, insist on the mental representation created by the reader (Amadiou, Tricot & Mariné, 2009; Calisir, Eryazici & Lehto, 2008; Potelle



Graph 2. Representation of the different topological structures in hypertexts.

& Rouet, 2003; Scheiter, Gerjets, Vollmann & Cantrabone, 2009). In this sense, it is shown that hypertext structures affect almost exclusively these readers having poor domain knowledge:

- Readers with poor domain knowledge benefit mainly from hypertext structures that constrain navigation at a topological level and establish supra-ordination/subordination relationships between nodes at a conceptual level (hierarchical and mixed structures), because they foster a coherent reading order (Calisir et al., 2008) and reduce the disorientation feeling (Amadiou et al., 2009). Additionally, such hypertext structures help to remember information (Amadiou et al., 2009), which in turn contributes to create suitable mental representations (De Jong & Van der Hulst, 2002).
- On the contrary, those readers with higher domain knowledge have better comprehension of hypertexts than those with poor domain knowledge (Jáñez, 2014); hypertext structure is not such a determining factor for the former, because their reading literacy depends to a great extent on the level of activation of their previous knowledge (Amadiou et al., 2009; Müller-Kalthoff & Möller, 2003; Potelle & Rouet, 2003).

### **Availability of navigational assistance: graphic diagrams**

Hypertext systems vary from each other in respect of the availability of navigational assistance or the absence thereof, which have different navigability levels (static navigability when they cannot be navigated or dynamic navigability when they can be navigated), and different structuration levels (ranging from hardly structured to highly structured). Alphabetical lists, topic or content lists, networks maps, link suggestions and content or hierarchical maps are some of the major examples of navigational assistance (Potelle & Rouet, 2003; Salmerón, 2006; Vörös *et al.*, 2011).

Nevertheless, there is no general consensus around the value attached to these instruments in order to improve reading literacy. Therefore, some authors state that hierarchical maps improve comprehension and reduce disorientation suffered by readers when they read barely cohesive hypertexts (De Jong & Van der Hulst, 2002; Vörös *et al.*, 2011). On the contrary, some studies like those presented by Nilsson & Mayer (2002) and Waniek & Edwald (2008), attach a negative impact to highly structured graphic diagrams because content maps increase ineffective cognitive workload. According to other studies, no substantial differences are found between hypertexts with and without graphic diagrams (Müller-Kalthoff & Möller, 2003), or suggest that the effect of graphic diagrams on comprehension mainly depend on domain knowledge; therefore, those readers with poor domain knowledge benefit to a greater extent from hierarchical maps than from network maps, while those readers with great domain knowledge benefit to a greater extent from network maps than from hierarchical maps because the former make them process information actively (Amadiou *et al.*, 2009). Other authors also state that those readers with poor domain knowledge benefit from content maps, but they believe that graphic diagrams do not

have a significant impact on comprehension in the case of those readers with great domain knowledge (Potelle & Rouet, 2003). Recent studies have also concluded that navigational assistance through text highlighting does not improve reading literacy (Li, Tseng & Chen, 2016).

Finally, it should be said that different authors suggest that, in addition to taking the domain knowledge variable into account, the impact of hierarchical maps on comprehension depends on the coherence level in the transition between nodes, on the moment the reader accesses such graphic diagrams and on the time he/she needs to process them (Salmerón, Baccino, Cañas, Madrid & Fajardo, 2009; Salmerón, Cañas, Kintsch & Fajardo, 2005). Therefore, Salmerón *et al.* (2005) concluded that those readers with poor domain knowledge create a better model of the situation when they follow a coherent reading order, and that those readers with greater domain knowledge create a better model of the situation when they follow a hardly coherent reading order. Subsequently, Salmerón *et al.* (2006a) concluded that those readers with poor previous knowledge improve their comprehension when they process content maps when they start reading hardly coherent hypertexts. These results were verified by Salmerón *et al.* (2009) who also assured that those readers with poor domain knowledge have worse comprehension when they process content maps when they finish reading coherent hypertexts.

### **Specific tasks and processes associated to hypertext comprehension**

When readers face hyperlinked texts, they handle reading and navigation tasks simultaneously; in other words, they start their own hypertext reading process, such as selecting their own reading order. We will be analysing these tasks hereinafter and pursue further the study of this process.

