# Individual differences in learning from hypermedia: learners' characteristics to consider to design effective hypermedia

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# Introduction: Demands of learning from hypermedia

Hypermedia systems allow free exploration of non-linear information. Such a free access to information is expected to satisfy the learners' needs (they navigate and process information according to their own needs). Nevertheless effectiveness of hypermedia for learning is less important than expected. Because individual differences may explain heterogeneous results in learning from hypermedia, identifying the learners' psychological dimensions is a fundamental aim to understand learning from hypermedia (Chen & Rada, 1996; Dillon & Gabbard, 1998). Different learners' characteristics play the role of moderating variables. Hence many studies on the effects of learners' characteristics have been conducted for example with adaptive hypermedia. Based on learners/users' characteristics, adaptive hypermedia consist usually in adaptive representations on the contents or adaptive navigational supports (Chen & Paul, 2003). Adaptive hypermedia systems attempt to tailor the contents and the navigational tools to response to the user's needs.

In comparison with classic linear texts, hypermedia systems require learners construct their learning sequences. Actually, learning from hypermedia implies learners perform two distinctive tasks (Amadieu & Tricot, 2006): a learning task and a use/navigation task. The learning task may be defined the task implying the processes useful for learning whereas the navigation task implies the processes engaged in selection, control and regulation in information reading. This second task may support learning but also it may hamper learning. The navigation task involves that learners construct their reading sequence making decisions and planning the reading order. To reach navigation relevant for learning, learners have to establish and maintain coherence between information nodes and also to build a mental representation of the document (structure, types of information, intention…). The reading sequence of nodes in hypermedia may have a low coherence if no organisational cues are provided. The construction of the reading sequence requires relational processing (Wenger & Payne, 1996). Learners need to organise the concepts in an interconnected mental representation.

Such a processing may be highly demanding for learners having few resources and cause disorientation. Disorientation is a psychological state resulting from difficulties to construct the reading sequence and establish coherence. Without any needed cognitive resources to cope with the task's requirements, no resources in working memory will be allocated to useful processes for learning. To reach good learning, cognitive resources have to be allocated to the effective processing for the construction of an elaborated and integrated representation. With this aim in view, the processes participating to the construction of knowledge are the processes of selective attention, organisation and integration of information in a coherent representation in long term memory.

In this paper, the research domain on individual differences involves studies from psychology and educational computing shields. Among the most studied characteristics that have an impact on learning in context of individual learning from hypermedia, we present the most predictive variables of learning performance. Designing hypermedia environments requires taking into account the strategies of the readers in such environments (Rouet, Levonen, Dillon, & Spiro, 1996) and thus the on-line cognitive processes. Thus the learning term refers to both learning outcomes and learners' use behaviors supporting learning performance (i.e. navigating, using tools, reading time, information selected…). Five main characteristics are evoked in the paper: prior domain knowledge, metacognition, prior systems knowledge, spatial abilities and field dependence-independence cognitive style. These characteristics would act as relevant resources to cope with the hypermedia demands.

## What learners' resources to cope with hypermedia's demands?

### *Prior domain knowledge*

Prior domain knowledge helps learners to regulate their learning from non-linear system. Shin, Schallert and Savenye (1994) showed that low prior knowledge learners reach higher performance thanks to advisements about the sequence and a hierarchical structure, whereas no significant effect of the type of structure is observed (hierarchy vs. network) for the high prior knowledge learners. A study carried out by Kerwin (2006) confirmed that low prior knowledge learners have a better learning efficiency (performance / learning time) with a low interactive condition (« forward » and « backward ») than with a more interactive condition. Also, Lee and Leed (1991) showed that when the learners have to control their learning (choice of the examples and choice of the sequence of tasks), high prior knowledge supports better performance However, when the learning control is led by the system (the system gives recommendations), the positive effect of prior knowledge disappears. A similar study of Recker and Pirolli (1995) suggests also that prior knowledge has an effect only if the system requires a high auto-regulation. These studies suggest the self-regulation imposed in hypermedia learning may be coped thanks to prior domain knowledge. Overall, many studies confirmed that prior domain knowledge support better comprehension or learning with hypermedia systems (Mishra & Yadav, 2006; Müller-Kalthoff & Möller, 2003; Potelle & Rouet, 2003; Shapiro, 1999). However, the results are not yet consistent concerning the type of information is affected by prior knowledge (i.e. micro-, macro-information, explicit or implicit information, structural information).

Providing organizational cues of the hypermedia structure appears more important than just guiding the learners' reading sequences (Calisir & Gurel, 2003; de Jong & van der Hulst, 2002). Without guidance in hypermedia, high prior knowledge learners would be less disorientated (e.g.Mohageg, 1992), but such results are still fuzzy. Nevertheless, different studies highlight a positive effect of prior domain knowledge on navigation and use behaviours. Firstly, experts seem to use deeper strategies. They lead detailed exploration of a topic and novices would use more exploration on the width to reduce their disorientation (Jenkins, Corritore, & Wiedenbeck, 2003). Carmel, Crawford and Chen (1992) also obtained results showing that novices jump more often from one topic to another and rather explore the main topics. Experts make explorations more complete and deep of a topic. Thus, novices would establish a representation of the overall topics whereas experts would develop their knowledge about some topics. A qualitative study of Last, O'Donnell and Kelly (2001) revealed that, in a opened learning task with a hierarchical structure, experts use elaborated strategies (i.e. seeking familiar or interesting contents) whereas novices use methodical and exhaustive strategies based on the hypertext structure. The study of Mishra and Yadav (2006), confirms that the experts may use structured navigation patterns. MacGregor (1999) observed also that the experts' strategies are less sequential and more flexible. The lack of prior knowledge entails more random or systematic strategies. However, some results indicate a lack of effect of prior knowledge on strategies (Salmerón, Cañas, Kintsch, & Fajardo, 2005; Zeller & Dillenbourg, 1997).

To conclude, prior domain knowledge is a main resource to cope with hypermedia requirements. It supplies relevant resources for different task levels: semantic processing of contents and structures, regulation of learning and use of relevant navigation strategies. Guiding tools such as hierarchical structure favours a better learning for learners having low prior domain knowledge.

### *Metacognition*

In hypermedia systems "…students need to analyze the learning situation, set meaningful learning goals, determine which strategies to use, assess whether the strategies are effective in meeting the learning goal, evaluate their emerging understanding of the topic, and determine whether the learning strategy is effective for a given learning goal. They need to monitor their understanding and modify their plans, goals, strategies, and effort in relation to contextual conditions…" (Azevedo & Cromley, 2004, p. 524). Marchionini (1995) considers for example that metacognitive activity is a central activity in information search tasks and construction of knowledge in electronic environments. Nowadays, there is more and more interest in this variable.

Veenman, Prins and Elshout, (2002) underlined positive influence of metacognitive abilities on behaviors and learning performance in hypermedia systems. Correlational analyses showed that acquisition of conceptual knowledge and the number of performed actions by learners increased with their metacognitive abilities. A study accomplished by Azevedo, Guthrie and Seibert (2004) showed, thanks to verbal protocols, that learners reaching the higher conceptual knowledge learning performance were the learning using the most effective strategies, constructing sub-goals, activating their prior knowledge and planning their time and effort. Another study showed that learners having self-regulation training before a learning task outperform learners who did not receive training (Azevedo & Cromley, 2004). Also, in a learning task, Kauffman (2004) obtained findings corroborating a positive effect of self-monitoring prompts on learning performance.

These positive effects of metacognitive abilities on learning from hypermedia would depend on the level of cognitive demand imposed by the hypermedia structure. The non-linearity of the structure is a condition to the effects of metacognitive abilities. Schwartz *et al.* (2004) observed a positive effect on recall performance only if the document structure was non-linear (the opposite structure was hierarchical). Hence, hypermedia systems providing a nonlinear information structure requires learners engage metacognitive abilities to evaluate, control and regulate learning. Guiding tools or structures with organizational cues (e.g. hierarchy) may decrease these requirements.

### *Prior systems knowledge*

Because hypermedia systems provide new tools to interact with information and because these tools may be numerous and different, prior systems knowledge appears as a central variable. The navigation tools allowed learners to interact with information and thus to perform the navigation task. If performing the navigation task demands high cognitive resources, the learning task will be hindered. A learner having good prior systems knowledge will encounter lower cognitive cost to perform the navigation task. Hence the learner will use free resources in working memory to perform the learning task.

In learning tasks, studies have more showed positive effects of prior systems knowledge on the type of behaviors engaged in interaction with the systems, on navigation performance or perception of systems by learners, than on learning outcomes. For instance, Mitchell, Chen and Macredie (2005) did not find any relations between learners' systems experiences (frequency of web use, learning systems with computers) and measured learning performance. Nevertheless their study indicated a positive effect of experience on perception of non-linear navigation tools. The participants having high systems experiences obtained at the end of the learning task a perception of the structure and navigation of the system less negative. In addition, Kraus, Reed and Fitzgerald (2001) showed that prior experiences with hypermedia systems provoked a longer use time of the hypermedia. According to the authors, an experimented user would be more able to understand the hypermedia system and thus would use more links and would follow non-linear pathways. These behaviors take more time.