### ***Specific processes involved in hypertext reading: selecting the reading order***

According to Jáñez (2014) & Madrid (2010), when readers face hypertexts, they put in place certain strategies or decision-making rules that specifically allow them to decide which nodes they are reading and in which order, and in global terms lead them to establish a specific navigational behaviour/profile (reflected in the number of nodes visited, the order they visit them and the time spend on each node). The major decision-making rules are: the coherence strategy, which leads the reader to read the nodes in a coherent order (Jáñez, 2014); the interest strategy, which makes them trigger the links depending on their interest in them (Ainley, Hidi & Berndorff, 2002); and their location and the screen-location strategy, which leads them to open the links in the order shown on the screen (Salmerón, 2006). As far as navigation behaviours are concerned, Lawless, Brown, Mills & Mayall (2003) identify three reader types: knowledge hunters, who focus on information related to the content of the hypertext; feature explorers, who spend more time on trying to understand how the hypertext works than on gathering important information of the written text; and apathetic users, who generally spend little time on each node and follow a linear navigation pattern.

In view of the above, we can believe that selecting the reading order is the main difference between multi-linear reading of hyperlinked texts and linear reading of printed texts. Therefore, Salmerón *et al.* (2005) noted that those readers with poor knowledge learn better by following a coherent reading order, while those with greater knowledge have better performance if they follow a hardly coherent order. This conclusion was qualified in two subsequent studies (Salmerón, Kintch & Cañas, 2006a; Salmerón *et al.*, 2006b), which also took into account the hypertext reading strategies variable into account, besides the domain knowledge variable and the coherence level of

the reading order variable. More specifically, both studies showed that:

- Those readers with poor previous knowledge benefit from selecting the reading order following a coherence strategy (whether instructed on such strategy or not) when they create the model of the situation, or when they read a hypertext in a coherent order without selecting the reading order. Nevertheless, they find adverse effects in terms of comprehension when they follow an interest or screen-location strategy, or when they read a hypertext in an incoherent order without selecting the reading order.
- As far as readers with greater knowledge are concerned, they benefit from reading hypertexts regardless of the strategy type used.

In view of the results, Salmerón *et al.* (2006a, 2006b) identify the effects generated by the text and the effects generated by the strategy. On the one hand, in the case of readers with poor domain knowledge, reading literacy seems to be generated by the text. When these readers read texts in a linear way, they have better comprehension when they follow a very cohesive reading order (coherence strategy) and worse comprehension when they follow a hardly cohesive order (interest and screen-location strategies). On the other hand, the reading literacy of readers with greater domain knowledge seems to be generated by the strategy itself, as the use thereof leads them to process information in an active way, using their previous knowledge to obtain a more coherent representation.

On their part, Madrid and collaborators (Madrid & Cañas, 2009; Madrid *et al.*, 2009) analysed the impact of the reading selection process, not only in terms of comprehension but also in terms of the cognitive workload borne by working memory. Therefore, Madrid *et al.* (2009) noted that those readers who select a highly coherent reading order bore less cognitive workload during reading and learnt better than those who follow a hardly coherent order (more specifically, they seemed to bear less cognitive workload when they selected the

links). Madrid & Cañas (2009) also concluded that readers with poor domain knowledge who followed a coherence strategy bore less cognitive workload during reading and attained higher comprehension than those who followed interest or screen-location strategies; while readers with greater domain knowledge who followed an interest strategy had more cognitive workload compared to those who followed a coherence strategy (although both learnt equally using both strategies).

Therefore, selecting the reading order is the main difference between linear and non-linear reading. The coherence level of texts always depends on the author, but in the case of hypertexts it can depend either on the author, if the reading sequence is predetermined, or on the reader, if he/she is free to select the reading order of the nodes. Therefore, as the reader's freedom to select the reading order increases, so does the possibility that significant differences appear in terms of comprehension of texts and hypertexts in respect of domain knowledge and reading skills.

## Conclusions

The study of the processes and variables involved in hypertext reading processes have allowed us to obtain different interesting conclusions. On one hand, it is noted that the features of hypertexts, such as granularity or size of the nodes, the number and type of links used, their global structure and the navigational assistance they provide, will have different impacts on the cognitive workload of readers depending on their domain knowledge. On the other hand, text cohesion results as a key comprehension element for readers with poor domain knowledge. These conclusions suggest that the outcome of the reading literacy evaluation of hyperlinked digital texts may vary significantly between readers, not because of their ability to comprehend digital texts but because their previous domain knowledge (topic) dealt in the relevant text. Consequently, it could be said that the design of the instructional material or of the

material used to perform such reading literacy evaluation should analyse carefully the features of the hypertext that is to be used in the relevant context. In last place, it should be noted that the interest in analysing the reading literacy of hyperlinked digital texts is expected to increase in the future as a result of the continuing expansion of mobile devices with access to the Internet. As a matter of fact, although many websites are being optimised for usage in mobile devices, the fact that it is inherently more difficult to browse using a mobile device than using a computer could result in the variables analysed acquiring particular connotations.

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