Results of Reed *et al*. (2000) also corroborated that high hypermedia systems experiences promote cross pathways in the hypermedia rather than linear pathways. Such learners would exploit more the non-linear organization provided by hypermedia. Prior systems knowledge may also influence learning from hypermedia systems. According to Brinkerhoff, Klein and Koroghlanian (2001), this knowledge allow learners to identify the hypermedia structure that would reduce cognitive load provoked by the navigation task. Learners having high prior systems knowledge could use free resources in working memory to perform the learning task.

In research domain on information search task, others studies contributed to the previous conclusions. Hölscher and Strube (2000) observed that experienced user of the Web used idiosyncratic search patterns. Nevertheless, they shared behaviors that were flexible. They varied their search strategies (e.g. browsing, search engine) and the requests in the search engine. The Lazonder's works (Lazonder, 2000; Lazonder, Biemans, & Wopereis, 2000) show that prior systems knowledge helps users to select quickly search strategies and to select relevant strategies. Conversely, systems experiences may also provoke a use of functions not relevant for the task and divert users away from the main task (Tricot, Drot-Delange, Foucault, & El Boussarghini, 2000).

Although the main results on prior systems knowledge converge, a distinction should take into account. Marchionini (1995) as well as Tricot, Drot-Delange, Foucault and El Boussarghini (2000) underline a distinction between system expertise (prior systems knowledge) and search activity expertise or informational expertise. More investigation might be conducted on the informational expertise. Another limit concerns the meaning of prior systems knowledge. It is possible that other psychological variables are linked to prior systems knowledge and explain observed results. Indeed the self-efficacy construct may be one of these variabbles. Torkzadeh and Van Dyke (2002) observed that a training program on computer use improved self-efficacy on Internet use. The self-efficacy would be the product of prior engagement in use tasks and thus linked to prior systems knowledge. Another variable that could be linked to prior systems knowledge is prior knowledge of documents. With experiences, users acquire schemas about the documents form and characteristics (Dillon, Mc Knight, & Richardson, 1993) and construct mental models of documents (Britt, Perfetti, Sandak, & Rouet, 1999 ; Rouet, Britt, Mason, & Perfetti, 1996).

## *Spatial abilities*

Spatial ability refers to the ability for manipulating and transforming pictures of spatial patterns in other patterns (Chen & Ford, 2000). Spatial ability was much studied in navigation tasks because navigation tasks would imply a spatial dimension (Padovani & Lansdale, 2003). Navigating in hypermedia systems is closed to a pathway in an information space. Results tend to show that learners or users having high spatial abilities reach higher performance than learners having low spatial abilities. For instance, Nilsson and Mayer (2002) studied a exploration task in a hypermedia system and obtained confirmation that high spatial abilities supported efficient navigation (i.e. taking less time and activated less nodes). Also, Downing, Moore and Brown (2005) showed shorter time in a information search task. Individuals having low spatial abilities benefit more from navigation help like a structured representation of the information space organization. Lin (2003) obtained results corroborating that a hierarchical structure would limit moves and provide more information about the semantics relations between the information nodes. Graphic maps are relevant organizational tools when the spatial abilities are low allowing these individuals to reduce the gap of their navigation performance with the navigation performance of individual having high spatial abilities (Chen & Rada, 1996). However, deep hierarchical levels may caused difficulties for individuals having low spatial abilities (Chen, Czerwinski, & Macredie, 2000).

To sum up, spatial abilities would be a relevant resource for navigation performance. However, authors such Stanney and Salvendy (1995) argue that spatial abilities would be effective only if the hypermedia systems require the construction of a mental model of the information organization. This construction would participate to decrease disorientation and to support efficient navigation. Notice that the main parts of the studies have been conducted on information search task and only a few on learning tasks.

### *Cognitive style: field dependence and independence*

Among cognitive styles, the most studied in research domain on hypermedia systems is the field dependence and independence style. The field dependence and independence (FDI) is defined as a style reflecting how much learners' perception or comprehension is affected by perceptual environment and contextual field (Chen & Macredie, 2002). Field independents produce behaviors more individual (i.e. they take less into account the extern framework such as individuals' opinions). They develop more easily intern referents and modify the knowledge structures.

Some studies tend to converge toward consistent results on the effects of the FDI in learning from hypermedia. Field dependant learners prefer use of well-structured navigation tools such as conceptual maps or overviews (Chen & Ford, 2000; Ford & Chen, 2000 ) and also prefer a rigid pathways (not flexible) to navigate (Dufresne and Turcotte, 1997). Conversely, field independent learners choose non-linear learning (Reed & Oughton, 1997) not using well structure navigation tools and spending more time in deep levels of hierarchical structures (Ford & Chen, 2000 ). Low learning performance of field dependant individuals compared to the learning performance of the field independent individuals in hypermedia systems (i.e. non-linear structure) would be caused by disorientation issues (Palmquist & Kim, 2000). Chen (Chen, 2002; Chen & Macredie, 2002) proposed a model illustrating the interaction between learners' characteristics (FDI) and the level of requirement imposed by the type of hypermedia structure.

To sum up, field independent learners reach better performance in hypermedia systems than field dependent learners because they use active approaches and make better transfer of concepts in new situations (Chen, 2002). Field dependent learners need to be guided in their learning, in their relevant information searching in order to reduce their disorientation. They are more passive in their learning and benefit from limited explorations. They depend on information structures and interaction modes.

## Conclusion

The mentioned findings offer interesting perspectives and underline relevant learners' dimensions for designing hypermedia and learner profile tool. Learners who do not have such characteristics would more benefit from guidance tools or more linear systems. The given characteristics in this paper play a role on different levels of task in learning from hypermedia. Prior domain knowledge and metacognitive abilities support the learning tasks and lead learners to construct relevant representations of the hypermedia contents. Prior domain knowledge helps learners to process semantic information and construct mental representation of conceptual contents. Metacognitive abilities support control and regulation of learning. Hence they support use of relevant explorations and learning strategies in hypermedia systems that improve learning. Prior systems knowledge, spatial abilities, field dependence-independence, have more an effect on the navigation/use tasks. Prior systems knowledge would reduce the cognitive costs imposed by use tasks. Learners would have more free resources in working memory to perform the learning task. Spatial abilities help learners to process spatial information and navigation. Learners having spatial abilities may construct spatial representation of non-linear hypermedia structures and use free resources for learning. The cognitive processes relying on field dependence-independence cognitive style are less clear, but field independence appears as a good predictor of flexible exploration and use. Field independent learners have resources to benefit from non-linear structures.

Different presented works underlined the conditions required to the expression of the learners' characteristics. If hypermedia systems provide guiding tools for navigating or hierarchical structures, these characteristics are less or not needed. Overall, results indicate positive effects of the presented characteristics when hypermedia systems present non-linear structures. They support navigation tasks and/or learning tasks. However there are not yet consistent results showing that hypermedia systems improve learning compared to others systems or hypermedia systems with guiding tools.

The diversity of methods, theories and studied hypermedia systems used in the studies increases difficulties to get an agreement about effects of the learners' characteristics. For example, disorientation is not a one-dimensional concept; measures of different disorientation dimensions are required. Moreover, the disorientation assessment methods are strongly different between the studies: interviews, forms, navigational behaviours. Many works should still be conducted to confirm findings and improve our comprehension of the effects based on learners' characteristics. To reach this aim, measurement tools of the individual characteristics have to be developed. Indeed characteristics such as prior domain knowledge or metacognition imply different dimensions. In addition more investigations of on-line data are needed to catch learning processes. The measures are usually too much general (e.g. reading time, number of opened nodes). For example, a long navigation time is considered as a negative performance by Nilsson and Mayer (2002) and as a positive performance by Kraus *et al*. (2001) because they argued that the users taking long time explore more the contents.

Moreover this paper dealt only with main effect of learners characteristics. Obviously the different characteristics may interact. Hence effects of a variables may disappear, or conversely increase, if one or more others characteristics are present. Others variables would not interact. For instance Downing, Moore and Brown (2005) observed main effects of prior domain knowledge and spatial abilities but no interaction between both variables. In addition, as mentioned earlier in the paper, a characteristic may be linked to others characteristics. Indeed prior domain knowledge is a wide concept referring to different concepts (expertise, knowledge base, prerequisite, familiarity…) and different types of knowledge (factual, conceptual, structural, procedural, linguistic…). For example, experts of a domain usually have metacognitive knowledge and abilities in this domain. Thus, issues of identification of dimension and characteristics are required to increase scientific knowledge about the effects of learners' characteristics on learning from hypermedia systems and design adaptive hypermedia systems.

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